Note from the Associate Administrator:

I am pleased to present the Transportation System Preservation (TSP) Research, Development, and Implementation Roadmap. The Roadmap has been a collaborative effort between FHWA and its partners in pavement and bridge preservation.

Historically, identification of needs and funding for research in the preservation and maintenance areas have been difficult to secure. This Roadmap responds to the clear need for a systematic approach to identify knowledge gaps and recommend research projects to address those gaps. The Roadmap establishes short-term and long-term research and implementation priorities to help transportation agencies use system preservation to cost-effectively extend the service life of their infrastructure.

The research needs statements contained within this Roadmap represent the integrated effort of FHWA, AASHTO, and TRB to discover and address the challenges facing our industry and the Nation. The next steps will be to establish a collaborative effort to undertake the research described in the Roadmap. The cumulative cost of the projects is great, as is the potential benefit. The FHWA does not have the resources to carry this out alone – it must be a collaborative effort.

Only through continued cooperation with our stakeholders and partners can we accomplish the desired results to overcome the barriers to transportation system preservation. We encourage you to examine the Roadmap and to participate in the execution of these research projects. Under the AASHTO Transportation System Preservation Technical Services Program (TSP²), this document and related agency and industry interests will be shared and updates presented as the research projects are developed, funded, and completed. We appreciate the valuable input of academic, industry, and transportation agency Federal preservation practitioners, without which this successful product would not have been possible.

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King W. Gee Associate Administrator for Infrastructure January 2008

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Transportation System Preservation Research, Development, and Implementation Roadmap

January 2008

Partners:





TRANSPORTATION SYSTEM PRESERVATION RESEARCH, DEVELOPMENT, AND IMPLEMENTATION ROADMAP

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Executive Summary

Transportation agencies are concluding that it is no longer possible to just "build their way" out of ever increasing needs for transportation facilities. An aging infrastructure of roadway pavements and bridges combined with inadequate resources and rapidly growing traffic volumes indicates a demand for different approaches. Preservation practices can extend the service life of the existing infrastructure and can be of help in providing better, safer, and more reliable service to users at less overall or life cycle cost. One major impediment to widespread implementation of preservation programs by transportation agencies is lack of knowledge on how to select preservation actions and when and where to apply them to get the most benefit for the least cost – or in other words, how to apply the *right* preservation action at the *right* time to the right pavement or the *right* bridge.

There are significant gaps in the understanding of pavement and bridge preservation and it will require a comprehensive and broadly supported program of research, development and technology transfer to fill those gaps. The FHWA has partnered with the American Association of State Highway Transportation Officials (AASHTO) and the preservation industry to sponsor a study to determine what the most critical knowledge gaps in pavement and bridge preservation are and what research is necessary to fill those gaps. This Transportation System Preservation (TSP) Research, Development, and Implementation Roadmap is the output of that partnership effort.

Working together with preservation practitioners from State, Provincial, and local transportation agencies, industry, academia, and FHWA, the effort has resulted in developing a broad array of pavement and bridge preservation research needs statements.

Peer-reviewed white papers were developed to articulate preservation issues within the following categories. These were used throughout the consideration and organization of the needs statements:

Pavement Preservation

- Asset Management
- Design
- Construction
- Materials
- Contracting Methods
- Performance

Bridge Preservation

- Asset Management
- Decks and Joints
- Superstructures
- Substructures
- Project Selection
- Performance

The number of needs statements and the estimated cost to complete all of them are:

Area	# of Needs Statements	Total Estimated Cost
Pavement Preservation	40	\$28.275 M
Bridge Preservation	25	\$12.770 M

The statement titles are summarized on pages 9-13 of this report, and the pavement and bridge preservation statements are enclosed in their entirety in Appendix A.

All of the statements were evaluated and ranked to present a sense of timing and priority for their funding and pursuit. The total estimated cost of all these projects is substantial, but so is the ultimate value of providing agencies with the knowledge and tools they will provide. Although it does not represent a commitment of FHWA funds for the research projects, the Roadmap will serve as a valuable guide. It presents relationships between technical and program needs and offers recommendations to help decisionmakers within FHWA, AASHTO, and TRB to allocate resources to conduct the research addressing these short-term and long-term needs.

1. Introduction and Background

1.1. The Nation's Transportation System as a Public Asset

The U.S. highway infrastructure represents a vital component in sustaining the health and growth of the nation's economy. Indeed, the nation's roadway network makes possible the transport of trillions of dollars in goods and services each year, providing the physical interconnectivity needed to accommodate an increasingly mobile workforce, and "just in time" inventory management. Moreover, as a key component of the nation's roadway network, the nation's roadways play a critical role in national defense, homeland security, emergency preparedness and response, and overall quality of life.

In 2006, approximately 237 million vehicles traversed U.S. highways, accounting for nearly 3 trillion VMT, with just over 1.2 trillion VMT occurring over the National Highway System (NHS) alone. These substantial volumes highlight the need to keep the infrastructure in good condition. These growing traffic volumes have not been met with a corresponding growth in roadway miles. Delays and congestion caused by roadway deterioration and long-term reconstruction and rehabilitation projects have become a major concern to transportation agencies and the motoring public.

1.2. The Need for Transportation System Preservation

It is now evident that increasing traffic volumes are far outstripping new roadway mileage. At the same time the traveling public is demanding a public highway system that is safe, efficient and economical to operate, with a minimum of the disruption and the safety hazards associated with highway and bridge work zones. Transportation agencies in the US face a common problem of budgets for improving the highway system being less than adequate to meet their estimated needs. For example, one State department of transportation (DOT) estimates that their primary source of state transportation construction money, from road use taxes has grown at an average annual rate of only 1.5 % for the last 6 fiscal years and meanwhile, the amount of federal funding available for core highway programs has leveled off. And, as is true across the US, compared to estimated public highway system needs over the next 10 - 20 years, there will be a significant shortfall in funding for its most critical construction and maintenance needs. Facing these challenges, transportation agencies must get the most out of the transportation infrastructure they already have, and the investment they have made in it.

Delaying maintenance and repairs until major rehabilitation or replacement is necessary requires extensive and disruptive work that increases the potential for accidents, injuries, and fatalities among motorists and road workers. A promising alternate to this scenario is preservation of sound roadway pavements and bridges to assure physical/structural integrity and extend their service life before they need major rehabilitation or replacement. These latter actions require extensive work zones and the additional cost of

maintaining traffic through the work zone may exceed the cost of the rehabilitation or replacement work. Preservation actions may save overall costs including those related to the extent and duration of the work.

Preservation practices can extend service life and can provide better, safer, and more reliable service to users at less cost. These points reflect common sense and intuitive conclusions, but many aspects of preservation actions or their effect on service have not been demonstrated quantitatively. As a result, transportation agencies face quandaries about how to apply the right preservation action at the right time to the right pavement or the right bridge. The tools for pavement and bridge preservation exist, but guidelines for their application are often limited. Research, development and implementation have historically focused on construction and rehabilitation activities and not on the topics of preservation and maintenance.

Some advancements in pavement preservation have been achieved as the result of several studies in the past by FHWA, several state DOTs, the Transportation Research Board, some universities, and the Foundation for Pavement Preservation. Useful outcomes include a CD entitled *Pavements Preservation Toolbox – Strategies for Preventive Maintenance Programs* that was produced by the FHWA and the Foundation for Pavement Preservation. Much less formal work has been done to advance the technology and tools for bridge preservation. In recent years, the need for more organized efforts to preserve bridges has been recognized and many DOTs have started bridge preservation programs. FHWA and AASHTO are working together to develop commonly accepted definitions of bridge preservation terminology in order to assist the nationwide implementation of bridge preservation programs.

While there have been broad-based efforts in recent years to identify critical research needs in pavement preservation, there has been no widespread effort to reach out to a broad spectrum of both pavement and bridge preservation professionals to devise and develop a comprehensive plan for identifying and conducting critically needed research and development activities for the entire transportation system.

1.2.1. Background on Pavement Preservation

The FHWA defines Pavement Preservation as: "...a program employing a network level, long-term strategy that enhances pavement performance by using an integrated, cost-effective set of practices that extend pavement life, improve safety and meet motorist expectations"¹. An effective program of pavement preservation will address pavements while they are still in good condition and before the onset of serious damage which can lead to costly rehabilitation and reconstruction. By applying an appropriate and cost-effective treatment to the right road at the right time, pavements can be restored to almost their original as-built condition. When pavement preservation is implemented as an integral part of a transportation asset management program, it produces a cumulative and systemic effect which progressively improves the overall condition of the network, while reducing costs, and increasing end-user satisfaction. Moreover, performing a series of

¹ FHWA Pavement Preservation Expert Task Group

successive pavement preservation treatments during the life of a pavement can be less disruptive to traffic flow than reconstruction or rehabilitation – translating into fewer delays and lower transportation costs.

Evaluating and defining the condition of pavements is essential. There are several measures used by DOT's to assess and track pavement condition. By tracking values for cracking, ride, and surface texture, DOT's can identify which of their pavements are in good condition and which are in need of more extensive repair. Ride, expressed as the International Roughness Index (IRI), is one of the chief measures used by FHWA and DOT's. However, other distresses may be present even in roads where the ride is good. While minor rehabilitation and surface treatment can restore the ride of distressed roadways, the ideal candidates for pavement preservation are roads which are still in good structural condition and where serious deterioration has not begun.

"Fair" and "mediocre" pavements quickly become "poor" pavements, as the effects of water, freeze-thaw, dynamic truck loading, and other degenerative environmental conditions rapidly work to degrade not only the pavement surface, but the underlying pavement structure. FHWA statistics clearly indicate that, as the costs for major rehabilitation and reconstruction continue to rise, there has been effectively no improvement in the percentage of roads classified as exhibiting "good" or better ride quality over the last 7 years. Moreover, rising construction costs and a trend toward highway funding which continues to fall short of the levels needed to improve overall system quality further increase the urgency to implement effective preservation practices nationwide.

Preliminary results of the FHWA-sponsored Pavement Preservation Technical Appraisal Program suggest that one of the primary obstacles to the acceptance of pavement preservation by DOT's is a general lack of knowledge as to the quantifiable benefits of preservation. To date, much of the research into preservation treatments, materials, construction best practices, life-extension, and cost-effectiveness, have largely been qualitative or anecdotal in nature. In this regard, well-defined and unambiguous empirical evidence is needed to produce a sound foundation upon which a compelling argument can be made for preservation to legislators, highway agency managers, and the motoring public.

1.2.2. Background on Bridge Preservation

Prior to the late 1960s the nation's bridge infrastructure could not be defined by any consistent measure such as numbers, types, construction materials, ages, conditions, or by total value as a public asset. Systematic programs of maintenance and preservation were generally not in place. The collapse of the Silver Bridge at Point Pleasant, West Virginia in December 1967 was the seminal event in the development of bridge inspection programs, bridge data collection, formal bridge maintenance and improvement programs and ultimately modern bridge management systems.

In rapid order, the National Bridge Inspection Standards (NBIS) were codified in law, the National Bridge Inventory (NBI) was created, formal bridge inspection programs were initiated, and AASHTO published the AASHTO Manual for Bridge Maintenance.



YEAR OF CONSTRUCTION BY HIGHWAY SYSTEM

Figure 2.1 – Age Distribution of All Bridges in the United States - 2001

The Federal Highway Administration (FHWA) now maintains an inventory of all bridges - structures with a total span greater than 20 linear feet (6.1 linear meters) - on all public highways. Data to support and continually update this inventory is submitted annually by all the State departments of transportation (DOTs) and federal agencies.

Figure 1 shows that even by the late 1960's the bridge population in the United States was large and aging. This was just prior to the development of the inspection standards and the NBI. Based on NBI data from 2005 there are 472,769 bridges (traffic bridges with total span length of 20 feet or more) on the nation's public highways. Of these, 399,727 (84.5%) highway bridges are not structurally deficient and are in fair to very good condition. A critical need exists within the community of transportation departments to develop the wherewithal to preserve these bridges in their current good condition with effective preservation treatments that extend the service life of the bridge, increase user service and safety and ultimately save public transportation dollars. A significant number of these sound bridges may be functionally obsolete. Highway bridges classified as functionally obsolete are, by definition, not structurally deficient, but their design is outdated. They may have lower load carrying capacity, narrower shoulders or less clearance underneath than bridges built to the current standards. Decisions on

preservation of these bridges should consider the timing of any future plans for functional improvement or replacement.

Until relatively recently, it was generally true that most bridge maintenance and rehabilitation programs were reactive instead of proactive. While some preventive maintenance was being accomplished, very little effort was taken to preserve physically sound structures from the normal processes of deterioration. Most state and a few local highway agencies use bridge management systems to develop a clear picture of the status of their bridge populations, identify bridge needs, prioritize bridge actions and projects and predict future status of bridge populations in what if scenarios. The most commonly used BMS software is the AASHTOWare[™] Pontis. This system tracks not only the severity of different problems, but also the extent. It provides two or more feasible actions to address each condition state. These actions include "do nothing" and one or more actions that span the spectrum from maintenance to major rehabilitation to replacement. A weakness in the current system is that it does not account for bridge preservation actions; i.e., it cannot evaluate the impacts and costs of actions that are proactive in nature instead of reactive to a deteriorated condition.

The need for more organized efforts to preserve bridges has been recognized and many state DOTs have started bridge preservation programs. For example, several states have programs to wash bridges periodically to remove corrosive materials from members vulnerable to corrosion damage. This is generally thought to delay the onset of corrosion and thereby delay major repair work with the attendant savings in money and congestion. However, there has been only one study that documents the effectiveness of bridge washing and analyzes the resulting benefits.

2. Identifying Critical Transportation System Preservation (TSP) R&D Needs

The value and importance of the transportation infrastructure is unquestioned and the challenges to preserving that infrastructure are daunting. What is needed now is a way to help transportation practitioners make better choices for allocation of precious transportation resources Practitioners need to know what works, what doesn't work, and why. They need to know how to select preservation actions and when to apply them to get the most benefit for the least cost. They also need to know the factors that affect extensions of service life and the sensitivity each factor has for affecting the outcome of preservation actions.

To close this knowledge gap the FHWA, along with AASHTO sought a practitionerdriven analysis of fundamental and applied research needs in transportation system preservation.

The FHWA has worked with its partners in transportation agencies, industry, and academia to develop this Roadmap for research, development and practical implementation of preservation tools for asset management practitioners. This Roadmap

addresses both fundamental and applied research, development and implementation needs for roads and bridges, and is comprised of specific research needs statements (including title, problem, objectives, general tasks, estimated research, development and/or implementation costs and time required). The completed Roadmap enables FHWA and its partners to seek funding and plan out activities which will enable preservation practitioners to address the knowledge gaps that impede program implementation and success.

This Roadmap was developed as collaborative effort between the FHWA and its partners in preservation – AASHTO, the Transportation Research Board (TRB) and other government, industry and academic groups. The pavement preservation part built on previous efforts to describe this issue, such as the 2005 NCHRP Report 184 *Pavement Preservation: Practices, Research Plan, and Initiatives,* NCHRP Synthesis 523: *Optimal Timing of Pavement Preventive Maintenance Treatment Applications,* and the National Center for Pavement Preservation's database of preservation practices and related research.

The roadmap describe activities to be undertaken within a variety of research tracks (e.g., asset management, design, materials, construction, maintenance contracting, data collection and analysis, evaluations of performance, selection of preservation activity, economics, etc.) which need to be coordinated. They provide a framework for a research management plan to help direct application and implementation of the R&D results within the short- and long-term time frames.

The effort to develop this roadmap was designed to incorporate the knowledge and recommendations of a broad spectrum of transportation (pavement and bridge) engineering experts and asset management practitioners. Input from state and local transportation agencies was sought along with input from TRB, academia, industry contractors and suppliers, and consultants. The study was conducted in a series of steps that would:

- Identify broad areas of concern
- Focus the thinking of these experts
- Draw out their expert recommendations in the form of clearly written, high priority needs statements for research, development and implementation studies related to pavement and bridge preservation
- Assemble these needs statements in prioritized R&D roadmaps

This roadmap and the conclusions and recommendations herein are based on those needs statements.

2.1. Identification of Key TSP Topics

This work was started by doing a comprehensive literature search that was the basis for a critical assessment of the state of the art in preservation technology and infrastructure

asset management. Based partly on the literature search, the technical panel identified several broad topics in pavement preservation and in bridge preservation for in-depth study:

Pavements
Asset Management & Preservation
Design
Materials
Concrete
Construction
Contracting Methods
Surface Characteristics
Performance of Preservation Actions

Bridge Asset Management & Preservation Bridge Decks Bridge Joints Concrete Superstructures & Substructures Steel Superstructures & Substructures Selection of Preservation Actions Performance of Preservation Actions

These broad topics served as the core for the analysis throughout the remainder of the project. In order to articulate the issues pertaining to each of these focus areas, brief white papers were prepared for each. Each white paper was co-authored by least two subject matter experts, summarized the state of the knowledge on the topic, and highlighted possible needs for research and development. The white papers are included in this report in Appendices D and C.

2.2. Transportation System Preservation R&D Needs Workshops

The next step in the project was to conduct workshops at which groups of preservation practitioners brainstormed ideas for research and development and prepared detailed needs statements on the issues that were deemed critical by the group. Two brainstorming workshops were held on pavement preservation and one was held on bridge preservation. The preservation of pavements was already a well-established practice with broad agency and industry interest. A total of ninety-two pavement preservation practitioners, representing highway agencies, FHWA, TRB, industry, and academia participated in either of two similar workshops to brainstorm, develop and ultimately prioritize research needs statements that would comprise the pavement preservation roadmap. For bridge preservation, the activities of the single workshop were carried out by forty-six participants representing highway agencies, FHWA, TRB, industry, and academia to achieve similar objectives.

The two workshops on pavement preservation R&D needs were conducted February 5 - 7, 2007 in Phoenix, Arizona and February 26 - 28, 2007 in Orlando, Florida. The bridge preservation R&D needs workshop was conducted May 22- 23, 2007 in Dallas, Texas, and scheduled in order to follow and build upon the FHWA-sponsored National Bridge Preservation Workshop (NBPW) in St. Louis, Missouri, April 17-18, 2007. The discussions at the NBPW and the resulting conclusions were deemed highly useful to the bridge preservation R&D needs workshop. Full attendance lists for the three workshops are included in Appendix H.

The format for all three workshops was the same: a plenary session where introductory remarks and a keynote talk were made and where the white papers were presented; following that, the participants divided into six working groups to brainstorm and generate research needs statements intended to address specific knowledge gaps related to each of the topics. Each group consulted with other sessions to share similar ideas and help minimize duplications of effort. The format for writing the research needs statements was based on a model used by the National Cooperative Highway Research Program – they include title, background, scope/objective, research tasks, deliverables, estimated costs, and estimated timeframe. Each workshop concluded with presentations and discussion of the results of each working groups.

For the purposes of the roadmap study, broad topic areas were identified by the technical panel and the breakout sessions and the resulting needs statement were aligned within those topic areas. This was a useful approach in that it further defined the subjects of the requirement white papers and helped focus the efforts of each of the groups within manageable boundaries. This second feature might also be seen as a disadvantage in that all participants were not able to contribute in each topic.

2.3. Recommended TSP R&D Needs Statements

Following the workshops, the technical panel evaluated the resulting needs statement (63 pavement preservation and 28 bridge preservation) and worked to refine of each needs statement for completeness, technical content, feasibility and estimated cost and duration; and to merge some statements that were similar, complementary or duplicative. The result was a collection of distinct, important needs statements (38 for pavement preservation and 25 for bridge preservation) that could be packaged as a comprehensive program of research, development, and implementation.

Pavements		Bridges	
Category	<u># of</u> <u>Statements</u>	Category	<u># of</u> <u>Statements</u>
Asset Management	8	Asset Management	7
Design	7	Decks & Joints	4
Construction	7	Superstructures	5
Materials	7	Substructures	5
Contracting Methods	3	Selection	2
Performance	6	Performance	2
Total	38	Total	25

Table 2.1 Preservation R&D Needs Categories & Final Draft R&D Needs Statements

Table 2.2 (pavements) and 2.3 (bridges) are complete lists of the recommended preservation R&D needs statements showing statement number, title, estimated cost and estimated duration.

Statement #	ASSET MANAGEMENT	ESTIMATED COST X 100 K	DURATION (Years)
Asset 01	Development of a Process for Estimating the Remaining Service Life (RSL) for Transportation Infrastructure	\$500	2
Asset 02	Improved Decision Making Through Effective Transportation System Preservation (TSP)	\$500	2
Asset 03	Adaptable National Guidelines to Identify the <i>Right</i> Pavement/ <i>Right</i> Time/ <i>Right</i> Treatment	\$400	2
Asset 04	New Technologies to Determine Preservation Indicators	\$500	3
Asset 05	Evaluate Safety Aspect of Pavement Preservation	\$200	1
Asset 06	Data and Performance Requirements Needed to Incorporate Pavement Preservation into Asset Management Systems	\$500	2
Asset 07	Integration of Transportation System Preservation (TSP) into the Asset Management Framework	\$450	2
Asset 08	Convincing the Stakeholders: Communications and Institutional Issues	\$350	2
<u>Statement #</u>	DESIGN	ESTIMATED COST X 100 K	DURATION (Years)
Design 01	Determine the Economic Benefits of Pavement Preservation Strategies	\$950	4.5
Design 02	Determining Pavement Preservation Treatment Lives and Related Pavement Life Extension	\$350	2.5
Design 03	Validate a Methodology for Determining Optimal Timing of Pavement Preservation Treatment Applications	\$500	3
Design 04	Develop Appropriate Pavement Preservation Treatments and Practices for Urban Areas	\$300	2.5
Design 05	Framework for a Coordinated Approach to Pavement Preservation Process from an Agency Perspective	\$300	2
Design 06	Integrating Pavement Preservation into the Design Process	\$600	2.5
Design 07	Integration with a Pavement Management System (PMS	\$350	2
Statement #	CONSTRUCTION	ESTIMATED COST X 100 K	DURATION (Years)
Construction 01	Development of Innovative Pavement Preservation Products, Equipment & Construction Methods	\$150	1.5

Table 2.2 Pavement Preservation R&D Needs Statements Generated at the Workshops

Construction 02	Performance Related Specifications (PRS) for Pavement Preservation treatments	\$500	3
Construction 03	Improving the Timeliness of Acceptance Testing Results	\$500	3 to 10
Construction 04	Pavement Preservation Contractor Qualification Program	\$350	1
Construction 05	Pavement Preservation: Contractor/Agency Training and Certification	\$3,000	5
Construction 06	Construction Equipment	\$300	2
Construction 07	QA/QC Guidelines for Pavement Preservation Projects	\$275	1
<u>Statement #</u>	MATERIALS	ESTIMATED COST X 100 K	DURATION (Years)
Materials 01	Mechanical Binder Properties to Predict Surface Treatment Performance	\$1,500	3 to 5
Materials 02	Acceptance Criteria for Surface Treatments	\$600	3 to 5
Materials 03	Appropriate Installation Geometry for Crack Treatments	\$250	3
Materials 04	Cost-Effectiveness of Quality Aggregates	\$250	9 Months
Materials 05	Performance Grading System for Asphalt Emulsions	\$4,500	5
Materials 06	Performance-Graded Aggregate System for Pavement Preservation Surface Treatments	\$4,000	5
Materials 07	Triggers" for the Timing of Surface Treatments	\$10,000	8 to 10
<u>Statement #</u>	CONTRACTING METHODS	ESTIMATED COST X 100 K	<u>DURATION</u> (Years)
Contracting Methods 01	Analysis and Synthesis of Pavement Preservation Contracting Methods	\$600	3
Contracting Methods 02	Performance Measures and Contracting Methods for Pavement Preservation Treatments	\$700	4

Contracting Methods 03	Development of Model Specifications and Testing Requirements for Pavement Preservation Contracting Methods	\$300	2
<u>Statement #</u>	PERFORMANCE	ESTIMATED COST X 100 K	DURATION (Years)
Performance 01	Synthesis: Pavement Preservation Data Sources	\$600	2.5
Performance 02	Development of Distress Identification System for Pavement Preservation Treatments	\$400	2
Performance 03	Quantify Performance and Benefits of Various Pavement Preservation Treatments and Develop Pavement Preservation Treatment Performance Models	\$900	6
Performance 04	Quantifying the Benefits of Pavement Preservation Treatments	\$500	3 to 5
Performance 05	Factors Affecting Pavement Preservation Treatment Performance and Expanded Treatment Selection and Design Guidance	\$400	2.5
Performance 06	Guidelines for Pavement Preservation	\$500	2

Table 2.3 Bridge Preservation R&D Needs Statements Generated at the Workshops

<u>Statement #</u>	ASSET MANAGEMENT	ESTIMATED COST X 100 K	DURATION (Years)
Asset 01	Development of a bridge preservation process framework ensuring a standardized repeatable process for bridge preservation	\$300	2
Asset 02	Establishment of Uniform Terminology and Definitions for Transportation System Preservation	\$20	6 Months
Asset 03	Development Of A Process For Estimating The Remaining Service Life (RSL) Of Bridge Components And The Overall Bridge System Based On Observable Data.	\$200	2
Asset 04	Evaluation of the AASHTO Commonly Recognized Elements (CoRe), Ten Years of Data	\$300	1.5
Asset 05	Better Direct and Indirect Cost Models for Bridge Management Systems	\$400	2
Asset 06	Modeling Early Bridge Deterioration and Prevention	\$400	2
Asset 07	Evaluation, Analysis, and Documentation of Successful Bridge Preservation Practices	\$1,100	6

<u>Statement #</u>	DECKS & JOINTS	ESTIMATED COST X 100 K	<u>DURATION</u> (Years)
Decks & Joints 01	Best practices for preserving bridge decks	\$300	1
Decks & Joints 02	Determine the recommended practice and the life-cycle cost savings for using thin overlays to preserve concrete bridge decks	\$900	3
Decks & Joints 03	Determine the recommended practice and the life-cycle cost savings for using sealers to preserve concrete bridge decks	\$500	3
Decks & Joints 04	Determine the recommended practice and the life-cycle cost savings for preserving superstructure and substructure elements through the use and maintenance of watertight joints	\$500	2
<u>Statement #</u>	SUPERSTRUCTURES	ESTIMATED COST X 100 K	<u>DURATION</u> (Years)
Superstructures 01	Development of a test for assessment of performance of weathering steel	\$350	2
Superstructures 02	Development of Procedures for Preservation of Weathering Steel Bridges	\$300	2
Superstructures 03	Performance Assessment of Existing Concrete Structure Corrosion Prevention/Mitigation Technologies	\$1,000	4
Superstructures 04	Improved Inspection Techniques for Steel Prestressing Strand, Cables, and Ropes	\$2,000	3.5
Superstructures 05	High-Durability Coatings and Sealer Materials for Structural Concrete	\$350	2
<u>Statement #</u>	<u>SUBSTRUCTURES</u>	ESTIMATED COST X 100 K	<u>DURATION</u> (Years)
Substructures 01	Preservation of concrete highway bridge substructure units by preventing or delaying the initiation of active corrosion of the steel reinforcement	\$400	2
Substructures 02	Preservation of concrete highway bridge substructure units by controlling the corrosion rate of the steel reinforcement once corrosion has initiated	\$300	1.5
Substructures 03	Development of a high performance galvanic anode	\$600	3
Substructures 04	Substructure preservation decision matrix to address corrosion issues of the steel reinforcement of concrete bridge substructure elements	\$450	2
Substructures 05	Preservation of steel bridge piles	\$500	3

<u>Statement #</u>	SELECTION of PRESERVATION ACTIONS	ESTIMATED COST X 100 K	<u>DURATION</u> (Years)
Selection 01	Implementation of Preservation Practices on Highway Bridges by State DOTs	\$500	3
Selection 02	Develop bridge design guidelines to enhance Constructability and Maintainability	\$300	2
<u>Statement #</u>	PERFORMANCE of PRESERVATION ACTIONS	<u>ESTIMATED</u> <u>COST</u> X 100 K	<u>DURATION</u> (Years)
Statement # Performance 01	PERFORMANCE of PRESERVATION ACTIONS Quantify the information necessary to guide bridge preservation decisions	ESTIMATED COST X 100 K \$1,125	DURATION (Years) 2

2.4. Evaluation and Ranking of TSP R&D Needs Statements

Presentation, adoption, and application of the Research Roadmap depends upon a sense of priority among the needs statements, so that FHWA and its partners can plan and program funding to carry out the research efforts in a coordinated fashion. The technical panel decided that a modified Delphi technique would be satisfactory for ranking the proposed needs statements. All workshop participants from the two pavement preservation workshops were asked to complete a ranking ballot for the research needs related to pavement preservation. The materials sent to pavement workshop participants for the first ranking (see Appendix C) included ballots for each of the six established pavement preservation needs categories, a set of ranking instructions, a sample completed ballot and copies of the 38 needs statements grouped according to the categories.

Pavement preservation workshop participants were asked to study the needs statements proposed for each category and to perform two evaluations. First, participants were asked to assign an importance index to each statement in each category by using the following index values: A – very important; B – important; and C – of little importance. Second, participants were asked to rank the statements within each category from 1 to N, where N is the total number of statements in the category. A value of 1 was to be assigned to the proposal the participant would fund as the highest priority within the category, and ascending values were to be assigned to the remaining proposals within the category. For example, if a category included 8 statements, then the participant would rank them from 1 to 8 in order of his/her view of funding priorities.

Participants at the pavement preservation workshops were also asked to take their highest priority statement from each of the six categories and rank them from 1 to 6, giving the highest priority a rank of 1. This process allowed for prioritization within each group and also a measure for comparing the top needs of different groups.

The bridge preservation R&D needs statements were distributed to the bridge preservation workshop participants according to the same process. The materials sent to

bridge workshop participants for the first ranking (see Appendix C) included ballots for the six established bridge preservation needs categories, a set of ranking instructions, a sample completed ballot and copies of the 25 needs statements grouped according to category.

A total of 64 pavement preservation questionnaires were mailed for evaluation on this first iteration, and 38 were received and summarized. A total of 41 bridge preservation questionnaires were mailed for evaluation on this first iteration, and 32 were received and summarized.

Each of the six pavement categories and each of the six bridge categories were evaluated separately for importance and for priority ranking. The overall evaluation of each statement within a category was summarized by calculating its weighted importance index and by calculating its normalized mean priority rating, which was its average rating by all the participants. The importance index was obtained by assigning a value of 3 to all "A" ratings received by a statement, a 2 to all "B" ratings, and a 1 to all "C" ratings and then summing these values and dividing by the total number of votes cast for that statement to obtain a total weighted value. The results of the importance index and the priority ranking evaluations for each category are given in Tables 2.2 through 2.13 in which the statements are ordered by their statement number. Column 5 in Tables 2.2 through 2.13 contains the product of columns 2 and 4. This number represents an overall evaluation of each needs statements within each category using a combined index of relative importance and relative priority. Ranking (Column 7) of the statements in each category is according to this weighted importance / mean priority index.

2.5. Highest Priority TSP R&D Needs Statements

Out of 38 pavement preservation needs statements and 25 bridge preservation needs statements, it is possible to identify the most important and urgent needs. Two analyses were done. The first developed a consensus ranking of each needs statement based on combination of relative importance and relative priority. Tables 2.4 (pavements) and 2.5 (bridges) below show the highest priority statements considering a combination of relative priority.

Table 2.4 - Top Pavement Preservation Priorities Rated by Combined Importance &
Priority

		Pavement Preservation Needs Statements	Index of
			<u>Importance +</u>
<u>Priority</u> <u>Ranking</u>	<u>Needs Statement #</u>	<u>Title</u>	<u>Priority</u>
1	Construction 02	Performance Related Specifications (PRS) for Pavement Preservation treatments	2.24

2	Design 02	Determining Pavement Preservation Treatment Lives and Related Pavement Life Extension	2.15
3	Design 01	Determine the Economic Benefits of Pavement Preservation Strategies	2.13
4	Contracting Methods 03	Development of Model Specifications and Testing Requirements for Pavement Preservation Contracting Methods	1.86
5	Performance 03	Quantify Performance and Benefits of Various Pavement Preservation Treatments and Develop Pavement Preservation Treatment Performance Models	1.85
6	Asset 01	Development of a Process for Estimating the Remaining Service Life (RSL) for Transportation Infrastructure	1.77
7	Construction 07	QA/QC Guidelines for Pavement Preservation Projects	1.77
8	Performance 04	Quantifying the Benefits of Pavement Preservation Treatments	1.75
9	Materials 07	Triggers" for the Timing of Surface Treatments	1.70
10	Contracting Methods 02	Performance Measures and Contracting Methods for Pavement Preservation Treatments	1.69
11	Asset 06	Data and Performance Requirements Needed to Incorporate Pavement Preservation into Asset Management Systems	1.67
12	Materials 02	Acceptance Criteria for Surface Treatments	1.62
13	Performance 05	Factors Affecting Pavement Preservation Treatment Performance and Expanded Treatment Selection and Design Guidance	1.57

		Bridge Preservation Needs Statements	<u>Index of</u>
			<u>Importance +</u>
<u>Priority</u> <u>Ranking</u>	<u>Needs Statement #</u>	<u>Title</u>	<u>Priority</u>
1	Superstructures 04	Improved Inspection Techniques for Steel Prestressing Strand, Cables, and Ropes	2.54
2	Performance 01	Quantify the information necessary to guide bridge preservation decisions	2.11
3	Decks & Joints 01	Best practices for preserving bridge decks	2.06
4	Selection 01	Implementation of Preservation Practices on Highway Bridges by State DOTs	2.04
5	Substructures 01	Preservation of concrete highway bridge substructure units by preventing or delaying the initiation of active corrosion of the steel reinforcement	1.87
6	Asset 07	Evaluation, Analysis, and Documentation of Successful Bridge Preservation Practices	1.79
7	Substructures 02	Preservation of concrete highway bridge substructure units by controlling the corrosion rate of the steel reinforcement once corrosion has initiated	1.74
8	Superstructures 03	Performance Assessment of Existing Concrete Structure Corrosion Prevention/Mitigation Technologies	1.72
9	Selection 02	Develop bridge design guidelines to enhance Constructability and Maintainability	1.66
10	Performance 02	Develop deterioration models that account for the performance of preservation actions	1.65
11	Substructures 04	Substructure preservation decision matrix to address corrosion issues of the steel reinforcement of concrete bridge substructure elements	1.62
12	Asset 03	Development Of A Process For Estimating The Remaining Service Life (RSL) Of Bridge Components And The Overall Bridge System Based On Observable Data	1.57
13	Decks & Joints 03	Determine the recommended practice and the life-cycle cost savings for using sealers to preserve concrete bridge decks	1.39

Table 2.5 - Top Bridge Preservation Priorities Rated by Combined Importance & Priority

In the second analysis the highest priority needs based solely on relative importance were identified. This is the results of the "A", "B", & "C" ratings weighted to equalize the categories with differing numbers of statements. As noted before, the values of the weighted importance can vary from a high of 3.00 (all "A"s) to a low of 1.00 (all "C"s). Tables 2.6 (pavements) and 2.7 (bridges) below show the highest priority statements considering only relative importance.

		Pavement Preservation Needs Statements	
			<u>Weighted</u>
			Importance
<u>Priority</u> <u>Ranking</u>	<u>Needs Statement #</u>	<u>Title</u>	<u>Index</u>
1	Design 02	Determining Pavement Preservation Treatment Lives and Related Pavement Life Extension	2.79
2	Design 01	Determine the Economic Benefits of Pavement Preservation Strategies	2.71
3	Construction 02	Performance Related Specifications (PRS) for Pavement Preservation treatments	2.63
4	Performance 03	Quantify Performance and Benefits of Various Pavement Preservation Treatments and Develop Pavement Preservation Treatment Performance Models	2.63
5	Performance 04	Quantifying the Benefits of Pavement Preservation Treatments	2.58
6	Asset 01	Development of a Process for Estimating the Remaining Service Life (RSL) for Transportation Infrastructure	2.50
7	Contracting Methods 03	Development of Model Specifications and Testing Requirements for Pavement Preservation Contracting Methods	2.50
8	Construction 07	Performance Related Specifications (PRS) for Pavement Preservation treatments	2.50
9	Materials 07	Triggers" for the Timing of Surface Treatments	2.47
10	Materials 02	Acceptance Criteria for Surface Treatments	2.45
11	Design 03	Validate a Methodology for Determining Optimal Timing of Pavement Preservation Treatment Applications	2.45
12	Asset 06	Data and Performance Requirements Needed to Incorporate Pavement Preservation into Asset Management Systems	2.45
13	Performance 05	Factors Affecting Pavement Preservation Treatment Performance <i>and</i> Expanded Treatment Selection and <i>Design</i> Guidance	2.45

Table 2.6 - Top Pavement Preservation Priorities Rated Solely by Importance

Table 2.7 - Top Bridge Preservation Priorities Rated Solely by Importance

		Bridge Preservation Needs Statements	
			Weighted
	-		Importance
<u>Priority</u> <u>Ranking</u>	<u>Needs Statement #</u>	<u>Title</u>	<u>Index</u>
1	Superstructures 04	Improved Inspection Techniques for Steel Prestressing Strand, Cables, and Ropes	2.84
2			2.00

3	Performance 01	Quantify the information necessary to guide bridge preservation decisions	2.59
4	Selection 01	Implementation of Preservation Practices on Highway Bridges by State DOTs	2.47
5	Selection 02	Develop bridge design guidelines to enhance Constructability and Maintainability	2.47
6	Substructures 02	Preservation of concrete highway bridge substructure units by controlling the corrosion rate of the steel reinforcement once corrosion has initiated	2.44
7	Performance 02	Develop deterioration models that account for the performance of preservation actions	2.41
8	Substructures 01	Preservation of concrete highway bridge substructure units by preventing or delaying the initiation of active corrosion of the steel reinforcement	2.38
9	Superstructures 03	Performance Assessment of Existing Concrete Structure Corrosion Prevention/Mitigation Technologies	2.38
10	Substructures 04	Substructure preservation decision matrix to address corrosion issues of the steel reinforcement of concrete bridge substructure elements	2.38
11	Asset 07	Evaluation, Analysis, and Documentation of Successful Bridge Preservation Practices	2.38
12	Decks & Joints 04	Determine the recommended practice and the life-cycle cost savings for preserving superstructure and substructure elements through the use and maintenance of watertight joints	2.31
13	Asset 03	Development Of A Process For Estimating The Remaining Service Life (RSL) Of Bridge Components And The Overall Bridge System Based On Observable Data	2.31

Tables that list all 38 pavement preservation need statements and all 25 bridge preservation needs statements in priority order are included in Appendix B.

2.6. Full Results of the Ranking Process

Compilations of the raw data from the pavement preservation and bridge preservation ballots are included in Appendix D. One table is provided for the bridge needs statements and one for the pavements needs statements. The first table shows the raw ranking data and indicates for each needs statement:

- 1. How many raters assessed the importance of the need as "A" Very Important; how many rated it as "B" Important; and how many rated it as "C" of Little Importance.
- 2. How many raters assessed the priority of the need as 1, 2 ..., or N.

The twelve tables below show the results of the ranking process for each of the 12 transportation system preservation categories (six pavement categories and six bridge categories). Column 2 shows the weighted importance of each need on a scale of 1 to 3. A rating of 3.0 would indicate that all raters assessed the importance of a need as "A" –

Very Important; a rating of 1.0 would indicate that all raters assessed the importance of the need as "C" – of Little Importance. Column 3 gives the mean value of the priority ranking for each need. Column 7 reflects the consensus ranking of each needs statement based on combination of relative importance and relative priority. The columns are:

- Column 1: Statement #
- Column 2: Weighted Importance Index
- Column 3: Mean Priority Value
- Column 4: Normalized Mean Priority Value
- Column 5: Weighted Importance / Mean Priority Index
- Column 6: Ranking within Category Based on Column 5 Values

Pavement preservation priority tables:

TABLE 2.8 - Pavement Preservation R&D Needs Priority Rankings - ASSET MANAGEMENT

Paveme	Pavement Preservation R&D Needs Priority Rankings – ASSET MANAGEMENT						
R&D Needs Statement #	Weighted Importance Index	Mean Priority Value	Normalized Mean Priority Value	Weighted Importance / Priority Index	Priority Rank		
Asset 01	2.50	3.34	0.71	1.77	1		
Asset 02	2.08	4.87	0.52	1.07	6		
Asset 03	2.39	3.95	0.63	1.51	3		
Asset 04	2.13	4.55	0.56	1.18	5		
Asset 05	1.95	5.32	0.46	0.90	8		
Asset 06	2.45	3.53	0.68	1.67	2		
Asset 07	1.92	5.66	0.42	0.80	7		
Asset 08	2.13	4.79	0.53	1.12	4		

	Pavement Preservati	ion R&D Needs	Priority Ranking	gs - DESIGN	
R&D Needs Statement #	Weighted Importance Index	Mean Priority Value	Normalized Mean Priority Value	Weighted Importance / Priority Index	Priority Rank
Design 01	2.71	2.58	0.77	2.10	2
Design 02	2.79	2.61	0.77	2.15	1
Design 03	2.45	3.45	0.65	1.59	3
Design 04	2.16	5.05	0.42	0.91	6
Design 05	1.82	5.37	0.38	0.68	7
Design 06	2.13	4.50	0.50	1.07	5
Design 07	2.13	4.45	0.51	1.08	4

TABLE 2.9 - Pavement Preservation R&D Needs Priority Rankings - DESIGN

TABLE 2.10 - Pavement Preservation R&D Needs Priority Rankings – CONSTRUCTION

Pave	Pavement Preservation R&D Needs Priority Rankings - CONSTRUCTION						
R&D Needs Statement #	Weighted Importance Index	Mean Priority Value	Normalized Mean Priority Value	Weighted Importance / Priority Index	Priority Rank		
Construction 01	2.08	4.61	0.48	1.01	6		
Construction 02	2.63	2.21	0.83	2.18	1		
Construction 03	2.16	4.55	0.49	1.06	5		
Construction 04	2.18	4.18	0.55	1.19	4		
Construction 05	2.29	3.37	0.66	1.51	3		
Construction 06	1.42	6.03	0.28	0.40	7		
Construction 07	2.50	3.05	0.71	1.77	2		

Pa	avement Preservation	R&D Needs Pr	iority Rankings -	MATERIALS	
R&D Needs Statement #	Weighted Importance Index	Mean Priority Value	Normalized Mean Priority Value	Weighted Importance / Priority Index	Priority Rank
Materials 01	2.29	3.63	0.62	1.43	3
Materials 02	2.45	3.37	0.66	1.62	2
Materials 03	1.74	5.16	0.41	0.71	7
Materials 04	1.84	4.53	0.50	0.91	6
Materials 05	2.21	3.58	0.63	1.40	4
Materials 06	2.05	4.55	0.49	1.01	5
Materials 07	2.47	3.18	0.69	1.70	1

TABLE 2.11 - Pavement Preservation R&D Needs Priority Rankings - MATERIALS

TABLE 2.12 - Pavement Preservation R&D Needs Priority Rankings – CONTRACTING METHODS _____

E

Pavement	Pavement Preservation R&D Needs Priority Rankings - CONTRACTING METHODS						
R&D Needs Statement #	Weighted Importance Index	Mean Priority Value	Normalized Mean Priority Value	Weighted Importance / Priority Index	Priority Rank		
Contracting Methods 01	2.11	2.42	0.53	1.11	3		
Contracting Methods 02	2.32	1.82	0.73	1.69	2		
Contracting Methods 03	2.50	1.76	0.75	1.86	1		

Pav	Pavement Preservation R&D Needs Priority Rankings - PERFORMANCE						
R&D Needs Statement #	Weighted Importance Index	Mean Priority Value	Normalized Mean Priority Value	Weighted Importance / Priority Index	Priority Rank		
Performance 01	1.84	4.87	0.36	0.65	6		
Performance 02	2.26	3.45	0.59	1.34	4		
Performance 03	2.63	2.79	0.70	1.85	1		
Performance 04	2.58	2.92	0.68	1.75	2		
Performance 05	2.45	3.16	0.64	1.57	3		
Performance 06	2.21	3.82	0.53	1.17	5		

TABLE 2.13 - Pavement Preservation R&D Needs Priority Rankings - PERFORMANCE

Bridge preservation priority tables:

TABLE 2.14 - Bridge Preservation R&D Needs Priority Rankings – ASSET MANAGEMENT

Bridge	Bridge Preservation R&D Needs Priority Rankings - ASSET MANAGEMENT				
R&D Needs Statement #	Weighted Importance Index	Mean Priority Value	Normalized Mean Priority Value	Weighted Importance / Priority Index	Priority Rank
Asset 01	2.00	4.19	0.54	1.09	4
Asset 02	2.13	3.94	0.58	1.23	3
Asset 03	2.31	3.25	0.68	1.57	2
Asset 04	1.78	4.97	0.43	0.77	7
Asset 05	1.88	4.59	0.49	0.91	6
Asset 06	1.91	4.34	0.52	1.00	5
Asset 07	2.38	2.72	0.75	1.79	1

Brid	ge Preservation R&I	O Needs Priority	Rankings - DEC	CKS & JOINTS	
R&D Needs Statement #	Weighted Importance Index	Mean Priority Value	Normalized Mean Priority Value	Weighted Importance / Priority Index	Priority Rank
Decks & Joints 01	2.69	1.94	0.77	2.06	1
Decks & Joints 02	2.22	2.72	0.57	1.27	4
Decks & Joints 03	2.22	2.50	0.63	1.39	2
Decks & Joints 04	2.31	2.84	0.54	1.25	3

TABLE 2.15 - Bridge Preservation R&D Needs Priority Rankings - DECKS & JOINTS

TABLE 2.16 - Bridge Preservation R&D Needs Priority Rankings – SUPERSTRUCTURES

Bridge Preservation R&D Needs Priority Rankings - SUPERSTRUCTURES					
R&D Needs Statement #	Weighted Importance Index	Mean Priority Value	Normalized Mean Priority Value	Weighted Importance / Priority Index	Priority Rank
Superstructures 01	1.84	3.78	0.44	0.82	4
Superstructures 02	1.75	3.94	0.41	0.72	5
Superstructures 03	2.38	2.38	0.73	1.72	2
Superstructures 04	2.84	1.53	0.89	2.54	1
Superstructures 05	2.03	3.41	0.52	1.05	3

TABLE 2.17 - Bridge Preservation R&D Needs Priority Rankings - SUBSTRUCTURES

Brid	ge Preservation R&D	Needs Priority	Rankings - SUB	STRUCTURES	
R&D Needs Statement #	Weighted Importance Index	Mean Priority Value	Normalized Mean Priority Value	Weighted Importance / Priority Index	Priority Rank

Substructures 01	2.38	2.06	0.79	1.87	1
Substructures 02	2.44	2.44	0.71	1.74	2
Substructures 03	1.81	3.72	0.46	0.83	4
Substructures 04	2.38	2.59	0.68	1.62	3
Substructures 05	1.75	4.19	0.36	0.63	5

TABLE 2.18 - Bridge Preservation R&D Needs Priority Rankings - SELECTION

Bridge Preservation R&D Needs Priority Rankings - SELECTION						
R&D Needs Statement #	Weighted Importance Index	Mean Priority Value	Normalized Mean Priority Value	Weighted Importance / Priority Index	Priority Rank	
Selection 01	2.47	1.34	0.83	2.04	1	
Selection 02	2.47	1.66	0.67	1.66	2	

TABLE 2.19 - Bridge Preservation R&D Needs Priority Rankings - PERFORMANCE

 Bridge Preservation R&D Needs Priority Rankings - PERFORMANCE							
R&D Needs Statement #	Weighted Importance Index	Mean Priority Value	Normalized Mean Priority Value	Weighted Importance / Priority Index	Priority Rank		
Performance 01	2.59	1.38	0.81	2.11	1		
 Performance 02	2.41	1.63	0.69	1.65	2		

3. Conclusions and Recommendations

The recommended needs statements, as ranked, reflect a broad-based consensus of the most critical needs for research, development and implementation in pavement and bridge preservation. The participants at the workshop represented a suitable cross-section of preservation practitioners across agencies, across geographical regions, climatic regions and across levels of experience with preservation activities. They also represented a cross-section of disciplines including system management design, maintenance, research and suppliers of materials, equipment, etc. Based on experience, knowledge and the synergy of brainstorming sessions, the group has identified and articulated the need for a comprehensive, large scale R&D program that will require

approximately \$41M and perhaps as many as 200 person-years of effort to be fully completed.

In the combined pavement preservation/bridge preservation list, there are several key issues that stand out.

- There is a lack of reliable, useable data on:
 - The degree of preservation that is accomplished by applying a particular treatment on a pavement or bridge element with variations due to such factors as:
 - Material used in the existing element
 - Pre-existing condition of the element
 - Quality control of the treatment application
 - Weather
 - Traffic loads
 - The actual costs of the treatment
 - How effective the preservation treatments is in preserving the element
 - How long the treatment is effective
- It is difficult to determine with significant confidence:
 - How much the service life of an element is extended by the preservation treatment
 - How much life cycle costs and user costs are lowered by the preservation treatment
- There are few established procedures, metrics, or other markers that can be used to determine optimum timing for application of preservation treatments
- The effect of preservation treatments is difficult to account for in decision-making processes, e.g., management systems
- Preservation practitioners are unable to present the benefits of preservation programs in terms that are familiar and informative to upper management and legislatures
- Securing funding for dedicated preservation programs has been and continues to be difficult in the face of tight budgets, large backlogs of necessary maintenance and rehabilitation work, demands for new capacity and a general misunderstanding of the benefits of preservation programs Well focused research studies, aimed at determining, calculating and documenting the safety, operational and financial benefits of preservation programs would provide the knowledge to support requests to agency leadership for dedicated funding.

• There is a lack of standard terminology and definitions for preservation, particularly on the bridge side where bridge preservation is only now becoming an issue of broad discussion amongst the bridge community.

A key first step towards increasing the acceptance and awareness of preservation among transportation infrastructure practitioners is to provide preventive maintenance training to civil engineering students at the University level. The typical civil engineering student in the U.S. receives only cursory foundational knowledge related to pavements and bridges. Such educational training generally focuses primarily upon aspects of design and construction - affording scant coverage of the importance of preserving the infrastructure investment through preservation strategies and treatment techniques. Indeed, it is widely recognized in the transportation infrastructure community that preservation education receives far less emphasis than its performance benefits should warrant.² The long-term impact of deficient educational preparation in preservation strategies and techniques is widely evident amongst even seasoned transportation practitioners, many of whom lack even basic knowledge of preventive maintenance concepts.

Thus, increasing the quality and quantity of University-level preservation training is essential to provide the newly minted transportation engineer with a better foundation upon which to build his/her skills in, and acceptance of, the preventive maintenance concept. Indeed, lacking this fundamental knowledge, professional transportation infrastructure practitioners and agency management face an often times up-hill battle when trying to integrate preservation practices into a comprehensive asset management program. Moreover, the high-turnover rates witnessed within most DOTs among experienced transportation engineers makes the need to ingrain preservation concepts early on amongst junior staff even more essential.

The development of the Roadmap has been the first step. The challenge remains for FHWA, TRB, AASHTO, and other partners to commit the resources according to its direction so that agencies have the tools and knowledge to effectively use transportation system preservation to extend the life of the nation's infrastructure.

² Yildrim, "Pavement Preservation Training in Texas", Transportation Research Circular E-C078: Roadway Pavement Preservation, pp. 184-189, 2005.

APPENDIX A – TRANSPORATION SYSTEM PRESERVATION RESEARCH NEEDS STATEMENTS

APPENDIX A-1 38 PAVEMENT PRESERVATION NEEDS STATEMENTS

Statement #	ASSET MANAGEMENT	ESTIMATED COST X \$100K	DURATION (Years)
Asset 01	Development of a Process for Estimating the Remaining Service Life (RSL) for Transportation Infrastructure	\$500	2
Asset 02	Improved Decision Making Through Effective Transportation System Preservation (TSP)	\$500	2
Asset 03	Adaptable National Guidelines to Identify the <i>Right</i> Pavement/ <i>Right</i> Time/ <i>Right</i> Treatment	\$400	2
Asset 04	New Technologies to Determine Preservation Indicators	\$500	3
Asset 05	Evaluate the Safety Aspect of Pavement Preservation	\$200	1
Asset 06	Data and Performance Requirements Needed to Incorporate Pavement Preservation into Asset Management Systems	\$500	2
Asset 07	Integration of Transportation System Preservation (TSP) into the Asset Management Framework	\$450	2
Asset 08	Convincing the Stakeholders: Communications and Institutional Issues	\$350	2
	DESIGN		
Design 01	Determine the Economic Benefits of Pavement Preservation Strategies	\$950	4.5
Design 02	Determining Pavement Preservation Treatment Lives and Related Pavement Life Extension	\$350	2.5
Design 03	Validate a Methodology for Determining Optimal Timing of Pavement Preservation Treatment Applications	\$500	3
Design 04	Develop Appropriate Pavement Preservation Treatments and Practices for Urban Areas	\$300	2.5
Design 05	Framework for a Coordinated Approach to Pavement Preservation Process from an Agency Perspective	\$300	2
Design 06	Integrating Pavement Preservation into the Design Process	\$600	2.5
Design 07	Integration of Pavement Preservation with a Pavement Management System (PMS)	\$350	2
	CONSTRUCTION		
Construction 01	Development of Innovative Pavement Preservation Products, Equipment & Construction Methods	\$150	1.5
Construction 02	Performance Related Specifications (PRS) for Pavement Preservation treatments	\$500	3
Construction 03	Improving the Timeliness of Acceptance Testing Results	\$500	3 to 10

Construction 04	Pavement Preservation Contractor Qualification Program	\$350	1
Construction 05	Pavement Preservation: Contractor/Agency Training and Certification	\$3,000	5
Construction 06	Advanced Equipment for Improved Pavement Preservation Treatments	\$300	2
Construction 07	QA/QC Guidelines for Pavement Preservation Projects	\$275	1
	MATERIALS		
Materials 01	Mechanical Binder Properties to Predict Surface Treatment Performance	\$1,500	3 to 5
Materials 02	Acceptance Criteria for Surface Treatments	\$600	3 to 5
Materials 03	Appropriate Installation Geometry for Crack Treatments	\$250	3
Materials 04	Cost-Effectiveness of Quality Aggregates	\$250	9 Months
Materials 05	Performance Grading System for Asphalt Emulsions	\$4,500	5
Materials 06	Performance-Graded Aggregate System for Pavement Preservation Surface Treatments	\$4,000	5
Materials 07	"Triggers" for the Timing of Surface Treatments	\$10,000	8 to 10
	MAINTENANCE CONTRACTING		
Maintenance Contracting 01	Analysis and Synthesis of Pavement Preservation Contracting Methods	\$600	3
Maintenance Contracting 02	Performance Measures and Contracting Methods for Pavement Preservation Treatments	\$700	4
Maintenance Contracting 02 Maintenance Contracting 03	Performance Measures and Contracting Methods for Pavement Preservation Treatments Development of Model Specifications and Testing Requirements for Pavement Preservation Contracting Methods	\$700 \$300	4
Maintenance Contracting 02 Maintenance Contracting 03	Performance Measures and Contracting Methods for Pavement Preservation Treatments Development of Model Specifications and Testing Requirements for Pavement Preservation Contracting Methods PERFORMANCE	\$700 \$300	4
Maintenance Contracting 02 Maintenance Contracting 03 Performance 01	Performance Measures and Contracting Methods for Pavement Preservation Treatments Development of Model Specifications and Testing Requirements for Pavement Preservation Contracting Methods PERFORMANCE Synthesis: Pavement Preservation Data Sources	\$700 \$300 \$600	4 2 2.5
Maintenance Contracting 02 Maintenance Contracting 03 Performance 01 Performance 02	Performance Measures and Contracting Methods for Pavement Preservation Treatments Development of Model Specifications and Testing Requirements for Pavement Preservation Contracting Methods PERFORMANCE Synthesis: Pavement Preservation Data Sources Development of Distress Identification System for Pavement Preservation Treatments	\$700 \$300 \$600 \$400	4 2 2.5 2
Maintenance Contracting 02 Maintenance Contracting 03 Performance 01 Performance 02 Performance 03	Performance Measures and Contracting Methods for Pavement Preservation Treatments Development of Model Specifications and Testing Requirements for Pavement Preservation Contracting Methods PERFORMANCE Synthesis: Pavement Preservation Data Sources Development of Distress Identification System for Pavement Preservation Treatments Quantify Performance and Benefits of Various Pavement Preservation Treatments and Develop Pavement Preservation Treatment Performance Models	\$700 \$300 \$600 \$400 \$900	4 2 2.5 2 6
Maintenance Contracting 02 Maintenance Contracting 03 Performance 01 Performance 02 Performance 03 Performance 04	Performance Measures and Contracting Methods for Pavement Preservation Treatments Development of Model Specifications and Testing Requirements for Pavement Preservation Contracting Methods PERFORMANCE Synthesis: Pavement Preservation Data Sources Development of Distress Identification System for Pavement Preservation Treatments Quantify Performance and Benefits of Various Pavement Preservation Treatments and Develop Pavement Preservation Treatment Performance Models Quantifying the Benefits of Pavement Preservation Treatments	\$700 \$300 \$600 \$400 \$900 \$500	4 2 2.5 2 6 3 to 5
Maintenance Contracting 02 Maintenance Contracting 03 Performance 01 Performance 02 Performance 03 Performance 04 Performance 05	Performance Measures and Contracting Methods for Pavement Preservation Treatments Development of Model Specifications and Testing Requirements for Pavement Preservation Contracting Methods PERFORMANCE Synthesis: Pavement Preservation Data Sources Development of Distress Identification System for Pavement Preservation Treatments Quantify Performance and Benefits of Various Pavement Preservation Treatments and Develop Pavement Preservation Treatment Performance Models Quantifying the Benefits of Pavement Preservation Treatments Factors Affecting Pavement Preservation Treatment Performance and Expanded Treatment Selection and Design Guidance	\$700 \$300 \$600 \$400 \$900 \$500 \$400	4 2 2.5 2 6 3 to 5 2.5

Asset Management # 01

Title: Development of a Process for Estimating the Remaining Service Life (RSL) for Transportation Infrastructure

Background: Over the years a variety of different measures has been used to evaluate and communicate the condition of transportation infrastructure. Many of these measures are limited in the sense that they describe current condition, but do not provide predictions for how the infrastructure will behave in the future. The ability to assess condition in future years is essential for planning and programming improvements, and also in determining overall agency funding needs over time. The use of remaining service life (RSL) is a method which allows agencies to establish a clear picture of their overall network health, and one which is easily communicated within the agency and also to legislators and the public.

The overall concept of RSL needs to be applied consistently throughout transportation agencies, but the means of its implementation for different aspects of the infrastructure (pavements, bridges, signs, etc.) may require specific and tailored effort. With bridges, the overall RSL of the structure will be a function of the condition of its particular elements – deck, substructure, superstructure, and foundation. The process will need to be able to distinguish between RSL of each of the elements and use them to collectively establish an RSL for the complete structure – and also to consider how the RSL of one element may influence the RSL of another. Similarly, the factors for correlation of condition data to RSL will be different for flexible and rigid pavements.

Agencies may understandably be reluctant to change their methods from current practices of collecting and analyzing condition data. For RSL to be adopted by agencies as a standard, they will need a methodology for establishing RSL data using the data they already collect, or by correlating their condition information into accurate values of RSL.

To reliably compare infrastructure condition (effectiveness of treatments), it will be necessary to be sure that meaningful values are used for what constitutes "good condition", and also for what constitutes "poor or failed condition". If different agencies are using significantly different values for these levels, it makes it difficult to compare the results they get from the application of treatments, or the cost-effectiveness.

How good is "good", and how bad is "bad" – what is the meaning of "zero years RSL"? Ideally, there should be different values assigned for different functional classification of roadways – the tolerance for condition level for the interstate would be quite different from what could be expected on an arterial. Also, the significance of zero RSL will potentially have very different meaning for bridges and pavements. Different agencies treat this differently, which will make it more difficult to assess national conditions or compare among agencies. Widespread adoption of RSL as a measurement of infrastructure condition will provide for a uniform descriptor of national conditions.

The adoption of RSL as a measure enables a more complete assessment of roadway network health and serves as a valuable decision-making tool for transportation agencies. It will assist
decision-makers in providing for a more predictable distribution of resources within an agency over time. By using a clear and consistent unit of measurement (years) to describe infrastructure condition, it enables for better comparison of program effect and treatment performance among agencies. It also enables agencies to make better use of the data they already collect – ability to forecast needs and extrapolate condition, and to better communicate needs/ activities to public/ politicians.

It will also contribute to agencies' treatment timing decisions, and enable agencies to provide more consistent policy applications and network condition information that is more easily comparable to the values used elsewhere.

Scope/ Objectives: The objective of this project is to provide a process/ tool to highway agencies for correlating condition data to RSL. The process will be iterative/ self-calibrating, adaptable to agencies' own procedures for data collection, and existing bridge condition tools and procedures. It should also relate the RSL to economic valuation of the Asset. Included within the development of the process will be the determination of concrete values (definition) for good condition and failure condition for the purposes of public expectation, comparison, and economic valuation.

Because of the breadth of the application of RSL across transportation agency operations and the variety of different infrastructure elements, the work should be approached in three phases:

- Phase I will provide guidance on how to establish use of RSL within agency operations.
- Phase II will generate the process and factors for correlation of condition data (currently measured by agencies) into RSL
- Phase III will merge the outputs of Phase I and Phase II to develop comprehensive guidance for agencies to incorporate the concept and measurement of RSL into their operations, planning, and programming.

Research Proposed: The following tasks would be required:

Phase I

- 1. Literature search, evaluation of existing use RSL for infrastructure evaluation.
- 2. Develop draft guide establishing RSL as a means for agencies to evaluate infrastructure condition based on collected condition data.

Phase II

1. Develop specific processes for converting existing agency condition description data to RSL. Separate measures should be used for flexible and rigid pavements, bridge elements, and bridge structures as a whole.

Phase III

- 1. Develop draft comprehensive RSL implementation guide. Review and comment, develop final guide.
- 2. Implementation and rollout through FHWA, AASHTO.

Proposed Deliverables:

- 1. Report summarizing Phase I
- 2. Report summarizing Phase II
- 3. Guidance manual for applying RSL to department decision-making procedures, and for the condition data RSL translation across different infrastructure elements

Potential Partners: AASHTO, Foundation for Pavement Preservation, NAPA, ACPA

Estimated Cost and Duration: \$500,000 2 years.

User Community: State and local transportation agencies at all levels can benefit from this study.

Implementation: Consistent program guidance and policy support from FHWA will be a key to the success of this activity. As FHWA works with AASHTO to adopt RSL as the consistent national measure of infrastructure condition, this guidance will be essential in assisting agencies in the process.

Asset Management # 02

Title: Improved Decision Making through Effective Transportation System Preservation (TSP)

Background: Asset Management requires an improved understanding of physical, environmental, social and economic impacts related to system preservation activities. This project will assist in determining funding needs for pavement preservation related to the needs for rehabilitation and reconstruction. The return on investment (ROI) for bridge, pavement and other roadway asset preservation needs to be established so that users can clearly understand why worst first is not an effective approach to managing assets.

This work will be an important tool to enable agencies to make funding decisions among assets categories, by work activities, and by district. This should assist in linking funding decisions to condition and expected future backlogs.

Scope/Objectives: The objective of this project is to develop methods for establishing or enhancing TSP programs within the context of asset management. This will include the following activities:

- Realistic valuation of assets
- Physical vs. economic remaining service life (RSL), RSL parameters, and the relationship between preservation, cost-effectiveness and RSL
- Trade-off analysis (preservation vs. capacity vs. reconstruction vs. other assets)
- Socio-environment-economic benefit calculations
- Establishing deterioration curves for the various alternatives
- Incorporating life cycle cost analysis (LCCA) into process
- Integration of different systems (PMS, BMS, etc.) into the asset management process tradeoffs, policies

Choosing preservation candidates, timing, and anticipated outcome

Research Proposed:

The following tasks have been identified to satisfy the objectives for this project:

Task 1. Literature Search, including but not limited to International Infrastructure Management Manuals, International and Domestic Scans, and National Database of State Preservation reviews.

Task 2. Identify gaps in existing methods and develop strategies for incorporating TSP into Asset Management frameworks in various agencies. Identify the controlling environmental, economic and social factors in decision making strategies.

Task 3. Develop guidance for project and network level TSP decisions.

Task 4. Conduct evaluation of the guidance through use of pilot programs, expert task groups, and demonstration projects. Revise the guidance to reflect the results of the evaluation.

Task 5. Identify future implementation procedures and training needs.

Proposed Deliverables:

1. Interim report documenting the results of tasks 1 and 2. It should also include a detailed work plan for completing the remainder of the project.

2. Final report documenting the results of phases 3-5

3. Guidance Manual for implementing transportation system preservation programs

Potential Partners: FHWA, NCHRP, FP2, AASHTO

Estimated Cost and Duration: \$500,000 2 Years

User Community: State highway agencies, provincial agencies and local owner-agencies

Implementation: The implementation efforts should include the development of a guidance manual and the associated training. Transportation system preservation must demonstrate clear benefits over the traditional ways of maintaining our assets.

Asset Management #03

Title: Adaptable National Guidelines to Identify the *Right* Pavement/ *Right* Time/ *Right* Treatment

Background: Agencies are currently spending significant amounts of their limited transportation dollars on treatments that are applied to the wrong pavement or at the wrong time. Consideration of distress mode, traffic and environmental factors, and pavement condition (its "place on the performance curve") all have dramatic effect on the success or failure of a pavement preservation treatment or the pavement itself. In order for a pavement preservation program to succeed, agencies need complete and accurate information to help guide their decisions on what can and should be done to preserve their pavements in good condition at reasonable costs. Premature failures or excessive costs may dissuade the agency from making use of treatment types that might actually be of great use to them.

By providing agencies with more refined tools for helping in this decision-making, they will be better equipped to make network-wide decisions on managing highways assets (the "*Right* Pavement at the *Right* Time and the *Right* Treatment"). NCHRP Report 523 has laid the groundwork for this effort by providing considerable analysis and tools to address the timing aspect of this decision. Decision trees exist, but agencies often face restrictions that might not be covered in a generic tool (for example, the right materials or contractors may be unavailable).

If agencies are applying the treatments according to a uniform decision process, then it becomes easier to evaluate the treatments' cost-effectiveness. It also enables agencies to make betterinformed decisions about the use of treatments, contributing to the treatments' success and giving agencies confidence to use a wide array of options. The project is important to ensure that pavement preservation succeeds.

Scope/Objectives: The objective of this project is to develop national guidelines to assist agencies in deciding on the appropriate use of pavement preservation treatments. The guidelines would be able to be tailored to address regional considerations such as environmental conditions and traffic, as well as incorporate agency policy restrictions where necessary. The guidelines should include the following:

- Establish thresholds for different distress measures (rut, ride, etc.) for different treatments.
- Consider materials aspects and their influence of initial cost on future decisions and on design aspects
- Dealing with isolated bad areas as a preparation or isolated maintenance activity.
- Identify restrictions related to specific distress types.
- Account for regional variations and concerns.

The project should include industry in the evaluation and development. In particular it should determine what contractors are doing on a national and regional level. Questions to be addressed include:

- Are the Contractors promoting the right products in the right regions and are they making efforts (or learning practices) to help address these considerations?
- What is the role of training and certification of contractors and key agency employees?
- What agencies are doing to address regional variation of the usability of some treatments?

Research Proposed: The following tasks have been identified to complete the work for this project:

Task 1. Conduct a comprehensive literature review of existing state policy, practices and guidelines

Task 2. Identify existing decision processes, guidelines, or tools used by the various agencies

Task 3. Develop national guidelines with consideration of regional differences

Task 4. Prepare a final report documenting all the tasks

Proposed Deliverables:

- 1. Bibliography of existing policy, practices and guidelines
- 2. National guidelines for selecting and applying pavement preservation treatments
- 3. Develop and implementation plan for use by various agencies
- 4. Final report documenting the study findings, recommendations and guidelines

Potential Partners:

FHWA, AASHTO Subcommittee on Asset Management, AASHTO Subcommittee on Maintenance, AASHTO Joint Task Force on Pavements, National and regional centers on Pavement Preservation

Estimated Cost and Duration: \$400,000 2 Years

User Community: Transportation agencies, state provincial and local governments

Implementation: Distribution of the final report and guides should be followed up with joint training involving industry and agency

Asset Management # 04

Title: New Technologies to Determine Maintenance Indicators

Background: In the past, new advances in technology have changed the way that agencies conducted their pavement evaluation and forecasting methods. As new innovations evolve, they can have dramatic impact on the way that pavement preservation programs are conducted. A systematic look at what new technologies exist which might have an impact on our field, and an assessment of what might need to happen to implement their introduction into pavement preservation, is the goal of this project.

By providing agencies with new, non-destructive and predictive methods for evaluating current and future pavement conditions, they will better be able to forecast program and funding needs. With more accurate measures and meaningful predictors of pavement condition, the process of convincing the public and decision makers of the value of pavement preservation can become considerably easier.

Scope/Objectives: The objective of this project is to identify new indicators to better characterize pavement condition and better forecast deterioration (early/ long-term indicators). Also included is an evaluation of tools under development (like GPR, RWD, etc.) and how advances in other fields can be applied to preservation needs. Of all the measures available, identify the best indicators of what condition the pavement is in, and how it will continue to deteriorate.

Research Proposed:

The following tasks have been identified to complete the work for this project:

Task 1. Identify emerging technologies with potential application to pavement analysis and evaluation. The literature search should include an assessment of proposed and ongoing research, and other outreach should be used.

Task 2. For select technologies and applications, develop an implementation and evaluation plan for prototype development and field testing as appropriate. Focus on near-term and long-term considerations in development and use of the technology within agency operations.

Task 3. For each selected technology and application, prepare a report describing the outcome of the evaluation process. Marketing materials should be developed for the most promising technologies.

Task 4. The Final report should include the results of the identification, evaluation, and implementation process.

Proposed Deliverables:

1. Interim Report of Task 1 identifying potential applications for development and testing

2. Implementation and evaluation plan specific to each selected technology

3. Final Report and marketing material describing the outcome of the implementation and evaluation of each technology

Potential Partners: AASHTO, TRB, FHWA

Estimated Cost and Duration: \$500,000 3 Years

User Community: State and local transportation agencies at all levels can benefit from this study.

Implementation: This activity is envisioned to be long-term and recurring, as an opportunity to foster innovation within the pavement community. As new technologies are implemented in pavement monitoring and evaluation applications, others will continue to emerge and require similar assessment.

Asset Management # 05

Title: Evaluate the Safety Aspect of Pavement Preservation

Background: It has long been argued that pavement preservation represents an opportunity for agencies to increase the overall safety on their system. The application of thin surface treatments or use of thin overlays requires periodic exposure of crews to traffic, and traffic to work zone congestion. However, these events are of short duration. The alternative is to wait for the road to reach a poor condition and carry out a major rehabilitation or reconstruction of the facility. Such an activity would take considerably longer and involve more elaborate work zone arrangements. Intuitively, this represents a major difference in crash and congestion risk. However, hard data or studies are needed to test this hypothesis.

FHWA regulations (23 CFR 630 Subpart J) require that agencies consider the impact of work zones on mobility and safety, and to incorporate measures throughout the project development and delivery processes to assess and reduce these impacts. Having a better understanding of the impact of pavement preservation work on mobility and safety, in comparison with other activities, would be of enormous value to agencies in their network safety analysis,

Scope/Objectives: The objective of this project is to conduct a safety evaluation of the types of activities used for pavement preservation, and a comparative analysis of the crash and injury/ fatality data against other types of activities. The desired result is that decision makers can be shown that there is a demonstrable difference in the safety (both for users and workers) of traffic interruptions that are more frequent (but of shorter duration) than what would be expected for major activities such as rehabilitation or reconstruction.

The analysis should be conducted to be able to draw meaningful conclusions based on analysis of crash and mobility data from many different types of projects, facilities, and geographic areas.

Research Proposed:

The following tasks have been identified to complete the work for this project:

Task 1. Develop a data collection and analysis plan to determine how crash and congestion data will be consistently gathered and evaluated for a broad spectrum of conditions

Task 2. Conduct data collection and analysis according to the approved plan outlined in Task 1.

Task 3. Prepare a report summarizing the findings of the data analysis.

Proposed Deliverables:

- 1. Data collection plan.
- 2. Draft report of data analysis.

3. Final report for publication and distribution.

Potential Partners: AASHTO, Foundation for Pavement Preservation, ATSSA, FHWA

Estimated Cost and Duration: \$200,000 1 Year

User Community: State and local transportation agencies at all levels can benefit from this study

Implementation: FHWA regulations (23 CFR 630 Subpart J) require agencies to consider the impact of work zones on mobility and safety, and to incorporate measures throughout the project development and delivery processes to assess and reduce these impacts. Having a better understanding of the impact of pavement preservation work on mobility and safety, in comparison with other activities, would be of enormous value to agencies in their network safety analysis,

Asset Management # 06

Title: Data and Performance Requirements Needed to Incorporate Pavement Preservation into Asset Management Systems.

Background: At the present time, much of the existing data are not readily available or lacks the quality and/or scope necessary to make effective decisions supporting pavement preservation as part of an Asset Management System. In addition, there is limited data on the performance of pavement performance activities and their observed effect on the performance of pavements.

Scope/Objectives: This project will address the following data and performance issues:

- How to collect, manage and maintain data on pavement preservation material and construction quality
- How to integrate pavement preservation data into legacy systems
- What, when and how much data is needed to support pavement preservation as part of asset management systems, i.e. trigger mechanisms, strategic planning?
- How to collect as-built information and incorporate it into PMS
- How to set indices and performance indicators for pavement preservation activities
- How to link preservation activities to overall pavement performance

Research Proposed:

The following tasks have been identified to complete the work for this project:

Task 1. Identify key data elements to support effective pavement preservation activities as part of Asset Management.

Task 2. Identify best practices for data collection, managing and maintaining quality data. This task includes practices for Quality Assurance and Quality Control of data.

Task 3. Identify best practices for incorporating relevant as-built data into pavement preservation decision making.

Task 4. Identify best practices for quantifying performance of pavement preservation treatments as a function of extended pavement life.

Task 5. Develop guidelines for quality data collection and management to support pavement preservation decisions. Quantify the benefits of pavement preservation on overall pavement performance.

Task 6. Develop an experimental plan for a demonstration of pavement preservation techniques for quantifying field performance.

Task 7. Identify future implementation procedures and training needs.

Proposed Deliverables:

1. Final Report summarizing all tasks.

2. Guidance Manual for implementing data management for pavement preservation programs.

3. Experimental and Implementation Plan from Tasks 6 and 7.

Potential Partners:

FHWA, NCHRP, Foundation for Pavement Preservation, Regional PP partnerships

Estimated Cost and Duration: \$500,000 2 years

User Community: State, Province, and Local Owner-agencies

Implementation: FHWA and AASHTO should take the lead on implementing the findings from this study. It should include distribution of the guidance manual and the associated training.

Asset Management # 07

Title: Integration of Transportation System Preservation (TSP) into the Asset Management Framework

Background: Although several preservation concepts are commonly practiced by the maintenance community, they have not yet been integrated into the Asset Management framework and decision making. There needs to be a systematic approach to this process. This research will draw on international and domestic experiences and seek to update existing guides and policies.

Scope/Objectives: The primary objective of the project is to develop a framework for incorporating TSP into asset management. The project will address the following key questions:

- What assets are to be managed? What decisions are to be made? How to make a business case for investment?
- How to link preservation into existing decision making frameworks?
- How to fit in with legacy management systems?
- How to fit economic analysis and financial management into processes?

The outputs will include:

- Developing and using a common framework to support analyses for decision making
- Integrating preservation into the AASHTO Asset Management guide
- Developing and distributing Model Guidelines and specifications

Research Proposed:

The following tasks have been identified to complete the work for this project:

Task 1. Conduct literature review on gaps in the Asset Management framework with respect to preservation elements to be included in TSP.

Task 2. Interview agencies to identify gaps in the guidance documents and existing frameworks. This needs to include what works, what doesn't work, and what is needed.

Task 3. Develop model guidelines for the framework to support decision making about pavement and bridge preservation and other roadway and roadside appurtenances.

Task 4. Evaluate effectiveness of model guidelines through pilot program, demonstration or expert task group, etc. Revise guidelines and disseminate.

Task 5. Identify future implementation procedures and training needs.

Proposed Deliverables:

1. Interim report summarizing tasks 1 and 2.

2. Guidance Manual for developing a framework for including transportation system preservation programs in Asset Management including a summary of the evaluation in task 4.

3. Final report documenting all tasks including recommendations for implementation and training.

Potential Partners: FHWA, NCHRP, FP2, AASHTO, TRB, NCPP, Region Preservation Centers

Estimated Cost and Duration: \$450,000 2 Years

User Community: State, Province, and Local Owner-agencies, other highway owners and operators

Implementation: The implementation efforts would include distribution of the reports and the guidance manual and any follow-up training. FHWA, AASHTO, and FP2 would all be involved in the implementation efforts,

Asset Management # 08

Title: Convincing the Stakeholders: Communications and Institutional Issues

Background: There is an opportunity to more effectively communicate the impacts of Transportation System Preservation (TSP) to elected officials, decision makers and other stakeholders. Preservation of bridges, pavements, and other roadway appurtenances have been shown by some agencies to have an enormous effect on the performance and life of the transportation infrastructure, and better understanding of the programs by decision makers and the public can help support and funding.

Scope/Objectives: This project will address the following issues:

- Improving communications about the technical/economic impacts of system preservation between agency staff, elected officials, and the public.
- Preserving institutional knowledge through documentation, training and succession planning.
- Establish and maintain communication between local, State, Federal governments, toll authorities, and other highway owners.
- Identify industry organizations to improve communications about TSP activities with Contractor community.
- Educate engineering Consultants to include TSP techniques in design and maintenance of roadway assets pavements, bridges, and other appurtenances.
- Promote development of TSP to academic community

Research Proposed:

The following tasks have been identified to complete the work for this project:

Task 1. Identify and study marketing strategies for TSP activities as part of Asset Management. Develop a summary of best practices for various infrastructure assets.

Task 2. Develop and deliver workshops on marketing TSP. Develop mechanism to evaluate effectiveness of workshops.

Task 3. Develop recommendations for outreach program to senior agency executives, Contractors, Consultants, trade organizations and academics. This includes methods of integrating preservation with PPP contracts.

Task 4. Develop guidelines for succession planning and preserving institutional knowledge about TSP in an agency.

Proposed Deliverables:

1. Marketing Strategy for System Preservation including pavements, bridges, and other highway assets.

2. Workshops on communication of preservation practices, policies, and decision-making.

3. Outreach and marketing plan for system preservation.

4. Workshops for university professors on pavement preservation.

5. Guide for succession planning and knowledge management for preservation of highway assets.

Potential Partners: FHWA, NCHRP, Foundation for Pavement Preservation, Universities, Trade Organizations, ASCE

Estimated Cost and Duration: \$350,000 2 Years

User Community: State, Province, and Local Owner-agencies; Contractors, Universities,

Implementation: FHWA, TAC, Universities, and LTAP should be involved in the implementation efforts. This would include workshops, outreach, and development of marketing materials including brochures and videos and media news releases.

Design #01

Title: Determine the Economic Benefits of Pavement Preservation Strategies

Background: Pavement preservation is an activity intended to keep good pavements in good condition. Determining when to apply preventive maintenance processes is not always obvious. Preventive maintenance tools perform best when they are applied under pavement conditions they were intended to repair or mitigate. Also, preventive maintenance treatments cannot be expected to perform adequately if applied at an inappropriate time in the pavement life. Therefore, there is a need to determine which treatments impact the pavement life and the economic benefits associated with the treatment.

Scope/Objectives: The objective of this project is to:

- Document the performance of various pavement preservation strategies associated with environment, pavement type,, and traffic conditions.
- Document pavement life extension due to pavement preservation versus pavements that received no preservation until rehabilitation

Research Proposed:

The following tasks have been identified to complete the work for this project:

Phase I

Task 1. Conduct literature review of highway projects

Task 2. Gather pavement, environment, traffic, and maintenance data from various agencies

Task 3. Analyze the data and develop performance curves for each treatment based on the functional class of the highway for each LTPP climatic region.

Task 4. Develop a methodology to compare the pavement lives of pavements with similar structure versus various Pavement Preservation strategies

Task 5. Develop a methodology for conducting a Life Cycle Cost Analysis and attendant cost benefits of pavement preservation

Task 6. Prepare a preliminary analysis and identify gaps in the data

Phase II

Task 1. Develop a research plan to obtain data missing from Phase I.

Task 2. Analyze the data and develop the performance curves based on the additional data

Task 3. Compare the pavement lives with similar pavement structures for various Pavement Preservation strategies based on the additional data

Task 4. Detail the process of conducting Life Cycle Cost and cost benefit analysis for various pavement preservation strategies

Proposed Deliverables:

- 1. Cost benefit analysis contrasting existing treatments to the recommended treatments
- 2. A matrix of pavement type and climate vs. recommended treatments to achieve optimal life extension
- 3. Final report describing the methodology used in the study to determine the above and recommendations.

Potential Partners: Regional and National Pavement Preservation Centers, FHWA, FPP, AASHTO, TRB – SHRP 2, Regional Pavement Preservation partnerships, National and Regional Pooled Funds, Industry/Agency Partnerships

Estimated Cost and Duration:

 Phase I :
 \$450,000
 2.5 Years

 Phase II:
 \$500,000
 2 Years

User Community: State and Local Transportation Agencies

Implementation: Create a framework for the development of regional/state adoption of course manuals and workshops for maintenance engineers and managers. Develop a white paper/press kit for decision makers to justify dedicated funding based on actual information.

Design #02

Title: Determining Pavement Preservation Treatment Lives and Related Pavement Life Extension

Background: Success of a pavement preservation technique is heavily dependent on its optimal application in terms of timing and existing pavement conditions. Performance of different treatments and life extension of existing pavements due to these treatments is a function of existing pavement conditions (e.g., type, severity, and extent of distresses) and prevailing site conditions (pavement type, pavement age at the time of application, traffic, climate, etc.). There is an urgent need to develop methodologies to predict treatment performance, life extension of existing pavements and its related cost savings.

Scope/Objectives: The objective of this project is to develop methodologies to estimate treatment lives and life extension of both flexible and rigid pavements as a function of treatment type, existing pavement conditions, and environmental and traffic conditions. It is anticipated that existing databases and PMS data will be used to develop these methodologies and estimates.

Research Proposed:

The following tasks have been identified to complete the work for this project:

Task 1. Conduct a literature search and survey of transportation agencies nationally and internationally on: (1) pavement preservation techniques used for various existing pavement conditions; (2) performance curves of different pavement preservation techniques; and (3) methodologies to determine the life extension of existing pavements due to the application of pavement preservation treatments.

Task 2. Develop a family of performance curves for each pavement functional category for different pavement preservation treatment techniques used, as a function of the existing pavement, environment and traffic conditions based on findings from Task 1.

Task 3. Develop a methodology to determine the life extension of existing pavements as a function of existing pavement, environment and traffic conditions for selected treatment types.

Task 4. Develop a methodology for estimating the potential cost savings associated with selected preservation treatments given existing pavement, environment and traffic conditions on a per mile basis.

Task 5. Prepare final report.

Proposed Deliverables:

1. Performance curves of various pavement preservation techniques for each pavement functional category, environmental and traffic condition.

- 2. Recommend optimal timing and expected treatment life for maximum benefit for each treatment
- 3. Methodology to predict the life extension of existing pavements.
- 4. Methodology to estimate cost savings associated with various treatments.

Potential Partners: FHWA, AASHTO, APWA, FP2, Contractors

Estimated Cost and Duration: \$350,000 30 months

User Community: State and local agencies, AASHTO, APWA, Contractors, Academia

Implementation: Prepare a marketing plan for the products that are developed as a result of this research project. The marketing plan should refine the target market and provide a systematic approach to making sure that key decision makers become aware of the features advantages and benefits. The plan should also facilitate distribution of the products to early adopters with sufficient support for timely implementation.

Design #03

Title: Validate a Methodology for Determining Optimal Timing of Pavement Preservation Treatment Applications

Background: In recent years, pavement preservation has become an increasingly important component of highway agencies efforts to manage their pavements. The selections of the treatment and timing of its application are among the important factors that contribute to the successful use of preventive maintenance treatments. Determining the optimal timing for a specific treatment requires understanding of the treatment's purpose and how it will perform when it is applied to a pavement with a specific condition under specific conditions of climate and traffic. Application of the treatment of the "optimal timing" is expected to yield the maximum benefit/cost ratio for the chosen treatment. NCHRP Report 523, "Guide for Optimal Timing of Pavement Preservation Treatment Applications" developed a methodology to identify the optimal time to apply a single treatment based on simultaneous analysis of the benefits observed from applying a treatment at a given time, and the cost of the application. However, the methodology has not been sufficiently validated using in-service data, therefore, there is a need to further evaluate this methodology and develop related manual. It is intended that this study follow Problem Statements 1 and 2.

Scope/Objectives: The objective of this project is to validate or if necessary, modify the methodology presented in NCHRP Report 523 for identifying the optimal timing of preventive maintenance treatments, using in-service data.

Research Proposed:

The following tasks have been identified to complete the work for this project:

Task 1. Identify in-service data that are required to evaluate the methodology applicability for different pavement types and conditions, treatment types, traffic levels, and climatic conditions.

Task 2. Develop an experimental design of in-service pavements that covers the parameters and data required for evaluating the optimal timing for the application of the different treatments.

Task 3. Develop a plan for acquiring the identified in-service data, coordinate with highway agencies, and obtain the data.

Task 4. Analyze the collected data evaluate/modify the earlier developed methodology.

Task 5. Prepare the modified methodology in an electronic format together with appropriate manuals to facilitate usage by highway agencies.

Task 6. Prepare a report that documents the entire research. The modified methodology and associated manuals shall be presented as stand-alone documents.

Proposed Deliverables:

1. Validated methodology, in an electronic format, for determining optimal timing of pavement preventive maintenance treatment application.

2. Manuals supporting the developed methodology.

Potential Partners: State DOT's, APWA, FHWA, Foundation for Pavement Preservation

Estimated Cost and Duration: \$500,000 3 Years

User Community: State DOT's, APWA, FHWA, consultants, contractors

Implementation: Prepare a marketing plan for the products that are developed as a result of this research project. The marketing plan should refine the target market and provide a systematic approach to making sure that key decision makers become aware of the features advantages and benefits. The plan should also facilitate distribution of the products to early adopters with sufficient support for timely implementation.

Design #04

Title: Develop Appropriate Pavement Preservation Treatments and Practices for Urban Areas.

Background: Maintenance activities performed in urban areas are often restricted to off peak hours. This can influence the selection of the treatment and/or its short-term and long-term performance. Additionally, the treatment type is often influenced by demographic and neighborhood considerations such as noise, texture, loose chips, etc.

Scope/Objectives: The objective of this project is to identify the most appropriate maintenance treatment considering climate, traffic levels, traffic delays, etc. It is also designed to identify tradeoffs between performance and length of delay by establishing an optimum window of opportunity for different traffic levels.

Research Proposed:

The following tasks have been identified to complete the work for this project:

Task 1. State of the practice. The first task is to determine current pavement preservation practices in urban areas dealing with the selection of maintenance treatments for various traffic levels and neighborhood considerations

Task 2. User delays per treatment. This task is to determine the traffic delays associated with the various treatments used in urban areas. Details developed to provide guidance for the engineering and construction delays are a function of the traffic volumes, the time required to complete a unit section before opening to traffic, etc.

Task 3. Windows of opportunity. This task will develop appropriate windows of opportunities for the various maintenance treatments to minimize user delays and/or maximize expected performance.

Task 4. Implementation manual. An implementation manual will be developed to provide guidance to the engineering and construction community as to the most appropriate maintenance treatments, considering climate, traffic level, user delay, and neighborhood considerations.

Proposed Deliverables:

1. The proposed deliverable will be a manual that can be used by agencies to select the most appropriate pavement maintenance treatments considering climate, traffic level, user delays and neighborhood considerations.

Potential Partners: FHWA, NACE, NLTAPA, LTAP, APWA

Estimated Cost and Duration: \$300,000 30 months

User Community: State and local transportation agencies. International communities

Implementation: Prepare a marketing plan for the products that are developed as a result of this research project. The marketing plan should refine the target market and provide a systematic approach to making sure that key decision makers become aware of the features advantages and benefits. The plan should also facilitate distribution of the products to early adopters with sufficient support for timely implementation.

Design #05

Title: Framework for a Coordinated Approach to Pavement Preservation Process from an Agency Perspective.

Background: Various divisions within transportation agencies tend to act independently resulting in many issues being compartmentalized that inhibits implementation of pavement preservation programs. Effective communication between custodians of design, maintenance, construction, materials, traffic, research, and pavement management is often lacking. Effective communication and coordination will ensure the success of the pavement preservation progress. Well meaning independent actions often results in inefficient, ineffective pavement preservation programs and lost opportunities.

Scope/Objectives: The objective of this project is to develop a framework and guidelines to assist transportation agencies in successfully communicating and implementing pavement preservation programs across all functional areas.

Research Proposed:

The following tasks have been identified to complete the work for this project:

Task 1. Conduct a literature search and transportation agencies nationally on processes used for pavement preservation program (reference ongoing FHWA state survey on pavement preservation). Make use of the FHWA/AASHTO Pavement Preservation Scanning Tour document and the pavement preservation program appraisal conducted by the National Center for Pavement Preservation

Task 2. Prepare a report indicating best practices identified in Task 1.

Task 3. Conduct an in-depth review of a minimum of eight agencies of different sizes in each AASHTO region.

Task 4. Develop a flowchart and operating procedures showing recommended process and lines of communication between functional areas to effect and enhance the pavement preservation program.

Task 4. Prepare a final report and training materials for implementation.

Proposed Deliverables:

1. Framework for delivering pavement preservation in a coordinated approach within an agency, which encompasses all functional areas.

2. Develop a flow chart and operating procedures for the pavement preservation program that can be customized to an individual agency's needs.

3. Develop a series of workshops to bring all parties together to communicate the roles and responsibilities in an effective pavement preservation program.

Potential Partners: State & Provincial DOT's, FHWA, Foundation for Pavement Preservation

Estimated Cost and Duration: \$300,000 2 Years

User Community: States, provinces, local agencies, regional transportation commissions, International communities

Implementation: Prepare a marketing plan for the products that are developed as a result of this research project. The marketing plan should refine the target market and provide a systematic approach to making sure that key decision makers become aware of the features advantages and benefits. The plan should also facilitate distribution of the products to early adopters with sufficient support for timely implementation.

Design #06

Title: Integrating Pavement Preservation into the Design Process

Background: Pavement maintenance practices have often been a reactive approach. Pavement preservation is a proactive approach and should be included at the beginning of the design process. The application cycle, performance impacts and funding should be considered at this time.

Scope/Objectives: The objective of this project is to develop information that can be incorporated into further enhancements of the M-E PDG. Currently within the M-E PDG the process for designing and rehabilitating pavements is considered but there is no consideration for intermediate treatments to preserve the functional characteristics of the pavement surface prior to rehabilitation. This project is dependent on the outcome of Projects Dallas #1 and #2.

Research Proposed:

The following tasks have been identified to complete the work for this project:

Task 1. Collect all available data and materials.

Task 2. Identify the elements in pavement preservation that need to be incorporated in the M-E Design Guide.

Task 3. Prepare a draft preservation module for the M-E PDG and beta test with user agencies.

Task 4. Develop a methodology to evaluate new and innovative treatments.

Task 5. Finalize the preservation module based on feedback from user agencies.

Proposed Deliverables:

- 1. A final report including findings in Tasks 1 and 2.
- 2. Module for the M-E PDG.
- 3. Methodology to evaluate new and innovative treatments.

Potential Partners: FHWA, AASHTO, State & Provincial Highway Agencies

Estimated Cost and Duration: \$600,000 30 months

User Community: AASHTO, Local Agencies, Academia, International

Implementation: Prepare a marketing plan for the products that are developed as a result of this research project. The marketing plan should refine the target market and provide a systematic

approach to making sure that key decision makers become aware of the features advantages and benefits. The plan should also facilitate distribution of the products to early adopters with sufficient support for timely implementation.

Design # 07

Title: Integration of Pavement Preservation with a Pavement Management System (PMS))

Background: Historically pavement preservation has not been "driven" by pavement management and pavement preservation and rehabilitation are often programmed by different groups within an agency and maintenance activities are often not reported in conjunction with the referencing system used in pavement management. The same maintenance treatment can be used as preventive, corrective, or stop-gap treatment. Recently transportation agencies have begun to integrate pavement preservation into their planning and design decisions because they realize that the early application of preservation treatments reduces life-cycle costs and keeps good roads in good condition.

Scope/Objectives: The objective of this project is to develop a methodology to integrate Pavement Preservation (PP) with a Pavement Management System (PMS).

Research Proposed:

The following tasks have been identified to complete the work for this project:

Task 1 – Conduct a literature search, identify those agencies that have successfully integrated pavement preservation with pavement management, and report on the mechanisms that they have used to accomplish this integration.

Task 2 – Identify all the elements in the PMS that are related to pavement preservation, or are impacted by pavement preservation such as treatment lives for various conditions, PP schedules, and life extension. Prepare a report detailing the conceptual integration approach.

Task 3 – Develop a methodology that agencies may use to integrate pavement preservation with PMS

Proposed Deliverables:

Final report detailing the approach and rational identified in Task 2 and the methodology for integrating PP with PMS

Potential Partners: Regional and National Pavement Preservation Centers, FHWA, Foundation for Pavement Preservation, AASHTO, TRB – SHRP 2, Regional Pavement Preservation partnerships, National and Regional Pooled Funds, Industry/Agency Partnerships

Estimated Cost and Duration: \$350,000 2 Years

User Community: State and Local Transportation Agencies

Implementation: Create a framework for the development of regional/state adoption of course manuals and workshops for maintenance engineers and managers.

Construction #01

Title: Development of Innovative Pavement Preservation Products, Equipment & Construction Methods

Background: There is little or no incentive to develop new products or equipment with the limitations on proprietary products. New and improved construction methods are difficult to develop with the current method specifications and no guarantee of a future market.

Scope/Objectives: The objective of this project is to: define a process for the development of new products, equipment and/or construction methods (using the European Model) that will be responsive to special needs such as: urban vs. rural conditions, specific challenging areas including: high traffic, environmentally sensitive areas, tight working space, allowing access during construction, cul-de-sac issues.

Research Proposed:

The following tasks have been identified to complete the work for this project:

Task 1. Determine the legal requirements requiring change to accommodate cooperative efforts between government agencies and industry for the development and use of new products, equipment, and/or methods that provide for recovery of invested capitol.

Task 2. Define the process for assembling the correct consortium of suppliers, equipment manufacturers, contractors and agency personnel for the specific need(s).

Task 3. Develop process for identifying problem areas that require a new product, process, equipment, and/or construction methods.

Proposed Deliverables:

- 1. Recommended legislative changes.
- 2. Process for Task 2
- 3. Process for Task 3

Potential Partners: Academia, Equipment manufacturers, Industry Associations, Foundation for Pavement Preservation, ISSA, AEMA, IGGA, ARRA, etc.), Material Suppliers, Contractors

Estimated Cost and Duration: \$150,000 18 Months

User Community: All public agencies that own roads.

Implementation: Signed Memorandum of Understanding (Agreement) between Government and Industry. The outcome would provide a mechanism to enable partnering and fostering more timely development of innovative products and equipment to better meet the needs of agencies.

Construction #02

Title: Performance Related Specifications (PRS) for Pavement Preservation treatments

Background: Pavement preservation treatments, by their diverse nature, do not lend themselves to traditional method based specifications. Many States have tried to develop warranty specifications to address this gap. Warranties do not necessarily provide the correct strategy for pavement preservation treatments, so construction specifications are moving into the PRS arena.

Quality of pavement preservation treatments is mostly dependent on the contractors operations, personnel, equipment, and methods. With the current specifications and the low bid process, there is no incentive for a contractor to make the extra effort to insure quality. In order to overcome this problem, some state and international agencies have developed performance related specifications where contractors do the design for PP treatments and are given economic incentives/disincentives based upon the end result (e.g. NCHRP Synthesis on Best Practices for Chip Seals).

Scope/Objectives: The objective of this project is to:

- determine which engineering properties need to be measured for performance/acceptance
- determine how performance parameters should be measured.
- determine which pavement preservation treatments lend themselves to
- incentive/disincentive clauses, and recommend limits for incentives / disincentives

Research Proposed:

The following tasks have been identified to complete the work for this project:

Task 1. Conduct a literature search of current PP performance related specifications as applied to asphalt and concrete pavements, and provide a report that provides the benefits of using PRS vs. traditional method based for PP specifications.

Task 2. Determine the desired attributes that can be measured to assure the quality of relevant PP treatments.

Task 3. Determine treatment-specific performance measures and acceptance criteria

Task 4. Determine criteria for the appropriate use of incentives/disincentives.

Task 5. Develop draft AASHTO Provisional Standards for PRS as they apply to PP treatments.

Proposed Deliverables:

- 1. Report from Task 1
- 2. Template for incorporating agency's PR Specifications into treatment specific projects

- 3. Manual that provides guidance and measurement techniques for the identified engineering properties.
- 4. Draft AASHTO provisional standards

Potential Partners:

FHWA NACE, APWA, LTAP, AASHTO Subcommittee on Maintenance Foundation for Pavement Preservation and PP technical centers (NCPP, CA, TX) Industry Trade Associations – AEMA, ARRA, ISSA, IGGA Contractors, Material Suppliers, Equipment Manufacturers, Academia

Estimated Cost and Duration: \$500,000 3 Years

User Community: Highway Agencies - State, County, Cities

Implementation: AASHTO Publication.

Construction #03

Title: Improving the Timeliness of Acceptance Testing Results

Background: Ideally, real time results are desirable due to the fast-moving (short duration) nature of PP projects. An entire pavement preservation project may be completed before out-of-spec material is determined from test results.

Scope/Objectives: The objectives of this project are to:

-Develop real-time, in process objective evaluation criteria or test methods for QC/QA.

-Consider visual acceptance with aid from testing and/or using standardized photos (similar to the SHRP Distress Identification Manual)

-In situ performance testing (i.e. thermo-imaging camera, lightweight profilometer, CT meter, etc.)

-Test method for determining the soonest the agency can open road to traffic.

Research Proposed:

The following tasks have been identified to complete the work for this project:

Phase 1

Task 1. Evaluate existing and/or develop proto-type real-time test methods or evaluation criteria.

Task 2. Determine which methods from task 1 show the most promise and complete further development, refinement, and validation. Discontinue test methods that are no longer applicable.

Phase 2

Task 3. Evaluate whether or not standardized visual acceptance criteria is an acceptable method for QC/QA.

Phase 3

Task 4. Propose in situ performance test method(s). This task should leverage existing technology such as thermo-imaging cameras, lightweight profilometer, CT meter, etc.

Task 5. Develop, refine, and validate the test methods from task 4.

Phase 4

Task 6. Evaluate existing and/or develop proto-type test methods for determining the earliest time a road can be open to traffic.

Task 7. Determine which methods from task 6 show the most promise and complete further development, refinement, and validation

Proposed Deliverables:

- Draft and Final Research Report(s)
- Proposed Test Standards, Equipment, and Methods
- Proposed Specifications

Potential Partners: Academia, Equipment manufacturers, Industry Associations, Foundation for Pavement Preservation, ISSA, AEMA, IGGA, ARRA, etc.), Material Suppliers, Contractors.

Estimated Cost and Duration: \$500,000 3 to 10 Years

User Community: All public agencies that own roads.

Implementation: Provides for higher quality projects, potentially lowers testing costs, reduces contractor and agency risks, and improves performance life of pavement preservation treatments. New test methods would have to be stewarded through the appropriate AASHTO and/or ASTM committees.

Construction #04

Title: Pavement Preservation Contractor Qualification Program

Background: Agencies are often challenged in their selection of preservation techniques by a shortage of knowledgeable contractors able to do quality work for a given treatment. It can be problematic for an unqualified contractor to come into a new market and perform poor quality work. An agency might then be reluctant to ever try that treatment again, even if the treatment would be an excellent fit with local needs .

By establishing a qualification program, agencies will be able to identify a contractor's capabilities prior to awarding work, and can expect a high-quality and well-performing product.

Factors of the qualification would be contingent on overall agency commitment to quality, training of their personnel, use of modern equipment and techniques, and employment of formal QA/QC plans.

Several industries already have qualification programs that vary in terms of their significance (such as ISSA membership qualification, SSPC qualification, ISO 9000).

Scope/Objectives: The objective of this project is to develop a contractor qualification program that agencies can use (adapt) for their preservation programs. The qualification program should be specific enough to provide for distinct qualifications for a variety of potential treatments (chip seals, slurry seals, microsurfacing, grooving, grinding, CPR, etc.) The program will be developed in such a way that it can be adapted to specific agency program needs.

Research Proposed:

The following tasks have been identified to complete the work for this project:

Task 1. Evaluate existing qualification programs that are used by transportation agencies, nationally or internationally. Prepare a report on the current state of the practice of these programs and their potential for application domestically.

Task 2. Determine the critical components of a qualification program to assess contractor characteristics that exemplify their ability to complete quality pavement preservation treatments.

Task 4. Establish criteria, measures, and other specifics of a qualification program. Monitoring, tracking, requalification, and disciplinary procedures will need to be considered. Reciprocity among agencies will be a consideration of this effort.

Task 5. Draft a user's manual that outlines the process for agencies to implement a qualification program suitable to the needs of their own agency.

Task 6. Develop a proposed implementation plan that will facilitate adoption of these programs among agencies nationwide, and which encourages the establishment of reciprocity programs
(regionally or otherwise) so that contractors are not burdened with acquiring qualifications among numerous states.

Proposed Deliverables:

- 1. Results of program survey
- 2. Report of Criteria and measures.
- 3. Agency user's manual
- 4. Nationwide implementation plan

Potential Partners: Foundation for Pavement Preservation and other industry organizations (broad application to include black and white), MPPP, NEPPP, etc, NCPP, Tex, CA Centers, AASHTO Maintenance, AASHTO Construction, AASHTO Materials, LTAPs

Estimated Cost and Duration: \$350,000 1 Year

User Community: Contractors currently doing pavement preservation work, or wishing to expand operations into doing pavement preservation work. State and local transportation agencies would benefit from developing this qualification program. Ultimately, the highway users will receive the benefit of this effort because of its ability to improve the efficiency and of pavement preservation programs and the quality and performance of the transportation infrastructure.

Implementation: The principal challenge of this effort will be to obtain buy-in from both agencies and the contracting community. The intention of the effort is not to create a policing mechanism, but rather to encourage and expand the capabilities of contractors nationwide.

Construction #05

Title: Pavement Preservation: Contractor/Agency Training and Certification

Background: Large variations in the performance of pavement preservation treatments are commonly attributed to a lack of knowledge & skills on the part of contractor, and local agency/contract project personnel. As demonstrated by initiatives such as the Approved Supplier Certification Program (AASHTO-???), which was developed to support the SuperPave PG Binder Grading System, well-design training and certification programs can effectively improve quality. By certifying all project personnel, a certain degree of consistency is introduced into the construction process. It is advantageous to qualify contractor, agency and construction management consultant inspection personnel within the same program to achieve a quality preservation program.

Pavement preservation includes widely varying techniques and tools, so training programs must be developed around specific competencies so that individual certifications can be issued for treatments used by local agencies. Preservation training materials are available from a number of sources (NHI, FHWA, NCPP), but none have been developed into uniform certification programs.

A modular approach to training would be most suitable, since contractor and inspection personnel need technical knowledge on the treatments for which they are responsible. Individual modules must deal with both asphalt and concrete preservation activities, and where possible combine similar treatments (e.g. slurry seal and micro-surfacing).

Scope/Objectives: The objective of this project is to develop a training and certification program for both contractors and agencies to ensure predictable quality and performance of all pavement preservation techniques and treatments. The program will consist of a competency-based curriculum for both agency and contractor personnel. Completion of the curriculum and associated testing will result in certification of the individuals for specific pavement preservation techniques and treatments.

This program is intended to serve as the foundation for a separate contractor qualification program to be developed as part other research.

Research Proposed:

The following tasks have been identified to complete the work for this project:

Phase I: Develop a plan for training and certifying all personnel working on pavement preservation Projects

Task 1: Literature Review1a: Conduct a world-wide survey/review of pavement preservation techniques and treatments.1b: Identify available training materials for various preservation techniques1c: Review world-wide pavement preservation certification programs

1d: Review personnel certification programs from other industry sectors, such as the binder ASC program, and analyze program elements that might be incorporated into a pavement preservation certification program.

Task 2: Establish the framework for a pavement preservation training & certification program 2a: Combine similar techniques and treatments into a manageable number of training/certification modules.

2b: Establish the training needs that should be developed for pavement preservation treatments. 2c: Develop certification requirements for each treatment.

2d: Make recommendations for an implementation plan involving the contractor and agency personnel.

Phase II: Develop a Training/Certification Program for Pavement Preservation

Task 3: Develop Training Materials that cover topics of importance to contractor and agency personnel for each of the preservations techniques, as selected in phase I and as approved by the research panel.

Task 4: Develop Certification Requirements specific for contractor personnel and for project inspectors. Contractor certification should include a proof-of-competency.

Proposed Deliverables:

Phase I: Final report documenting Tasks 1 - 2Phase II: Formal Training and Certification Program

Potential Partners: Foundation for Pavement Preservation and pavement preservation technical centers (NCPP, CA, TX), NHI, AASHTO, IGGA, ACPA, ISSA, ARRA, AEMA, TRB, NAPA,

Estimated Cost and Duration: \$3,000,000,000 5 Years

User Community: Agency inspectors and contractor crews, State DOT's, FHWA, Contractors, Local Highway Agencies, Consultants

Implementation: Transfer of knowledge to the appropriate user community.

Construction #06

Title: Advanced Equipment for Improved Pavement Preservation Treatments

Background: Most pavement preservation techniques involve light application of materials that must be precisely monitored in order to meet quality expectations. In addition, timing material quality is critical to the success of many efforts. In northern climates, the work force is seasonal and must be able to come up to speed quickly at the beginning of each season and execute quality workmanship immediately. Even in southern climates pavement preservation work is somewhat seasonal requiring maximum use of equipment during the production season. Contracting agencies that traditionally provided inspection and contract administration have experienced significant losses of expertise and people available to perform administrative and inspection functions.

A number of opportunities in electronics, computers and worker ability are now available to address some of these challenges and equipment could be manufactured and retrofitted to capitalize on these opportunities. Several suggestions have been made such as:

- Using GPS Location to ensure proper roller coverage during chip seal operations.
- Combining GPS location and conveyor belt revolution counting to estimate application rates of micro-surfacing at various locations for Pavement Management Records.
- Development of an asphalt distributor truck that measures surface texture with lasers and automatically adjusts application rates with individual nozzles as necessary to provide proper aggregate embedment.

However, the volume of production of pavement preservation equipment is limited and the expense of engineering improvements cannot be spread over many units to provide economies of scale.

The industry must take advantage of these opportunities for equipment improvement in order to increase the use of pavement preservation techniques. Other segments of the industry are taking advantage of these items and pavement preservation operations must similarly improve. It is expected that workers will increase motivation by being included in a technologically advanced industry and that record keeping will improve by automatically recording machine position and material output. Lessons learned can be fed back more quickly avoiding rework and future problems. Machine information can also be fed into pavement management systems.

Scope/Objectives: The objective of this project is to encourage the development of equipment or modifications to existing equipment that will support improvements in pavement preservation construction projects by providing greater control in application rates, feedback in quality control and automatic record keeping.

Research Proposed:

The following tasks have been identified to complete the work for this project:

Task 1. Establish constraints with several investigations. Review current specifications for equipment used in various pavement preservation techniques to establish a baseline of the current state of the art in equipment manufacture. Define application rate tolerances, timing requirements, and quality control and quality assurance needs.

Task 2. Investigate uses of advanced technology in related areas of construction such as paving, earthmoving and building construction including GPS positioning, automatic machine control, real time quality control and automated record keeping. This will be accomplished by interviewing equipment manufacturers and contractors who use advanced technology

Task 3. Conduct field visits to projects involving all types of pavement preservation activities to observe the construction process and identify opportunities for equipment improvements. Harvest ideas for equipment improvements from experienced equipment operators.

Task 4. Present the findings of tasks 1-3 to a committee of experts and develop a list of equipment improvements for possible further development. Evaluate the items in the list and develop a ranking of priority. Select from the list a subset of ideas for prototype development. It is the intention that the prototype would be an idea that could be demonstrated during one construction season using a combination of existing construction equipment, off the shelf components and a limited amount of equipment specially built for the demonstration.

Task 5. Execute the demonstration during one construction season. Monitor results and modify and refine the equipment in the field based on lessons learned. Document the results.

Task 6. Write a report that documents the results of this project including initial investigations, the ideas developed by the expert panel, the results of the demonstration project and improvement and modification recommended as a result of the demonstration project. Also listed will be ideas that were not demonstrated, but have potential value along with suggestions on how to proceed with development.

Proposed Deliverables:

1. Expert task group meeting to recommend ideas for equipment improvement. A proceeding document would be included.

2. Demonstration of ideas that can be demonstrated and evaluated within the scope of this project. A field demonstration day could be included with invited guests.

3. Final report

Potential Partners:

Equipment manufactures, constructors, and contracting agencies

Estimated Cost and Duration:

2.5 Years (two construction seasons and enough time after the second season to write the report) \$300,000 (\$50,000 for equipment, \$100,000 per year for other items).

User Community: Ultimately the traveling public and taxpayers. Intermediate users are Equipment manufacturers, constructors, and contracting agencies.

Implementation: Equipment manufacturers and owners of existing equipment will need to build new equipment or retrofit existing equipment with the recommended improvements. The amount of further effort required will depend on the complexity of the idea. Some ideas may be easily implemented by retrofitting existing equipment or improving new equipment with off the shelf items. Other ideas may require considerable additional development, funding and risk. It is expected that the demonstration project will reduce the risk of implementing at least one of the ideas by providing proof of concept.

Construction #07

Title: QA/QC Guidelines for Pavement Preservation Projects

Background: In HMA and PCC, the QA/QC processes have been developed over time and in conjunction with the owner agency. Small contractors do not have staff capable of developing QA/QC programs for Pavement Preservation activities. This is due in part to the diverse and often proprietary nature of preservation treatments.

Scope/Objectives: The objective of this project is to develop a generic QA/QC program for pavement preservation activities. It is anticipated to have multiple QA/QC programs that small contractors can incorporate utilizing the agencies specifications and placing QC in the hands of the contractors.

Research Proposed:

The following tasks have been identified to complete the work for this project:

Task 1.Determine which QA/QC activities need to be developed for individual asphalt and concrete PP treatments

Task 2. Determine availability of existing best practices by agencies in this area.

Task 3. Develop a generic framework for the QA/QC plan for each identified activity.

Task 4. Validate the developed generic programs.

Proposed Deliverables:

1. Generic QA/QC program guidelines for each PP treatment which can be modified by contractors to match agency specifications for a preservation treatment.

2. User Manual and Training Guide for each process.

Potential Partners: AASHTO Subcommittee on Maintenance, NCPP, Foundation for Pavement Preservation, FHWA, Industry Associations – develop the list, NACE, APWA

Estimated Cost and Duration: \$275,000 1 Year

User Community: Highway Agencies - State, County, Cities.

Implementation: Deployed by User Manual and Training Guide through national, regional and local workshops.

Materials #01

Title: Mechanical Binder Properties to Predict Surface Treatment Performance

Background: It is widely recognized that the relevant and desirable performance characteristics of surface treatments differ substantially from typical full depth asphalt pavements. Examples of key physical properties which are of particular importance in surface treatment applications include adhesion, cohesion, tensile elongation, and shear and abrasion resistance. Thus, differences in mechanical properties and the rate at which these properties change with time (aging) mandate the use of alternate approaches in binder testing and specifications.

The mechanical properties of binders (both asphalt cement and emulsions) as they are used in thin surface treatments are not well understood as they related to long-term performance. Thus, it is important to define what specific performance characteristics are desired from a given surface treatment, in order to specify appropriate testing techniques and thus, performance specifications. Moreover, additional issues exist between asphalt cement and emulsions within the context of surface treatment applications. For instance, one key issue pertains to the evaporation/extraction of residual asphalt from emulsions in a manner which are reproducible, and will yield physical test results which are representative of actual field conditions.

Scope/Objectives:

- 1. Develop key performance metrics.
- 2. Identify appropriate testing protocols to accurately measure key performance metrics.
- 3. Assess different emulsion evaporation methods to identify techniques which will yield residue test results that are representative of actual field conditions, while remaining sensitive to time and cost constraints.
- 4. Develop prototype performance specifications for the selection of binders.

Research Proposed:

The following tasks have been identified to complete the work for this project:

Task 1. Literature Search and Review – Collect and evaluate existing literature including published and unpublished sources and personal contacts with industry and DOT leaders.

- Task 2. Analysis of Existing Field and Laboratory Test Data Utilize collected existing field and laboratory data to evaluate correlation between laboratory test results and actual field performance.
- Task 3. Confirmatory Laboratory Testing Program Design and implement laboratory testing program to refine performance measures, and correlate same with field performance data.

Task 4. Compile the results of Tasks 1-3 above to develop model performance specifications to be used in the selection of binders.

Proposed Deliverables:

- 1. A list of tests and test methods to achieve longer lasting surface treatments
- 2. A matrix of test requirements for pavement types and treatment types
- 3. Life cycle cost analysis contrasting existing treatments to longer lasting treatments
- 4. Final report describing the study and the recommendations

Potential Partners:

American Society of Testing Materials American Association of State Highway and Transportation Officials International Slurry Surfacing Association Asphalt Emulsion Manufactures Association National Association of County Engineers American Public Works Association Asphalt Pavement Association National Center for Asphalt Technology

Estimated Cost and Duration: \$1,500,000 3 – 5 Years

User Community: Transportation agencies, material suppliers, and contractors at all levels can benefit from this study

Implementation:

- 1. Distribution of the final report to industry and agencies
- 2. Joint industry/agency training module to distribute the findings of the study

Materials #02

Title: Acceptance Criteria for Surface Treatments

Background: The proliferation of method specifications has resulted in thin surface treatment performance deficiencies. In response to these difficulties, contractors, industry, and agencies have begun moving toward the development and implementation of performance specifications.

The key challenge in the development of performance specifications is the need to identify appropriate testing protocols and acceptance criteria which will reliably predict long-term treatment performance or the potential for failure. By developing reliable acceptance criteria, agencies will have the means to determine when a treatment has been satisfactorily constructed and to aid in assessing the appropriate level of compensation (i.e., performance incentives and penalties).

Scope/Objectives

- 1. Development of reliable acceptance criteria and to ensure adequate performance of thin surface treatments.
- 2. Allow contractors more flexibility, thereby increasing innovation, potentially resulting in lower costs.
- 3. Validate the prototype specifications.

Research Proposed:

The following tasks have been identified to complete the work for this project:

Task 1. Literature Search and Review – Collect and evaluate existing literature including published and unpublished sources and personal contacts with industry and DOT leaders.

- Task 2. Analysis of Existing Field and Laboratory Test Data Utilize field and laboratory data to evaluate correlation between laboratory test results and field performance.
- Task 3. Develop prototype performance specifications.

Task 4. Validate prototype specifications via field studies performance evaluation.

Proposed Deliverables:

- 1. A list of acceptance criteria to achieve longer lasting surface treatments
- 2. Life cycle cost analyses of treatments done with proposed acceptance criteria
- 3. Final report describing the study and the recommendations

Potential Partners:

American Society of Testing Materials American Association of State Highway and Transportation Officials International Slurry Surfacing Association Asphalt Emulsion Manufactures Association National Association of County Engineers American Public Works Association Asphalt Pavement Association National Center for Asphalt Technology

Estimated Cost and Duration: \$600,000 3 – 5 Years

User Community: Transportation agencies, material suppliers, and contractors at all levels can benefit from this study

Implementation:

- 1. Distribution of the final report to industry and agencies
- 2. Joint industry/agency training module to distribute the findings of the study

Materials #03

Title: Appropriate Installation Geometry for Crack Treatments

Background: It is understood that reservoir shape and crack size have a significant impact on the performance of crack treatments. The strain limits of any crack treatment are dependent upon the material used and the size and shape of the reservoir. Thus, the crack treatment material must be selected based upon the anticipated crack movement and temperature extremes.

In general, there has been a widespread failure to recognize the importance of crack movements in the long-term performance of crack treatments. Moreover, the magnitude of crack movements has not been well documented. Therefore, in order to establish the appropriate installation geometry for crack treatments, it is necessary to determine crack movement magnitude under various climate conditions and applied loadings.

Scope/Objectives:

- 1. Develop typical crack movement estimates for various climate zones and applied loadings.
- 2. Develop a model to estimate crack movements for various climate and loading conditions.
- 3. To develop appropriate installation geometries based upon the crack movement, traffic, climate conditions, and sealant properties.

Research Proposed:

The following tasks have been identified to complete the work for this project:

- Task 1. Literature Search and Review Collect and evaluate existing literature including published and unpublished sources and personal contacts with industry and DOT leaders, on available crack movement data for various climate zones.
- Task 2. Analysis of Existing Field Data Utilize collected existing data to evaluate correlation between climate and crack movement and use data to populate database.
- Task 3. Develop guidelines for proper sealant use based on climate and traffic conditions to minimize crack movement.

Proposed Deliverables:

- 1. Guidelines for appropriate installation geometries to achieve longer lasting surface treatments
- 2. Life cycle cost analyses of treatments done with appropriate installation geometries
- 3. Final report describing the study and the recommendations

Potential Partners:

American Society of Testing Materials American Association of State Highway and Transportation Officials International Slurry Surfacing Association Asphalt Emulsion Manufactures Association National Association of County Engineers American Public Works Association Asphalt Pavement Association National Center for Asphalt Technology

Estimated Cost and Duration: \$250,000 3 Years

User Community: Transportation agencies, material suppliers, and contractors at all levels can benefit from this study

Implementation:

- 1. Distribution of the final report to industry and agencies
- 2. Joint industry/agency training module to distribute the findings of the study

Materials #04

Title: Cost-Effectiveness of Quality Aggregates

Background: It is desirable to establish the incremental and/or break-even costs and benefits between the performance differential realized from higher-quality imported versus local aggregate used in pavement preservation treatments.

As an essential component in the success and viability of thin surface treatments, aggregates of sufficient quality should be employed to optimize performance and long-term reliability. In many areas of the country, quality aggregate sources are either absent, or have been severely depleted through years of overuse. This raises a question as to whether the increased costs of importing higher quality aggregates into these areas may be warranted if it results in increases in performance, treatment life, or extends effective service life of the pavement, particularly when compared to lower quality but more readily available local aggregate sources.

Once incremental costs and benefits are established by this research, practitioners will be able to utilize this information to calculate actual project costs per ton-mile through various means of transport (e.g., truck, rail, water). This will enable maintenance engineers to determine when it might be beneficial to import higher quality aggregate, or alternately, when locally available materials are sufficient to meet design objectives.

Scope/Objective:

- 1. Define the principal aggregate quality indicators that influence treatment performance under various climate and operational conditions (e.g., chains, studded tires, etc.).
- 2. Evaluate life cycle costs for treatments using local and higher quality imported aggregate.

Research Proposed:

The following tasks have been identified to complete the work for this project:

- Task 1. Literature Search and Review Collect and evaluate existing literature including published and unpublished sources and personal contacts with industry and DOT leaders, on aggregate performance under varying climate conditions.
- Task 2. Evaluation of life-cycle costs for various surface treatments.
- Task 3. Develop quantitative evaluation "tools" to assessing economic cost-benefit of imported versus local aggregates.

Proposed Deliverables:

- 1. A list of quality aggregate indicators to achieve longer lasting surface treatments
- 2. Life cycle cost analyses of treatments done with quality aggregates

3. Final report describing the study and the recommendations

Potential Partners:

American Society of Testing Materials American Association of State Highway and Transportation Officials International Slurry Surfacing Association Asphalt Emulsion Manufactures Association National Association of County Engineers American Public Works Association Asphalt Pavement Association National Center for Asphalt Technology

Estimated Cost and Duration: \$250,000 9 months

User Community: Transportation agencies, material suppliers, and contractors at all levels can benefit from this study

Implementation:

- 1. Distribution of the final report to industry and agencies
- 2. Joint industry/agency training module to distribute the findings of the study

Materials #05

Title: Performance Grading System for Asphalt Emulsions

Background: As the demand for asphalt emulsions has increased due to the widespread acceptance of pavement preservation, it is recognized that a need exists to develop an appropriate grading system for emulsion residues based on environmental and traffic conditions.

Scope/Objective:

Phase I

- 1. Modify existing binder testing equipment and protocols to achieve accurate, representative, and repeatable estimates of performance of the residual asphalt.
- 2. Create practical and cost-effective testing protocols, which build upon existing PG methodologies and equipment.
- 3. Develop appropriate residue recovery methods for testing.

Phase II

- 4. Use phase 1 results to develop new grading standards for the appropriate preservation treatments
- 5. Develop application-specific performance-graded residue specifications.

Research Proposed:

The following tasks have been identified to complete the work for this project:

- Task 1. Literature Search and Review Collect and evaluate existing literature including published and unpublished sources and personal contacts with industry and DOT leaders, on test methods and correlation of same to field performance.
- Task 2. Develop, evaluate, and standardize residual asphalt extraction techniques and determine their impact on performance test results.
- Task 3. Create and implement a laboratory test program to evaluate the effectiveness of various grading techniques in predicting long-term field performance. Utilize construction and evaluation of field test sections as part of this work task.
- Task 4. Correlation of best grading practices with various surface treatment applications.
- Task 5. Development of application-specific performance grading system.

Proposed Deliverables:

- 1. Description of asphalt extraction techniques with recommendations for longer lasting treatments
- 2. Application specific performance grading system to achieve longer lasting surface treatments
- 3. Life cycle cost analyses of treatments done with proposed acceptance criteria
- 4. Final report describing the study and the recommendations

Potential Partners:

American Society of Testing Materials American Association of State Highway and Transportation Officials International Slurry Surfacing Association Asphalt Emulsion Manufactures Association National Association of County Engineers American Public Works Association Asphalt Pavement Association National Center for Asphalt Technology

2 years (Phase I) 3 years (Phase II)

User Community: Transportation agencies, material suppliers, and contractors at all levels can benefit from this study

Implementation:

- 1. Distribution of the final report to industry and agencies
- 2. Joint industry/agency training module to distribute the findings of the study

Materials #06

Title: Performance-Graded Aggregate System for Pavement Preservation Surface Treatments

Background: As the demand for pavement preservation surface treatments has increased dramatically, it is recognized that a need exists to develop an appropriate performance grading system for the aggregates used in these treatments based on safety, environmental, and traffic conditions.

Scope/Objective:

- 1. Development of testing protocols and performance criteria to define texture and friction characteristics, which will optimize motorist safety.
- 2. Development of performance criteria for functional surface characteristics such as splash and spray, durability for winter operations, and noise.
- 3. Document the effects of physical characteristics of aggregates on performance
- 4. Establish criteria for all aggregate physical characteristics (e.g., size, shape, fracture, absorption, durability, etc.) and mineralogy to improve the performance of surface treatments. Some specific issues which should be examined as part of this objective, include:
 - a. Examine existing durability tests (e.g., LA abrasion versus Nordic abrasion or Micro Deval) to determine their suitability to different environments and traffic conditions including the use of studded tires.
 - b. Evaluate existing testing methods used to determine aggregate shape for costeffectiveness, ease of use, and practicality.
 - c. Determine the quality and quantity of P200 materials as they relate to the performance of specific surface treatments.
- 5. Develop methodologies, which will match the appropriate aggregate characteristics to the intended treatment, environmental conditions, and traffic volumes.

Research Proposed:

The following tasks have been identified to complete the work for this project:

- Task 1. Literature Search and Review Collect and evaluate existing literature including published and unpublished sources and personal contacts with industry and DOT leaders, on aggregate test methods and correlation of same to field performance.
- Task 2. Evaluation aggregate grading methods related to impact on field performance with respect to critical parameters such as durability, skid resistance, etc.
- Task 3. Correlate aggregate performance, test methodologies, and cost-benefits for various surface treatments.

Task 4. Develop standards on aggregate grading methodologies and produce guidance on aggregate selection based on treatment type, environment/climate, and traffic volumes.

Proposed Deliverables:

- 1. A list of aggregate characteristics to achieve longer lasting surface treatments
- 2. Life cycle cost analyses of treatments done with recommended aggregate characteristics
- 3. Final report describing the study and the recommendations

Potential Partners:

American Society of Testing Materials American Association of State Highway and Transportation Officials International Slurry Surfacing Association Asphalt Emulsion Manufactures Association National Association of County Engineers American Public Works Association Asphalt Pavement Association National Center for Asphalt Technology

Estimated Cost and Duration: \$4,000,000 5 Years

User Community: Transportation agencies, material suppliers, and contractors at all levels can benefit from this study

Implementation:

- 1. Distribution of the final report to industry and agencies
- 2. Joint industry/agency training module to distribute the findings of the study

Materials #07

Title: "Triggers" for the Timing of Surface Treatments

Background: While many agencies focus on conventional distress indicators to identify the timing of preventive maintenance treatments, other meaningful performance measures related to the properties of materials at the pavement surface might be beneficial for determining the "right time" for surface treatments. These surface material properties, which evolve as the pavement ages, should be integrated into existing data collection activities for incorporation into the pavement management system.

Scope/Objective:

- 1. Determine the mode and mechanisms of pavement failure as driven by pavement aging such as the changes in the physical properties of pavements/binders with depth.
- 2. Determine the material property changes which lead to failure.
- 3. Characterize and quantify the appropriate time windows of opportunity for the application of various treatments in relation to these trigger events.
- 4. Determine variability in materials characteristics and climate and their impact on timing triggers.
- 5. Incorporate the results and data sources such as the WRI Field Validation Study into this research.

Research Proposed:

The following tasks have been identified to complete the work for this project:

- Task 1. Literature Search and Review Collect and evaluate existing literature (including published and unpublished sources and personal contacts with industry, DOT leaders, and world wide agencies) on data pertaining to mode and mechanisms of pavement failure as related to aging.
- Task 2. Evaluation of material properties that lead to failure, and delineation of pavement "triggers" that signal the need for proactive intervention.
- Task 3. Develop guidance on treatment timing and application based on identified pavement failure mechanisms and distress "triggers".

Proposed Deliverables:

- 1. A list of triggers for the timing of surface treatments to achieve longer lasting surface treatments
- 2. Life cycle cost analyses of treatments done with proposed triggers
- 3. Final report describing the study and the recommendations

Potential Partners:

American Society of Testing Materials American Association of State Highway and Transportation Officials International Slurry Surfacing Association Asphalt Emulsion Manufactures Association National Association of County Engineers American Public Works Association Asphalt Pavement Association National Center for Asphalt Technology

Estimated Cost and Duration: \$10,000,000 8 – 10 Years

User Community: Transportation agencies, material suppliers, and contractors at all levels can benefit from this study

Implementation:

- 1. Distribution of the final report to industry and agencies
- 2. Joint industry/agency training module to distribute the findings of the study

Contracting Methods # 01

Title: Analysis and Synthesis of Pavement Preservation Contracting Methods

Background: The nation is currently undergoing a major paradigm shift from reconstructing and rehabilitating its highways to maintaining and preserving them. With this shift comes a change in the way highway agencies do business. There is a substantial amount of completed research on appropriate contracting methods for large and complex projects, but for simple preservation projects, there is not much knowledge in this area. With the new focus on preservation, it is critical that we find ways to effectively manage these projects.

In order to provide guidance in determining appropriate contracting methods for a given pavement preservation treatment, it is essential that information be obtained on current agency practices, and that the effect of these methods on the cost and performance of pavement preservation treatments be analyzed.

Scope/Objectives: The objective of this project is to determine the state of the practice with respect to pavement preservation contracting procedures. The scope may include, but is not limited to, the following:

- Types of specifications used in pavement preservation projects.
 - Warranties
 - Method
 - Performance
 - Incentive/Disincentive
- Innovative contracting.
- Other contracting methods.

These practices will be evaluated to determine their overall effectiveness based on their ability to contribute to the following:

- Reduce overall risk to both the agency and contractor.
- Encourage innovation.
- Improve project performance.

Research Proposed:

This project is broken down into two phases, as described below.

Phase I—State of the Practice

Task 1. Perform a literature review.

Task 2. Survey state and local agencies and industry representatives to determine what contracting methodologies are currently being used for pavement preservation treatments.

- Task 3. Document findings, produce a synthesis of findings, and distribute this draft report for review.
- Task 4. Prepare final report based on feedback.

Phase II—Develop Case Studies and Perform Analysis

- Task 1. Determine an approach to establish how the methods should be analyzed.
- Task 2. Develop case studies for each contracting method.
- Task 3. Evaluate case studies to determine if the contracting method resulted in improved performance.

Task 4. Develop final report based on the criteria and findings.

Proposed Deliverables

- 1. Synthesis.
- 2. Final report.

Potential Partners

FHWA, AASHTO, FOUNDATION FOR PAVEMENT PRESERVATION, Industry groups (ARRA, AEMA, ISSA, IGGA, and so on) This could potentially be accomplished as part of the ongoing FHWA/NCPP Technical Appraisals

Estimated Cost and Duration: \$600,000 3 Years

User Community: FHWA, state agencies, local agencies, industry

Implementation: Share these best practices and use them in order to provide guidance on selecting the appropriate contracting methodologies for a given pavement preservation treatment.

Contracting Methods # 02

Title: Performance Measures and Contracting Methods for Pavement Preservation Treatments

Background: While method specifications may not be the best contracting method for all pavement preservation treatments, there is a long history—and therefore a very high level of comfort—associated with their use. As agencies begin to consider contracting methods that focus less on specifying how the pavement preservation treatment is applied and more on the performance of that treatment, it is recognized that there is a lack of guidance on precisely what measures of performance are appropriate for different treatments.

As a simple example, where a method specification for crack sealing might focus on the crack preparation and sealant application method, a warranty contract for crack sealing might focus on how long the sealant remains in place and a performance-based contract might focus on in-place sealant properties such as adhesion and cohesion.

In order to consider the appropriateness of different pavement preservation contracting methods, it is essential to have a good understanding of which measures of performance are most appropriate for different treatments and different contracting methods.

While identifying the relationship between performance measures and contracting methods for different treatments is a necessary undertaking, acceptance/adoption and widespread implementation are unlikely to occur without field trials in which the performance measures are used in different types of contracting and the results are evaluated.

Scope/Objectives: The objective of this project is to identify and evaluate measures for preservation treatments and treatment categories for different contracting methods that reflect the following:

- The performance of the treatment
- The impact of the treatment on pavement performance
 - o short term and long term
 - o structural and functional

Research Proposed:

The following tasks have been identified to complete the work for this project:

- Task 1. Perform a national survey and international literature review of how the performance of various pavement preservation treatments is measured by different agencies, which distresses are considered important for evaluating the performance of preservation treatments, and which contracting methods are used.
- Task 2. Based on the information obtained from Task 1, identify a preliminary set of performance measures and any gaps that may exist in currently used measures.

Summarize performance measurements and relate them to different pavement preservation treatments.

- Task 3. Based on the information obtained from Task 1, identify the different types of contracting methods that are used. Identify if different performance measurements are specified under different types of contracts.
- Task 4. Develop an experimental design to evaluate various performance measures for different treatments and contracting methods.
 - Number of sites per treatment
 - Number of replicates per site
- Task 5. Solicit sponsoring (test site) agencies
- Task 6. Hold workshop on project design and expected outcomes
- Task 7. Develop specifications, advertise project, award
- Task 8. Project construction
- Task 9. Apply performance measures (monitor performance)
- Task 10. Close contracts
- Task 11. Analyze results
- Task 12. Develop and report on lessons learned

Proposed Deliverables

- 1. List of performance measures and contracting methods for pavement preservation treatments.
- 2. Experimental design to evaluate performance measures and contracting methods.
- 3. Workshop on project design and anticipated results.
- 4. Lessons learned report.

Potential Partners: Participating highway agencies, materials suppliers, preservation treatment contractors, preservation industry organizations (AEMA, ARRA, IGGA, ISSA, and so on).

Estimated Cost and Duration: \$700,000 4 Years

User Community: Contracting agencies, contractors, industry organizations, consulting community

Implementation: Two implementation activities are planned as part of this project. The first is to take the results and findings of tasks 1 through 4 and present them to stakeholders at a national

workshop. The second implementation activity is to take the results of the field experiment and report on them in a "lessons learned" document.

Contracting Methods # 03

Title: Development of Model Specifications and Testing Requirements for Pavement Preservation Contracting Methods

Background: Many highway agencies have expressed interest in guidance in writing method and performance-based specifications for given pavement preservation treatments. The use of model specifications will provide a template that would provide a framework that agencies can use to improve their pavement preservation program.

Scope/Objectives: The objective of this project is to provide model specifications, including applicable testing and acceptance provisions that may be used in contracting pavement preservation. These specifications should address the full range of pavement preservation treatment categories and contracting methodologies, to include method and performance-based contracting for both flexible and rigid pavements.

Research Proposed:

The following tasks have been identified to complete the work for this project:

- Task 1. Collect all available specifications from state and local agencies, along with agency/industry input on what works well and what didn't. Also use the specifications and the results/lessons learned from the field trials of performance measures and contracting methods.
- Task 2. Synthesize into draft specifications.
- Task 3. Solicit feedback on the draft specifications from agency and industry stakeholders.
- Task 4. Refine the specifications based on feedback received.

Proposed Deliverables

The proposed deliverable for this project is a set of model specifications, including testing requirements, for each pavement preservation treatment, based on various types of contracting methodologies.

Potential Partners: Industry organizations, state and local agencies, contractors, FHWA, AASHTO

Estimated Cost and Duration: \$300,000 2 Years

User Community: State and local Agencies, FHWA, industry, and consultants.

Implementation: The results can be published and therefore widely distributed as appendices to the Guide for Pavement Preservation Contracting. These model specifications will then serve as a source of guidance in how to write specifications for a given pavement preservation treatment.

Many industry organizations also distribute draft specifications.

Performance # 01

Title: Synthesis: Pavement Preservation Data Sources

Background: State Departments of Transportation (DOTs) and other public transportation agencies have collected various types of data on performance of pavements for many years. These collections of data are stored in various locations and in various formats. In order to determine the benefits of various pavement preservation treatments, it is important and urgent to begin by identifying what data is available and if/how it can be used to quantify these benefits. It is envisioned that the following agencies/sectors/organizations may have these data:

- State DOTs
- Transportation Authorities, e.g., NYS Thruway, New Jersey Turnpike, etc.
- Industry
- The International transportation community
- US Forest Service
- US Military and Army Corps of Engineers
- LTPP

Scope/Objectives: The objectives of this project are to identify existing sources of pavement data, examine the types, quality, completeness and format of data related to pavement preservation, assess the availability and potential use of the data for future research studies, develop a database template for accumulating pavement preservation performance data and developing recommendations standardized practice in collecting future data.

Research Proposed:

The following tasks have been identified as necessary in order to achieve the objectives of this project:

- Task 1. Identify potential sources of data on pavement preservation treatments and performance thereof.
- Task 2. Collect sample data from various sources in various data formats. Categorize data by format, completeness, quality and type, e.g.:
 - ➢ Friction
 - > IRI
 - ➤ type of treatments
 - materials properties
 - underlying materials data
 - ➢ distress
 - > pavement type
 - design features
 - ➤ treatment type
 - timing of treatment

- > pavement condition before and after treatment, \parallel
- delamination, etc)

Task 3. Assess collected sample data and evaluate their potential use for future research study.

Task 4. Develop database template (schema).

Task 6. Develop recommendations for standardized practice in collecting future data.

Proposed Deliverables:

- 1. Catalog of data sources and data types; assessment of current usefulness of existing data
- 2. Proposed database schema (template) for a centralized database
- 3. Recommendations for standardized practices
- 4. Final report outlining the process and findings

Potential Partners: State agencies, municipalities, industry, pavement preservation centers, regional centers.

Estimated Cost and Duration: \$600,000 30 Months

User Community: State pavement preservation and maintenance engineers, county and city engineers, future researchers

Implementation: PP centers, web-based dissemination of information?

Performance # 02

Title: Development of Distress Identification System for Pavement Preservation Treatments

Background: Since the effects of a treatment on pavement performance and the performance of a treatment itself are two different things, they should be evaluated separately. The definition of failure is important for the measurement of performance. Even though failures for pavements are well defined, this is not sufficient in itself for understanding and evaluating performance of pavement preservation treatments. Failure of a pavement and failure of a pavement preservation treatment need to be investigated separately. Without identifying the failure, we can't understand the concept of performance for pavement preservation treatments. The definition of failure should include forms and threshold values for the pavement preservation failures. Research is required to determine which distress measures truly identify key performance characteristics of pavement preservation treatments.

Most state agencies have their own procedures for field pavement condition survey and for identifying distresses with intent for the evaluation of existing pavement structure and possibly for the development of rehabilitation design. FHWA developed a comprehensive Distress Identification Manual (DIM) with intent for identifying nearly all distress types encountered on both flexible and rigid pavements. However, there is currently no such a DIM specific for pavement preservation purposes and for performance measurements as a result of applying preservation treatments.

Scope/Objectives: The objective of this project is to develop a DIM specific to pavement preservation for performance measurements.

- 1. Characterize differences between pavement preservation treatment failure and existing pavement failures to aid practitioners in understanding treatment performance and impact of treatment on pavement performance.
- 2. Identify and recommend an evaluation system for the distresses observed on pavement preservation treatments based on the existing research. If existing research is not sufficient, then identify additional research required to accomplish the project objectives.
- 3. Identify and characterize failure distresses of pavement preservation treatments and develop and justify failure thresholds.
- 4. Develop standard procedure for quantifying distresses for pavement preservation treatments

Research Proposed:

The following tasks have been identified to complete the work for this project:

- Task 1. Collect and review pertinent domestic and foreign literature, research findings and current practices related to pavement preservation treatment failure.
- Task 2. Based on the collected information, identify what is being measured, proper distress identification, indicators of quality, and effects of preservation treatment

- Task 2. Assess and evaluate collected data and their usefulness related to pavement performance assessment.
- Task 3. Based on the existing information, identify and recommend an evaluation system, including the types of distresses that should be considered for each preservation treatment, for the distresses observed on pavement preservation treatments. If existing research is not sufficient, identify the additional research required to complete this project and provide a plan for that research and completion of the project.
- Task 4. Present the findings of Task 1 3 in an interim report
- Task 5. Implement the plan developed in Task 3 (as approved/modified by the project panel) to develop a Distress Identification Manual (DIM) that provides a standard procedure for quantifying distresses for pavement preservation treatments.

Proposed Deliverables:

1. Interim report documenting the outcome of Tasks 1 -3

2. Distress identification manual for pavement preservation treatments providing recommended practices for preservation treatment performance data collection and measurement.

3. Final report documenting the full research effort.

Potential Partners:

Estimated Cost and Duration: \$400,000 2 Years

User Community: State pavement preservation and maintenance engineers, county and city engineers, future researchers

Implementation: PP centers, web-based dissemination of information

Performance # 03

Title: Quantify Performance and Benefits of Various Pavement Preservation Treatments and Develop Pavement Preservation Treatment Performance Models.

Background: Pavement performance is affected by several factors: construction materials and practices, QA/QC, traffic loadings, climate and environment. This is also true for pavement preservation treatments. Pavement preservation treatment application has to be efficient, cost effective, and durable and must provide at least its intended service life to ensure that the treated pavement maintains its structural and functional capabilities. However, in many cases, pavement preservation treatments do not always perform, as expected and additional treatment may be required within a short period of time. It is well documented that pavement treatment is affected by composition materials, construction quality, traffic characteristics, pavement design, and environmental conditions.

Durability of the treatment may include minimum raveling, bleeding, surface cracking, etc. Cost effectiveness may include costs related to environment, delays, as well as construction and possibly maintenance. The treatment performance should be measured using reliable and quantitative techniques and should meet the expectation of the users and stakeholders. The impact of the treatment on pavement performance must be similarly assessed. Performance models for both the preservation treatments and the treated pavements are needed in performance-based and warranty specs, pavement management systems, performance optimization, and decision trees, etc.

Scope/Objectives: The objective of this project is: to quantitatively measure the performance of various treatments applied to rigid and flexible pavements and their impact on the performance of the underlying pavements; to develop new improve existing performance models; to validate the models; and to prepare guidelines for using the validated models. It will include examination and validation of the pavement preservation performance models developed under NCHRP Project 14-XX.

These various treatments may include, but not be limited to, the following for flexible pavements: fog seal, chip seal, slurry seal, microsurfacing, thin hot-mix asphalt overlays, crack sealant, scrub seal, double chip seal, and chip seal under-laid by fabrics. For rigid pavements, this may include but not be limited to the following: dowel bar restoration, grinding, grouting, joint sealing, patching, and undersealing.

Research Proposed:

In order to achieve the multiple and sequential objectives of this project, the work plan is divided into three phases:

Phase I shall cover include:

- > A detailed research review literature search of all available information on:
 - Current practices of pavement treatment in the US & abroad

- Pavement treatment life expectancy and performance benefits in the U.S & abroad and
- Methods of determination of life expectancy and performance benefits. In addition,
- Availability of data to support the models
- > Developing and executing a plan to obtain the necessary data

Phase II of this project should focus on the development or improvement of performance models of for various pavement treatment applications and the impact of those treatments on pavement performance.

Phase III of the project should focus on developing and implementing plans to validate the new and/or improved performance models and a cost/benefit assessment for each treatment.

Research Proposed:

The following tasks have been identified as necessary to complete the work for this project:

Phase I:

Task 1. Conduct a literature search of the current practices and life extensions expected of pavements due the application of various pavement preservation treatments and of the models currently available to evaluate performance of pavement preservation treatments.

Task 2. Identify the data currently available and obtainable for improving existing models or developing new models

Task 3. Develop a plan to obtain the necessary data

Task 4. Submit an interim report for approval prior to proceeding to Task 5

Task 2. Recommend a plan for development of pavement preservation treatment performance model.

Task 3. Submit interim report for approval prior to proceeding to Phase II. Task 5. Implement the plan to obtain necessary data

Task 6. Prepare a final report that presents the results and summarizes the findings and conclusions of Phase I

Phase II:

Task 1. Recommend a plan for development of pavement preservation treatment performance models.

Task 2. Submit an interim report for approval prior to proceeding to Tasks 3 & 4.

Task 3. Develop performance models of various pavement treatments and their impact on pavement performance

Task 5. Develop a cost-to-benefit ratio for various pavement treatments

Task 4. Develop a validation plan for the calibration of the performance models

Task 5. Prepare a final report that presents the results and summarizes the findings and conclusions of Phase II

Phase III:

Task 1. Design a comprehensive experiment to validate the performance prediction models of the various types of treatments and their impact on pavement performance

Task 2. Submit an interim report for approval prior to proceeding to Tasks 2 - 6

Task 3. Conduct the experiment(s) proposed in Task 1

Task 4. Prepare guidelines on the use of the various prediction models

Task 4. Conduct a cost benefit analysis for each treatment

Task 5. Prepare a final report that presents the results and summarizes the findings and conclusions of the 3-phase project

Proposed Deliverables:

Phase I:

- Comprehensive literature search including an evaluation of existing performance models for various treatments
- A plan to obtain data necessary to support pavement preservation treatment performance models
- > Data necessary to support performance models
- Recommendations for future data collection to improve developed models
- Phase I final report

Phase II:

- Recommended plan for development of pavement preservation treatment performance models.
- Documented performance models of various pavement treatments and their impact on pavement performance and a Task 5. Develop a cost-to-benefit

ratio for various pavement treatment validation plan for the calibration of the performance models

Phase II final report

Phase III

- > Interim report on development of experiments to validate performance models
- > Interim report on results of experiments to validate performance models
- Guidelines that provide a step-by-step procedure on the use of the validated performance prediction model(s) for each treatment; documented cost-benefit analyses for each treatment
- Phase III final report

Potential Partners: AASHTO, State DOTs, Industry companies, NCPP, etc

Estimated Cost and Duration:

Phase I	Phase II	Phase III
\$500,000	\$300,000	\$100,000
3 Years	2 Years	1 year

User Community: Transportation agencies

Implementation: Provide a tool for a systematic approach to selecting pavement preservation treatments and permit agencies to validate assumptions used in pavement management systems. Implement thru activities at/by/on PP centers, workshops, training courses, web-based dissemination of information, etc.
Performance # 04

Title: Quantifying the Benefits of Pavement Preservation Treatments

Background: Preservation treatment selection is based on many variables of which performance benefits – both structural and functional - and cost are primary considerations. Various performance characteristics are impacted by selection of an individual treatment and the materials to be used in that treatment, including structural integrity as well as functional characteristics such as noise, friction/ skid resistance, smoothness, aesthetics, etc. Currently, there is no research that quantifies the various changes to these characteristics. Research will provide information allowing owner agencies to evaluate the full performance impacts of preservation treatments as well as cost in the treatment selection process. This research will also assist in performing performance evaluations of various treatments based upon the initial treatment selection criteria (i.e. this treatment was selected to improve skid-resistance and the treatment provided this functional increase for 'x' years.)

Scope/Objectives: The objective of this project is to quantify the performance and cost benefits of pavement preservation treatments, including the following:

- 1. Identify the performance characteristics that are affected by the individual pavement preservation treatments.
- 2. Recommend practices for quantifying and measuring benefit or loss in performance characteristic values.
- 3. Conduct research to quantitatively assess the benefits (performance and cost) of pavement preservation treatments.
- 4. Deliver findings in a form readily usable by pavement designers and preservation practitioners

Research Proposed:

The following tasks have been identified to complete the work for this project:

Task 1. Perform a national and international literature search and evaluate any research already performed in this area.

Task 2. Determine functional and structural characteristics affected by the individual preservation treatments.

Task 3. Evaluate existing standard practices and available data, and develop methods of measuring and quantifying structural and functional performance characteristics.

Task 4. Prepare an interim report document the findings of Tasks 1-3 and presenting a plan for quantitatively assessing the structural and functional performance benefits of preservation

treatments, including any additional field data collection that may be required to produce meaningful results.

Task 5. Execute the plan developed in Task 4 as approved/modified by the project panel.

Proposed Deliverables:

1. An interim report documenting the outcome of Tasks 1-3, including a menu of standard pavement preservation treatments used nationally along with structural and functional characteristics affected by each treatment type, standard practices to use in measuring and quantifying structural and functional characteristic changes, and a plan for completion of the project.

2. A final report documenting – in quantitative terms - the structural and functional performance benefits of pavement preservation treatments, to include a cost/benefit analysis.

Potential Partners: DOTs,

Estimated Cost and Duration: \$500,000 3 to 5 Years

User Community: State Pavement preservation and maintenance engineers, county and city engineers, future researchers

Implementation: PP centers, web-based dissemination of information,

Performance # 05

Title: Factors Affecting Pavement Preservation Treatment Performance and Expanded Treatment Selection and Design Guidance.

Background: Many factors affect the performance and impact of pavement preservation treatments including construction, traffic, environmental conditions, existing pavement materials, the quality of the materials used in the preservation treatments and others. Resources are optimized when the right treatment is selected for the right road at the right time. With the limited resources available to transportation agencies, practitioners are often faced with making decisions based on limited data. They also must make tradeoffs between material cost and material quality. Selecting the right treatment for the right road can be a challenge without the right information available to decision makers. In theory, a practitioner would have numerous laboratory tests, field information and data available when making treatment selections for a given project. In practice, it is not possible to gather all possible information for every project and doing so could potentially be a waste of resources if such data is not really needed for making decisions.

Scope/Objectives: The objective of this project is to perform a sensitivity analysis of various factors that affect the performance and impact of pavement preservation treatments. Based on this sensitivity analysis, guidelines for data collection, field and laboratory tests and material selection will be developed. Key factors that affect performance of pavement preservation treatments will be identified.

Various pavement preservation treatments will be analyzed to identify the key factors that affect the performance of each preservation treatment. Questions to be addressed include: How is performance a function of traffic loading? Is performance for certain treatments more sensitive than other for a given factor such as traffic? How do climatic conditions affect various treatments? What are the limiting conditions for each treatment to be studied? To what extent does material selection/quality affect performance?

Research Proposed:

The following tasks have been identified to complete the work for this project:

Task 1. Literature search to identify key factors that affect the performance and impact of pavement preservation treatments.

Task 2. Develop a work plan to perform a sensitivity analysis for review and approval.

Task 3. Execute the work plan developed in Task 2.

Task 4. Develop guidelines for field and laboratory tests for use in project selection.

Task 5. Identify the key factors that affect the performance of pavement preservation treatments.

Task 6. Prepare a final report that presents the results and summarizes the findings and conclusions of the project

Proposed Deliverables:

1. Interim report

2. Final report documenting the sensitivity analysis of key factors and providing guidelines for selection of field and laboratory testing required for selection of pavement preservation treatments

Potential Partners: AASHTO, NCPP, etc.

Estimated Cost and Duration: \$400,000 30 Months

User Community: Transportation agencies

Implementation: Provide a guideline for transportation agencies to optimize resources for pavement preservation treatment selection.

Performance # 06

Title: Guidelines for Pavement Preservation

Background: Many highway agencies have developed, through various experiences, decision trees for preventive maintenance treatments. These decision trees identify the preferred treatment for that agency based on pavement indices such as distress, age, traffic levels, etc. In order to advance the pavement preservation treatment selection process, there is a need to synthesize the current state-of-the-practice with regard to decision trees used by various agencies.

The specific treatment is generally selected based on the pavement condition, distress type, distress extent, distress severity, and economics. The timing of the application of the treatment has a significant influence on the effectiveness of the treatment in prolonging the performance of the pavement; therefore, applying the right treatment to the right pavement at the right time is the core of the pavement preservation. If the pavement condition is allowed to deteriorate without any proactive preservation treatment, the windows of opportunities of keeping it in a good condition with least expenses would be lost and the preservation treatment is no longer appropriate since the pavement has deteriorated and a more expensive rehabilitation measure would have to be considered.

The key to effective pavement preservation (and indeed one of the keys to achieving optimal pavement performance at the lowest possible cost) is achieving high-quality construction of the right treatment to the right pavement at the right time. Pavement preservation is considered successful when it results in a cost-effective extension of the useful service life over what would be achieved absent preservation. The efforts of agencies and their contractors to achieve effective pavement preservation would be greatly facilitated by the availability of a comprehensive single source of guidance addressing the following issues pertaining to pavement preservation:

- Treatment selection what treatment(s) or category of treatments are applicable and appropriate (and conversely NOT applicable or appropriate) under what circumstances
- Optimum timing of treatments has a significant influence on the effectiveness of the treatment in prolonging the performance of the pavement
- Contracting practices and provisions advantages and disadvantages of different contracting approaches and provisions for pavement preservation, with particular emphasis on practices and approaches that promote rather than inhibit innovation for the betterment of pavement preservation treatments and practices.
- Performance measurement what parameters should be measured to assess the performance of the preservation treatment itself AND effect of the preservation treatment on the ultimate performance and life-cycle cost of the pavement.

The proposed project is envisioned as a "capstone" effort that will bring together the outcomes of several supporting research projects to create the "single source" guide document that is needed. It is envisioned that the product of this research would be submitted to the AASHTO Subcommittee on Maintenance for possible adoption by AASHTO as a standard.

Scope/Objectives: The ultimate goal of this project is to prepare a single-source guideline for pavement preservation. Specific objectives include:

- identify and evaluate existing/available decision trees used by various agencies to validate these decision trees with appropriate real data, develop/improve decision process, and to develop guidelines for treatment selection.
- provide a framework for agencies to follow in the areas of treatment selection, contracting, and performance measurement, but allow flexibility for innovation.
- determine the optimum timing and define tolerance (window of opportunity) for applying pavement preservation treatments.

Research Proposed:

The following tasks have been identified to complete the work for this project:

Task 1. Assemble and review the pertinent literature. This review shall encompass, but not be limited to research reports and other deliverables from the following supporting research projects:

- Performance Measures for Pavement Preservation
- Development of Model Specifications and Testing Requirements for Pavement Preservation
- Best practices in Pavement Preservation Contracting
- ...(*will revisit*)

Subtask 1.1 - Identify and evaluate existing decision trees. Validate decision trees identified in Task 1 with appropriate real data. Improve the decision-making process.

Subtask 1.2 - Identify data related to the timing of pavement preservation treatments, assess data quality and usefulness. Develop appropriate regression models. Define tolerance (window) of pavement preservation timing change. If the data is insufficient, provide guidelines on data needs.

Task 2. Based on the information gleaned from the literature, prepare an initial draft, "Guide for Pavement Preservation: Treatment Selection (including decision trees), Optimum Timing, Contracting, and Performance Measurement." It is envisioned that this Guide will include construction monitoring techniques and reference model specifications.

Task 3. Develop a plan for stakeholder outreach to obtain feedback on the draft guide. This plan shall provide mechanisms for obtaining feedback from all pertinent groups having a stake in pavement preservation, including, but not necessarily limited to:

- Federal, State, and local highway agency staff members responsible for pavement preservation;
- Consultants employed by highway agencies to formulate recommendations, designs, and/or plans for pavement preservation;

- Contractors engaged by highway agencies to construct/apply pavement preservation treatments;
- Academics engaged in teaching and/or research related to pavement preservation and/or asset management; and
- Industry organizations representing the above stakeholders.

Task 4. On approval of the plan developed in Task 4, execute the stakeholder outreach plan.

Task 5. Revise the draft Guide in response to the feedback received, and prepare a summary of the changes made.

Task 6. Prepare a technical report documenting the development of the Guide.

Proposed Deliverables:

- 1. Recommendations for developing an appropriate/improved decision tree supported by data including an outline that State DOTs can use to collect data and develop improved/enhanced decision trees.
- 2. Guide for Pavement Preservation: Treatment Selection (including decision trees), Optimum Timing, Contracting, and Performance Measurement
- 3. Summary of Guide revisions
- 4. Technical report documenting the research, findings and Guide development

Potential Partners: AASHTO Joint Task force on Pavements, Subcommittee on Maintenance, Asset Management Committee, TRB, FHWA, state agencies, municipalities, industry, pavement preservation centers, regional centers.

Estimated Cost and Duration: \$500,000 2 Years

User Community: State DOT pavement preservation and maintenance engineers, county and city engineers, consultants, contractors, and researchers

Implementation: It is envisioned that the primary product of this research will be submitted to AASHTO for possible adoption as a formal AASHTO standard. Such adoption will facilitate implementation of the research results and support the broader effort to achieve more widespread implementation of effective pavement preservation practices. Implementation will be led by State DOTs along with their contractors and consultants and should be supported by state and regional PP Centers. Implementation could be assisted by web-based dissemination of the information.

APPENDIX A-2 BRIDGE PRESERVATION NEEDS STATEMENTS

Statement #	ASSET MANAGEMENT	<u>COST X</u> <u>\$100K</u>	DURATION (Years)
Asset 01	Development of a bridge preservation process framework ensuring a standardized repeatable process for bridge preservation	\$300	2
Asset 02	Establishment of Uniform Terminology and Definitions for Transportation System Preservation	\$20	6 Months
Asset 03	Development Of A Process For Estimating The Remaining Service Life (RSL) Of Bridge Components And The Overall Bridge System Based On Observable Data.	\$200	2
Asset 04	Evaluation of the AASHTO Commonly Recognized Elements (CoRe), Ten Years of Data	\$300	1.5
Asset 05	Better Direct and Indirect Cost Models for Bridge Management Systems	\$400	2
Asset 06	Modeling Early Bridge Deterioration and Prevention	\$400	2
Asset 07	Evaluation, Analysis, and Documentation of Successful Bridge Preservation Practices	\$1,100	6
	DECKS & JOINTS		
Decks & Joints 01	Best Practices for Preserving Bridge decks	\$300	1
Decks & Joints 02	Determine the Recommended Practice and the Life-Cycle Cost Savings for Using Thin Overlays to Preserve Concrete Bridge Decks	\$900	3
Decks & Joints 03	Determine the Recommended Practice and the Life-Cycle Cost Savings for Using Sealers to Preserve Concrete Bridge Decks	\$500	3
Decks & Joints 04	Determine the Recommended Practice and the Life-Cycle Cost Savings for Preserving Superstructure and Substructure Elements Through the Use and Maintenance of Watertight Joints	\$500	2
	SUPERSTRUCTURES		
Superstructures 01	Development of a Test for Assessment of Performance of Weathering Steel	\$350	2
Superstructures 02	Development of Procedures for Preservation of Weathering Steel Bridges	\$300	2

Superstructures 03	Performance Assessment of Existing Concrete Structure Corrosion Prevention/Mitigation Technologies	\$1,000	4
Superstructures 04	Improved Inspection Techniques for Steel Prestressing Strand, Cables, and Ropes	\$2,000	3.5
Superstructures 05	High-Durability Coatings and Sealer Materials for Structural Concrete	\$350	2
	SUBSTRUCTURES		
Substructures 01	Preservation of Concrete Highway Bridge Substructure Units by Preventing or Delaying the Initiation of Active Corrosion of the Steel Reinforcement	\$400	2
Substructures 02	Preservation of Concrete Highway Bridge Substructure Units by Controlling the Corrosion Rate of the Steel Reinforcement once Corrosion has Initiated	\$300	1.5
		¢(00	2
Substructures 03	Development of a High Performance Galvanic Anode	\$600	3
Substructures 04	Substructure Preservation Decision Matrix to Address Corrosion Issues of the Steel Reinforcement of Concrete Bridge Substructure Elements	\$450	2
Substructures 05	Preservation of Steel Bridge Piles	\$500	3
	SELECTION of PRESERVATION ACTIONS		
Selection 01	Implementation of Preservation Practices on Highway Bridges by State DOTs	\$500	3
Selection 02	Develop Bridge Design Guidelines to Enhance Constructability and Maintainability	\$300	2
	PERFORMANCE of PRESERVATION ACTIONS		
Performance 01	Quantify the Information Necessary to Guide Bridge Preservation Decisions	\$1,125	2
Performance 02	Develop Deterioration Models that Account for the Performance of Preservation Actions in Bridge Management Systems	\$300	3
1		1	1

Title: Bridge Preservation Process Framework (Development of a bridge preservation process framework ensuring a standardized repeatable process for bridge preservation).

Background: Data quality and consistency, and process transparency across multiple organizations in multiple states is essential. Beyond the technical development of the algorithms and underlying models, a process is needed to ensure data collection, cleansing, modeling and forecasting is conducted in a systematic manner that incorporates standard repeatable processes.

The bridge preservation process framework is stakeholders-centric, how stakeholders both internal to department of transportation, and external partners, policy makers, and the public use data (that is, decisions they make).

Scope/Objective: To generate a new process management framework that can be used as the baseline by state/local DOTs to ensure data quality, consistency and process transparency:

- 1. both internal and external stakeholders views are assessed in developing the desired outcomes of the BMS
- 2. A standard repeatable process is defined that details responsibility to achieve these outcomes.

Research Proposed:

The following tasks would be required:

- Task 1. Conduct a "scanning tour of" and/or benchmark state DOTs to determine best practices, lessons learned, and constraints.
- Task 2. Transform the AASHTO BMS activities into a process model (example ISO 9002 and SEI-CMMI). The resulting model should detail:
 - Activity level deliverables
 - Tasks needed to produce the deliverables
 - Pre-conditions (needed inputs and authorizations) to each phase
 - Post-conditions (what is triggered once a task is completed)
 - Triggers (what triggers an activity/task)
 - Responsible roles
 - Quality Assurance Process

Task 3. Iteratively validate and refine the process model

Task 4. Develop a deployment handbook

Proposed Deliverables:

- 1. Bridge management process manual
- 2. Deployment handbook/users guide

Potential Partners: AASHTO

Cost and Duration: \$300,000 2 Years

User Community: Bridge management engineers, bridge maintenance engineers. When proven in use, as a model for development of pavement management process.

Implementation: Implemented through workshops, training courses, etc.

Title: Establishment of Uniform Terminology and Definitions for Transportation System Preservation

Background: The lack of consistent terminology differentiating preservation from other program activities has been observed as an impediment to effectiveness of implementing a bridge preservation program. The classification of a particular activity as preservation or not is significant in the sense of relating program requirements (safety, geometrics, accessibility, environmental) and funding consideration. Additionally, a uniformly understood distinction of preservation activities from other improvements (corrective maintenance, reconstruction, etc.) will better enable departments to track the effect that preservation is having on their program as a whole. On a national level, this will give a clear picture of how successfully agencies are implementing bridge preservation and provide for a basis for comparison of programs and treatments.

A similar effort has been undertaken to define terminology in the area of pavement preservation. Those definitions were established to be consistent with terminology developed by the AASHTO Subcommittee on Maintenance. This effort should establish uniform terminology that is useful to FHWA and transportation agencies, and consistent across program lines of pavements, bridges, and other infrastructure elements.

Clear and distinct definitions of bridge preservation terminology are essential for implementing a bridge preservation program and communicating its effectiveness to agency leadership. The definitions should be established quickly so that other related program and technical research will have a common frame of reference.

Scope/Objective: To provide transportation agencies with a clear and consistent definition of constitutes preservation. The definitions should cover the spectrum of maintenance and capital improvement efforts, providing qualitative differentiation between rehabilitation and preventive maintenance, elemental replacement, routine versus corrective maintenance, etc.

Research Proposed:

The following tasks would be required:

- Task 1. Develop straw language, developed in partnership with Bridge Technology, Pavement Technology, and other program offices.
- Task 2. Share the straw language for comment among FHWA Division and AASHTO partners to ensure that it addresses field considerations.
- Task 3. Revise the straw language to address comments.

Proposed Deliverables:

1. Manual of uniform terminology for bridge preservation and pavement preservation actions

Potential Partners: AASHTO, Foundation for Pavement Preservation, National Centers for Pavement Preservation, Industry stakeholders

Cost and Duration: \$20,000 6 Months

User Community: Bridge management and maintenance engineers, pavement management and maintenance

Implementation: Distribution of the guide

Title: Development of a Process For Estimating the Remaining Service Life (RSL) of Bridge Components and the Overall Bridge System Based on Observable Data.

Background: Over the years a variety of different measures has been used to evaluate and communicate bridge condition. Many of these measures are limited in the sense that they describe in detail the bridge's current condition but do not provide predictions of the bridge's future condition. The ability to assess a bridge's condition in future years is essential for planning and programming improvements, and also to determine overall agency funding needs over time. The use of remaining service life is a method which allows agencies to establish a clear picture of their overall network health, and one which is easily communicated within the agency and also to legislators and the public.

With bridges, the overall RSL of the structure will be a function of the condition/ RSL of its particular elements – deck, substructure, superstructure, and foundation. The process will need to be able to distinguish between RSL of each of the elements and use them to collectively establish an RSL for the complete structure – and also to consider how the RSL of one element may influence the RSL of another.

Agencies will understandably be reluctant to change their methods from current practices of collecting and analyzing bridge condition data. In order for RSL to be adopted by agencies as a measure, they will need a methodology for establishing RSL data using the data they already collect, or by correlating their condition information into accurate values of RSL.

In order to reliably compare the condition of bridges, effectiveness of treatments, etc., we need to be sure that meaningful values are used for what constitutes "good condition", and also for what constitutes "poor or failed condition". If different agencies are using significantly different values for these levels, it makes it difficult to compare the results they get from the application of treatments, or the cost-effectiveness.

How good is "good", and how bad is "bad" – what is the meaning of "zero years RSL"? Ideally, there should be different values assigned for different functional classification of roadways – the tolerance for condition level for the interstate would be quite different from what could be expected on an arterial. Different agencies treat this differently, which will make it more difficult to assess national conditions or compare among agencies.

Widespread adoption of RSL as a measurement of bridge and network condition will provide for a uniform descriptor of national conditions.

The adoption of RSL as a measure enables a more complete assessment of roadway network health and serves as a valuable decision making tool for transportation agencies. It assists decision makers in providing for a more predictable distribution of resources within an agency over time. By using a clear and consistent unit of measurement (years) to describe infrastructure condition, it enables for better comparison of program effect and treatment performance among agencies. It also enables agencies to make better use of the data they already collect – ability to

forecast needs and extrapolate condition, and to better communicate needs/ activities to public/ politicians.

Will contribute to agencies' treatment timing decisions and enable agencies to provide network condition information that is more easily comparable to the values used elsewhere. More consistent policy applications.

Scope/Objective: The objective of this project is to provide a process/ tool to highway agencies for correlating condition data to RSL. The process will be iterative/ self-calibrating, adaptable to agencies' own procedures for data collection, and existing bridge condition tools and procedures. It should also relate the RSL to economic valuation of the asset. Included within the development of the process will be the determination of concrete values (definition) for good condition and failure condition for the purposes of public expectation, comparison, and economic valuation.

Research Proposed:

The following tasks would be required:

- Task 1. Literature search & evaluation of existing use of RSL for infrastructure evaluation.
- Task 2. Develop draft guide for determining RSL for bridge elements based on collected condition data.
- Task 3. Develop methodology for estimating RSL of the bridge based on the RSLs of the critical bridge elements.
- Task 3. Review and comment, develop final guide.

Task 4. Implementation and rollout through FHWA, AASHTO.

Proposed Deliverables:

1. Guide manual for calculating RSL of various types of bridges in varying environments and operating conditions

Potential Partners: AASHTO

Cost and Duration: \$200,000 2 Years

User Community: AASHTO

Implementation: Implemented through workshops, training courses, etc

Title: Evaluation of the AASHTO Commonly Recognized Elements (CoRe), Ten Years of Data

Background: The CoRe elements have been the state of the practice for the past fifteen years. Uses of the elements and definitions have caused the misalignment of required preservation and corrective actions. Over time protective system condition has influenced the structural condition rating. In addition, the use of the element's condition ratings has caused issues with related performance and safety measurements. These measures include:

Sufficiency Rating Deck, Superstructure, Substructure and Culvert Ratings Health Index Agency Developed Performance Index

Bridge Asset Managers have been developing these additional elements. With this project, a national standard could be established and implemented. The long-term payoff will be the ability to model need and protective system needs. This project will also allow better definitions for the bridge for safety evaluation and asset management needs. The long-term payoff is a national standard for collection and evaluation of bridge defects and needs

Scope/Objective: This proposed project will identify missing safety condition elements. This project will consider the re-aligning current CoRe elements into structural and protective system. This division will allow the bridge community to evaluate structural defects with out the influence of the condition of the protective system. This project will develop a recommendation to modify and supplement the current list of elements.

The proposed modified and new elements will be presented to AASHTO's Bridge Management Community for adoption and integration into current and future bridge management systems.

Research Proposed:

The following tasks would be required:

- Task 1. Conduct literature search of current bridge structural and protective system elements related specifications.
- Task 2. Review data from agencies that do not use the CoRe elements. Supplement with published papers and research. Collect CoRe and non-CoRe elements from agencies.
- Task 3. Develop new and modify existing bridge elements that will be needed to fully describe a bridge from a structural definition. Develop new bridge elements that will describe the protective system. In conjunction with these element definitions, these elements will need condition descriptions using standard engineering language.
- Task 4. Develop recommended actions for each of these elements. In addition, a unit of measures will need to be developed.

Task 5. Develop a possible migration path between the current CoRe elements and the proposed elements.

Task 6. Develop draft AASHTO CoRe element manual for implementation.

Proposed Deliverables:

1. New AASHTO CoRe element manual

Potential Partners: AASHTO

Cost and Duration: \$300,000 18 Months

User Community: Bridge management and bridge maintenance engineers

Implementation: Distribution to bridge management and bridge maintenance engineers; incorporation in bridge management systems and inspection procedures

Title: Better Direct and Indirect Cost Models for Bridge Management Systems

Background: NCHRP 14-15 has developed a standardized data structure for reporting and sharing bridge work accomplishment data. Once data become available in this format, it will be possible to develop new quantitative cost models that are much more in line with existing agency maintenance practices, than the cost models in use today.

Existing bridge management system (BMS) cost models are expressed in units of measure appropriate to bridge inspection, to make the most direct possible connection to observed conditions and desired outcomes. However, existing agency maintenance practice tends to record work in the form of resources (inputs), or actual work performed (outputs). Often the units of measure and costing assumptions make it difficult to use this work accomplishment data in bridge management analysis.

In addition, current BMS, by using outcome measures for costs, are unable to account accurately for indirect costs whose magnitude doesn't vary with outcome quantities. Such indirect costs, including traffic control, mobilization, design, and construction engineering, can often add up to more than half of a project. This is widely regarded as the biggest source of inaccuracy in current BMS.

A solution to this problem is to develop production functions, which relate inputs to outputs in bridge maintenance activities; cost functions, which relate input or output quantities to costs; and outcome functions, which relate agency outputs to observed outcomes as seen subsequently by inspectors and the public. The framework for this type of economic analysis is described in the NCHRP 14-15 report.

Cost models are widely regarded as a significant barrier to implementation of bridge management systems in many agencies. The NCHRP 14-15 project was designed to address the first part of the costing problem, of standardizing work accomplishment data for use across agencies and show how such data might be converted to BMS inputs data in the format currently used by BMS. The second part of the problem is making use of the standardized data, once available, to improve the modeling techniques of bridge management systems.

The proposed research will be eagerly welcomed by agencies that have been using bridge management systems for years but are waiting for better cost models to supply more trustworthy estimates of project and program funding requirements. It is likely that the research results will be widely and quickly implemented by the 50% of states currently using some part of a bridge management analysis. It is also likely that this improvement will motivate even more agencies to take advantage of the analytical capabilities of their systems

Scope/Objective: The proposed research will gather bridge work accomplishment data in NCHRP 14-15 format from any agency able to provide it. It will then quantify production

functions, cost functions, and outcome functions as envisioned in the 14-15 report. The production functions and cost models will account for both direct and indirect resource inputs.

Research Proposed:

The following tasks would be required:

The researcher will gather relevant data to estimate an improved cost model following the guidelines of NCHRP 14-15, using data obtained from bridge owners. The resulting models will be documented and tested, and delivered with instructions for modification of existing bridge management systems to incorporate the results.

- Task 1. The researcher will study the NCHRP 14-15 report and existing data sources published by bridge owners containing compatible work accomplishment data. Additional states that may not have published 14-15 data, but may have data in a form convertible to the 14-15 formats, will be identified and contacted. This may include the states who contributed data to the original 14-15 study, and other states. This will result in a plan for obtaining all the agency data to be used in the study.
- Task 2. The researcher will download available 14-15 data and obtain data sets from other participating agencies. For data that are not yet transformed to 14-15 format, the research will perform the necessary conversion. This may involve manual translation of maintenance work descriptions into the standardized 14-15 categories. Special care will be devoted to identifying indirect cost activities such as traffic control, mobilization, and engineering.
- Task 3. The researcher will use the data gathered in Task 2, with statistical analysis techniques, to quantify production, cost, and outcome functions. These will be designed for compatibility with the definitions used by existing BMS tools. The analysis will include measures of statistical uncertainty.
- Task 4. The software product of NCHRP 12-67 will be modified to incorporate the new production, cost, and outcome functions. This will allow full-scale testing with a bridge inventory, including sensitivity analysis of the new models. Based on the sensitivity analysis, additional model estimation work will be conducted to narrow the uncertainly of portions of the models that have particularly large effects on model results.
- Task 5. The final models will be delivered in the form of a final report, describing the model specification and estimation process, and with instructions on how to modify existing bridge management systems to incorporate the products.

Proposed Deliverables:

- 1. New models for analyzing direct and indirect costs in bridge management systems
- 2. Manual of implementation and use of the new models

Potential Partners: AASHTO

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Cost and Duration: \$400,000 2 Years

User Community: Bridge management engineers

Implementation: Delivery thru training courses or CD based training; incorporation in bridge management systems

Title: Modeling Early Bridge Deterioration and Prevention

Background: Bridge owners need reliable forecasting information on the deterioration of structural elements and the effect of preventive maintenance actions, in order to evaluate the possible outcomes of policy and project decisions. Bridge management systems (BMS), typically used in transportation agencies to develop this information, have relied on expert judgment and historical data as inputs to these forecasting models.

Research and implementation efforts, particularly NCHRP Project 12-67 ("Multi-Objective Optimization for Bridge Management Systems"), FHWA's National Bridge Investment Analysis System (NBIAS), and various state efforts, have found that current methods have not been sufficiently effective in describing what happens to bridge elements in the early stages of life and after major rehabilitations, when they are in good to excellent condition. In particular, BMS currently have very little forecasting power for the time between new condition and the first, slightly deteriorated condition level observed in visual inspection. BMS typically don't define the preventive maintenance actions taken on bridges in excellent condition (such as washing and sealing), and don't have the capability to model the lasting improvement in durability that may result from such treatments.

As a result of this need, research projects such as NCHRP 12-67 have found that it is difficult or impossible to analyze long-term condition trends in agencies wanting to keep bridges in relatively excellent condition network-wide. Such policies are believed to be very cost-effective in the long-term, and respond to community values for public confidence in the infrastructure.

Transportation agencies have invested significant resources into the implementation of bridge management systems, particularly in the visual inspection process. Recent efforts to implement the analytical techniques have found that there is an urgent need to improve the models' sensitivity to certain important policies, especially preventive maintenance regimes to maintain inventories in excellent condition so more expensive and disruptive actions can be delayed as long as possible.

By demonstrating the positive effects of low-impact early interventions, agencies can make the case for state and local funding of such activities, and can determine the optimal level of such treatments. The products of the research can be immediately added to bridge management systems, or immediately put to use through the NCHRP 12-67 product. Agencies implementing the results should be able to demonstrate near-term savings in costs for corrective actions.

Scope/Objective: The proposed research will develop quantitative models of the time until onset of deterioration, sensitive to preventive maintenance policies that may be followed. The models will be quantified for common routine maintenance treatments such as washing and sealing, and can be extended by agencies for other types of preventive maintenance. Such models will be developed for the AASHTO Commonly-Recognized (CoRe) Structural Elements and will be compatible with their standardized condition state language for visual inspection.

Research Proposed:

The research project will evaluate alternative functional forms of models of the onset of deterioration. Candidate models and data requirements will be compared, and a preliminary solution will be chosen. The selected model framework will be quantified using data from a selected group of bridge owners. This may result in modifications to the model formulation. A final model will be delivered in a form suitable for modification and implementation of existing bridge management system tools.

The following tasks would be required:

- Task 1. The researcher will consult the literature and existing practice to investigate applicable functional forms of probabilistic models for the onset of deterioration, compatible with deterioration models already in common use for more advanced stages of deterioration. Such models may include, but are not limited to, Markov or semi-Markov models, survival probability models, maximum likelihood models, and other models that give a probability distribution of the time from new construction or major rehabilitation, to the visual observation of the onset of deterioration or other milestones of observed early deterioration.
- Task 2. The models from Task 1 will be evaluated for sensitivity to preventive maintenance policies, availability of required data, and compatibility with the AASHTO CoRe Elements and existing data and models maintained by bridge owners. The intention is to develop models for all the CoRe elements that are sensitive to common preventive maintenance policies applied to the whole bridge or any part. A recommended approach will be documented for approval by the Project Panel.
- Task 3. The researcher will gather relevant data from a selection of bridge owners who engage in preventive maintenance activities, and who have historical bridge condition data suitable for the selected modeling approach.
- Task 4. Using appropriate statistical analysis methods, the model formulation will be quantified and refined as needed to provide a reliable model with reasonable data requirements. The models will be tested by modifying the software product of NCHRP 12-67, to show how the models perform in a network-wide project programming framework with relatively high condition goals such as a health index of 95 or above.
- Task 5. The final model will be delivered in a Final Report with full specification of the model, the procedure for estimating it, the quantitative results, and instructions for modifying existing bridge management systems to incorporate the products.

Proposed Deliverables:

1. Models for analyzing impact of preservation actions on early stage deterioration of bridge elements in good to very good condition

Potential Partners: AASHTO

Cost and Duration: \$400,000 2 Years

User Community: Bridge management engineers

Implementation: Incorporation in bridge management systems

Title: Evaluation, Analysis, and Documentation of Successful Bridge Preservation Practices

Background: There are many maintenance and preservation technologies, materials, and systems that can be used by agencies to keep their transportation system "healthy." Unfortunately, the application of these treatments and methods is largely based on anecdotal or historical experience, so there are large knowledge gaps in terms of appropriate timing, effectiveness, durability, and other important factors. Therefore, the true life cycle costs and cost savings related to many of these approaches to preserve have not been quantified. This much-needed information would help provide agencies with the tools needed to provide the "right fix, to the right bridge, at the right time."

The goal of this study is to document successful bridge preservation approaches and practices by utilizing existing bridge management data to identify geographically dispersed areas in the country with bridges in good to excellent condition relative to their age distribution by system and network. The areas could be at local levels such as counties and cities, or districts and regions.

Once these bridges are identified, conduct interviews of field bridge engineers to obtain performance information and approaches/practices used to maintain those bridges in good/excellent condition.

This study shall also make recommendations as to how the information collected and analyzed can be incorporated into performance models derived from effective preservation practices.

Results of this study are critical to the development and implementation of successful bridge preservation programs. Implementation of dedicated bridge preservation programs requires a culture change at many levels. This change in culture will not happen overnight. Development of a handbook of successful practices will provide a convincing argument in support of a preservation program and facilitate the paradigm shift. Examples of successful bridge preservation programs provide the best guidance for others making this transition.

Scope/Objective:

Phase I: Collect and analyze the bridge management data information. Develop a handbook of successful preservation practices identified.

Phase II: Make recommendations as to how the information collected and analyzed can be incorporated into performance models derived from effective preservation practices.

Phase III: Develop life-cycle costing process for the reliable and proven actions.

Research Proposed:

The following tasks would be required:

Phase I

- Task 1. Analyze NBI data to identify bridges with components that sustained good/excellent conditions relative to their age.
- Task 2. Identify subsets of this data for more detailed investigation of specific preservation activities that may have contributed to the sustained good/excellent condition level. This may require the collection of element level inspection data for the selected areas.
- Task 3. Interview field engineers in a selected number of the subset areas.
- Task 4. Synthesize results to identify successful preservation practices and document in a handbook.

Phase II

Task 5. Analyze information collected during phase I and recommend how the results can be incorporated into performance models derived from effective preservation practices.

Phase III

Task 6. Develop life-cycle costing processes for the reliable and proven actions.

Proposed Deliverables:

1. Report with recommendations as to how the successful preservation practices can be incorporated into performance models.

2. Report on life cycle costing processes

Potential Partners: AASHTO

Cost and Duration:

Phase I Phase II Phase III	\$500,000 \$100,000 \$500,000
Phase I	18 months
Phase II	3 months
Phase III	18 months

User Community: Bridge management and bridge maintenance engineers

Implementation: Distribution of the reports; workshops and training courses

Decks & Joints # 01

Title: Best Practices for Preserving Bridge decks.

Background: All states recognize the need for preservation treatments for their concrete bridge decks. The purpose of using treatments is to protect the deck and extend the service life. All agencies are challenged to maximize the service life of bridge decks with limited resources. Typical treatments include:

- Concrete Surface and Crack Sealers
 - o Polymer, Bituminous-based, etc.
- Thin Overlays
- Periodic Washing
- Electrochemical Treatments
- Cathodic Protection
- Membranes
- Coatings

Research is needed to establish cost-effective programs for maintaining and preserving concrete bridge decks.

Scope/Objective: Determine a cost-effective program that would include various strategies of bridge deck preservation treatments. This would be a program-level research project. It would benefit this project if it followed the research projects on sealers and overlays.

Research Proposed:

Each of the research tasks needs to address the following questions:

- 1. What is the practice for preserving bridge decks?
 - What preservation treatments are being used?
 - What is the cost for maintaining and preserving bridge decks?
 - Under what conditions is each of these treatments being used?
 - Bridge Rating
 - Age
 - Concrete Condition
 - Surface Condition
 - Climate/Geographical
 - Environmental
- 2. What are the benefits and limitations of maintaining and preserving bridge decks?
 - What are the benefits that are being measured?
 - o Longer service Life
 - lower chloride intrusion
 lower corrosion
- 128

- What are the costs to implementing a preservation program?
 - What are the costs of deck repairs as a result of an inadequate or nonexistent preservation program?
- 3. What is the recommended practice for preserving bridge decks?
 - What are the best practices?
 - What are the annual cost savings for the practices recommended?

Task 1: Survey the State DOT's and municipalities to determine current practices.

Task 2: Identify and review relevant research reports and other literature.

Task 3: Develop a work plan to verify answers from Tasks 1 and 2 through field evaluations of existing applications, which might include:

- Visual Inspection
- Corrosion related measurements
- Chloride intrusion

Task 4: Prepare a research report that describes recommended practices and life-cycle cost savings for preserving bridge decks.

Proposed Deliverables:

1. Report on the recommended practices and life-cycle cost savings for preserving bridge decks.

Potential Partners: AASHTO

Cost and Duration: \$300,000 1 Year

User Community: Bridge management and bridge maintenance engineers

Implementation: Distribution to State and local DOTs

Decks & Joints # 02

Title: Determine the Recommended Practice and the Life-Cycle Cost Savings for Using Thin Overlays to Preserve Concrete Bridge Decks.

Background: Some states use overlays for their concrete bridge decks and some states don't. The purpose of thin overlays is to seal the deck, increase skid resistance, and provide additional wearing capability. It is difficult to determine the actual benefits of using thin overlays and to communicate that to decision makers. Research is needed to determine cost-effective strategies for using the following materials to preserve concrete bridge decks. Thin overlays are typically ¹/₄" to 2" in thickness. Some of the thin overlays may include:

- Polymer Overlays (Epoxy, Polyester, Acrylic, etc.)
- Concrete Overlays (Latex-modified, Silica-fumed, Low slump, etc.)
- Modified Asphalt Overlays (pavement preservation treatments including membrane and asphalt, rubberized asphalt, polymer-modified asphalt, etc.)

Scope/Objective: Determine recommended preservation treatment strategies and practices using overlays for preserving concrete bridge decks.

Research Proposed:

Each of the research tasks needs to address the following questions:

- 1. What is the practice for preserving decks using thin overlays?
 - What overlays are being used?
 - What are the physical and chemical characteristics of the materials being used?
 - What is the cost per treatment?
 - Under what conditions are they being used?
 - Environmental
 - Deck age
 - Deck condition
 - Cracked decks
 - Un-cracked decks
- 2. What are the benefits and limitations from using thin overlays?
 - What are the benefits that are being measured?
 - lower permeability
 - lower chloride intrusion
 - lower corrosion
 - improve skid resistance
 - ride quality
 - noise reduction
 - How long does the overlay provide benefits?
 - New decks

- Old decks
- What are the drawbacks for each thin overlay?
 - Environmental
 - Hazardous material storage
 - Preparation Cost
 - Application
 - Cure time/lane closure time
 - Maintenance
- 3. What is the deck service life extension from using thin overlays?
 - What additional deck life is achieved with each overlay?
 - What is the LCC for overlaid vs. bare concrete decks?
- 4. What is the recommended practice for preserving decks using thin overlays?
 - What are the best practices?
 - What are the annual cost savings for the practices recommended?

Task 1: Survey the State DOT's and municipalities to determine current practices.

Task 2: Identify and review relevant research reports and other literature.

Task 3: Develop a work plan to verify answers from Tasks 1 and 2 both through laboratory and field evaluations of existing applications, which might include:

- Ground penetrating radar
- Visual Inspection
- Crack Mapping
- Corrosion related measurements
- Bond Strength
- Permeability

Task 4: Prepare a research report that describes recommended practices and life-cycle cost savings using thin overlays to preserve bridge decks.

Proposed Deliverables:

1. A report that describes recommended practices and life-cycle cost savings using thin overlays to preserve bridge decks.

Potential Partners: AASHTO

Cost and Duration: \$900,000 3 Years

User Community: Bridge management and bridge maintenance engineers

Implementation: Through workshops and training courses

Decks & Joints # 03

Title: Determine the Recommended Practice and the Life-Cycle Cost Savings for Using Sealers to Preserve Concrete Bridge Decks.

Background: Some states seal their cracked and un-cracked bridge decks and some don't. Some states are using sealers that provide a hydrophobic surface, some use pour blockers, some use crack fillers, and some use a combination of these. Some surface sealers may not be compatible with crack fillers. It is difficult to determine the actual benefits of using sealers and to communicate that to decision makers.

Research is needed to determine cost-effective strategies for using these materials to preserve concrete bridge decks.

Scope/Objective: Determine recommended preservation treatment strategies and practices using sealers for preserving concrete bridge decks.

Research Proposed:

Each of the research tasks needs to address the following questions:

- 1. What is the practice for preserving decks using sealers?
 - What sealers are being used?
 - What is the cost per treatment?
 - Under what conditions are they being used?
 - Environmental
 - Deck age
 - Deck condition
 - Cracked decks
 - Uncracked decks
- 2. What are the benefits from using sealers?
 - What are the benefits that are being measured?
 - lower permeability
 - lower chloride intrusion
 - lower corrosion
 - less spalling
 - How long does the treatment provide benefits?
 - New decks
 - Old decks
- 3. What is the deck service life extension from using sealers?
 - What additional deck life is achieved with each treatment?
 - What is the LCC for treated vs. untreated decks?

- 4. What is the recommended practice for preserving decks using sealers?
 - What are the best practices?
 - What are the annual cost savings for the practices recommended?

Task 1: Survey the State DOT's and municipalities to determine current practices.

Task 2: Identify and review relevant research reports and other literature.

Task 3: Develop a work plan to verify answers from Tasks 1 and 2 both through laboratory and field evaluations of existing applications, which might include:

- Ground penetrating radar
- Visual Inspection
- Corrosion related measurements
- Permeability of cracked and un-cracked concrete
- Penetration Depth in Surface and Cracks
- Task 4: Prepare a research report that describes recommended practices and life-cycle cost savings using sealers to preserve bridge decks.

Proposed Deliverables:

1. A report that describes recommended practices and life-cycle cost savings using sealers to preserve bridge decks

Potential Partners: AASHTO

Cost and Duration: \$500,000 3 Years

User Community: Bridge management and bridge maintenance engineers

Implementation: Through workshops and training courses

Decks & Joints # 04

Title: Determine the Recommended Practice and the Life-Cycle Cost Savings for Preserving Superstructure and Substructure Elements Through the Use and Maintenance of Watertight Joints.

Background: All states recognize the need for watertight joints for their concrete bridge decks. The purpose of using watertight joints is to protect the superstructure and substructure elements below. It is difficult to determine the actual benefits of using watertight joints and to communicate that to decision makers. Some owners spend consider effort and resources in maintaining watertight joints and some don't. Research is needed to determine cost-effective strategies for using and maintaining watertight joints to preserve elements below the deck.

Scope/Objective: Determine the effectiveness of maintaining watertight joints on the preservation of superstructure and substructure elements.

Research Proposed:

Each of the research tasks needs to address the following questions:

- 1. What is the practice for preserving decks using watertight joints?
 - What watertight joints are being used?
 - What is the cost for installation and maintaining watertight joint?
 - Under what conditions are they being used?
 - Environmental
 - Bridge Type
 - Span Length
- 2. What are the benefits and limitations from using and maintaining watertight joints?
 - What are the benefits that are being measured?
 - Deterioration of super- and substructure elements
 - lower chloride intrusion
 - o lower corrosion
 - o reduce section loss of steel girders
 - pier deterioration
 - bearing condition
 - How long do various joints remain watertight?
 - What are the costs to keep these joints watertight?
 - o Lane Closure
 - o Materials
 - What are the costs of repairing super- and substructure elements as a result of leaking joints?
 - Concrete removal and replacement
 - Girder ends
 - o Bearings

- 4. What are the consequences of having leaking joints?
 - Accelerated deterioration rates
 - Chlorides
 - Costs of repair to elements below the deck
- 5. What is the recommended practice for preserving super- and substructure elements using watertight joints?
 - What are the best practices?
 - What are the annual cost savings for the practices recommended?

Task 1: Survey the State DOT's and municipalities to determine current practices.

Task 2: Identify and review relevant research reports and other literature.

- Task 3: Develop a work plan to verify answers from Tasks 1 and 2 through field evaluations of existing applications, which might include:
 - Visual Inspection
 - Coatings on girders compromised
 - Corrosion related measurements
 - Chloride intrusion

Task 4: Prepare a research report that describes recommended practices and life-cycle cost savings using watertight joints to preserve super- and substructure elements.

Proposed Deliverables:

1. A report that describes recommended practices and life-cycle cost savings using watertight joints to preserve super- and substructure elements.

Potential Partners: AASHTO

Cost and Duration: \$500,000 2 Years

User Community: Bridge management and bridge maintenance engineers

Implementation: Through workshops and training courses

Superstructures # 01

Title: Development of a Test for Assessment of Performance of Weathering Steel

Background: Weathering steel bridges have been constructed over roadways and may be subjected to chloride contamination from deicing chemical fogging from traffic. Therefore, there is a need to determine if the weathering steel is performing as intended. The formation of a proper patina is critical to long term protection of the steel substrate. There is presently no written criteria or test procedure for inspectors to evaluate the adequacy of the protective patina.

In aggressive environments weathering steel can continue to corrode causing severe loss of section. A means of determining the potential for continued corrosion earlier in its life is needed.

A significant number of weathering steel bridges have been built and the number is expected to grow. Some of these bridges have experienced corrosion. Mitigation for unexpected corrosion of weathering steel is extremely difficult and expensive. Therefore, early detection of unexpected corrosion is critical to ensuring adequate performance of these bridges.

Scope/Objective: The objective of this research is to develop a test or procedure which can be used by field inspectors to evaluate the performance of the steel. The test may be a physical test that can be applied to various locations or a set of visual performance standards to compare against the actual appearance of the steel patina. Guidance should be provided to direct the inspector to test specific locations that are susceptible to continued corrosion or to a sampling process that will adequately represent the performance of the entire steel superstructure.

Research Proposed:

The following tasks would be required:

- Task 1. Conduct a literature search for existing performance evaluation reports and performance criteria.
- Task 2. Develop a test or procedure for evaluating weathering steel performance.
- Task 3. Conduct pilot evaluations to calibrate the test or procedures on actual bridges.
- Task 4. Prepare a manual or procedures for use by inspectors.
- Task 5. Prepare training course material.
- Task 6. Prepare material for incorporation of the test or procedures in the Bridge Inspectors Reference Manual.

Proposed Deliverables:

- 1. Tests/procedures for evaluating weathering steel performance
- 2. Manual or procedures for use by inspector
- 3. Training course material and text for Bridge Inspectors Reference Manual.

Potential Partners: AASHTO, NACE, SSPC

Cost and Duration: \$350,000. 2 Years

Implementation: Through workshops and training courses

Superstructures # 02

Title: Development of Procedures for Preservation of Weathering Steel Bridges

Background: Weathering steel bridges have been constructed over roadways and may be subjected to chloride contamination from deicing chemical fogging from traffic, debris accumulation, and animal droppings. This has the potential to affect the performance of weathering steel by accelerating the corrosion rate. The formation of a proper patina is critical to long term protection of the steel substrate. There are presently no written criteria for keeping the surface in condition or cleanliness to allow the proper formation of the protective patina. The impact of accumulation of chloride is assumed to accelerate the corrosion process, but there is no documented evidence describing the mechanism or long term affect.

In aggressive environments weathering steel can continue to corrode causing severe loss of section. Documented evidence to quantify the benefits of washing or other methods of cleaning or protecting weathering steel is needed along with frequency guidelines.

A significant number of weathering steel bridges have been built and the number is expected to grow. Some of these bridges have experienced excessive corrosion. Therefore, early preservation activities such as washing contaminated steel are critical to ensuring adequate performance of these bridges. Mitigation for unexpected corrosion of weathering steel is extremely difficult and expensive.

Scope/Objective: The objective of this research is to determine the cost and benefits of washing or other methods of cleaning on the performance of the weathering steel. Recommended practices will be developed to provide guidance on the procedures and how to evaluate the need and frequency of washing bridges in various locations. Guidance should be provided to allow owners to select priority specific locations on the structure where washing or cleaning is needed that are susceptible to continued corrosion.

Research Proposed:

The following tasks would be required:

- Task 1. Conduct literature search for other studies or existing guidance on cleaning weathering steel bridges.
- Task 2. Develop a test method and procedure for evaluating the degree of chloride contamination on the surface of the weathering steel.
- Task 3. Select a sufficient number of representative bridges that are of various ages and in various susceptible locations for testing for the degree of chloride contamination and various types of debris.
- Task 4. Develop washing and cleaning methods to use in field testing on the selected bridges.
Task 5. Conduct field tests using the washing and cleaning methods on the selected bridges.

Task 6. Conduct tests to measure the effectiveness of the washing and cleaning techniques.

Task 7. Prepare a report of recommended practices and evaluation methods to allow owners to develop a bridge washing and cleaning policy.

Proposed Deliverables:

1. A test method and procedure for evaluating the degree of chloride contamination on the surface of the weathering steel.

2. A report of recommended practices and evaluation methods to allow owners to develop a bridge washing and cleaning policy.

Potential Partners: AASHTO, NACE, SSPC

Cost and Duration: \$300,000 2 Years

Implementation: Through workshops demonstrations and training courses

Superstructures # 03

Title: Performance Assessment of Existing Concrete Structure Corrosion Prevention/Mitigation Technologies

Background: Various methods of corrosion protection and corrosion mitigation techniques have been used over the past 20 years for concrete structures and components, including epoxy-coated rebar (ECR), other rebar coatings and materials, cathodic protection (CP), surface sealants, and chloride extraction techniques. Although all of these technologies have been evaluated in laboratory settings, their actual performance in the field, over the long term, has not been systematically evaluated. There is therefore no quantifiable basis for making decisions regarding the selection of appropriate techniques under varying environments and conditions, for different structure types and details, etc....or even if these techniques are cost-effective and provide longer-term bridge performance than other maintenance, repair, or rehabilitation options.

A study is therefore needed to review the in-service performance of the range of corrosion protection and mitigation technologies that have been used, in order to provide the basis for improved bridge management and maintenance decision-making.

The recent FHWA report on "cost of corrosion" in the United States demonstrates that this is a critical issue; and the impact on highway system performance from structurally deficient bridges and bridge rehab and replacement activities is widely known. Bridge owners currently do not have good tools or information regarding the appropriate application of corrosion protection and mitigation technologies, other than anecdotal or potentially industry-biased information. This research is therefore considered as a critical national need, and will have a huge payoff potential.

Scope/Objective: The objective of this study is to conduct an extensive field evaluation of the most common concrete structure corrosion protection and mitigation technologies that have been used since approximately 1980. The study must address the following parameters:

- Initial cost (difference) during construction or post-construction application
- Complexity of installation/construction (level of effort, training, environmental concerns, etc.)
- Performance since installation (and comparison if possible to the performance of similar bridges in similar environments without these protective systems)
- Required maintenance (if any) performed to keep the technology functional
- Cost of maintenance performed to keep the technology functional

Research Proposed:

The research will require at least the following:

• Conduct a literature review to collect information regarding relevant research on the operation and optimization of concrete bridge corrosion prevention and mitigation technologies

- Identify a representative sample of concrete bridges employing corrosion prevention and mitigation technologies throughout the United States
- Collect and assess State-specific evaluations that have been conducted on bridges in their states using these technologies; and international experience including Canada and Europe.
- Develop and implement a field inspection process
- Collect maintenance data for each bridge used in the field study
- Identify if there is any forensic data available from bridges that have been removed from service; and identify any bridges that have such technologies that will be removed from service (replacement, realignment) in the near future, that could be used for forensic evaluation in a subsequent research project.
- Based on evaluation of all data and information collected during the project, prepare a report documenting the performance, cost, etc., of the various systems; and develop a tool to assist bridge owners to select appropriate prevention and mitigation strategies based on a range of parameters (structure type, desired service type [short- versus long-term performance] environmental exposure, loading, etc...)

Proposed Deliverables: A report documenting the performance, cost, etc., of the various systems; and develop a tool to assist bridge owners to select appropriate prevention and mitigation strategies based on a range of parameters (structure type, desired service type [short-versus long-term performance] environmental exposure, loading, etc...)

Potential Partners: AASHTO, NCBC

Cost and Duration: \$1,000,000 4 Years

Implementation: Through distribution of the report

Superstructures # 04

Title: Improved Inspection Techniques for Steel Prestressing Strand, Cables, and Ropes

Background: In the past few years, there have been several "unexpected" failures of prestressing strand embedded in concrete or encased in ducts, some cases just weeks after the bridge was inspected. It is commonly recognized that the current state of non-destructive evaluation (NDE) technology is inadequate to evaluate the condition of these embedded and ducted strands both for active corrosion and section loss, breakage, quality of grout, etc. Similarly, for suspension and stay cables, and ropes and hangers, there have been many examples of active corrosion and wire breakage that is not readily identifiable without labor-intensive, intrusive inspection techniques.

Failures have immediate consequences, including potential loss of life, serious transportation network disruption, and expensive repair and replacement costs. Corrosion, section loss and wire breakage will have serious impacts due to work-zone repair and rehabilitation actions, traffic detours, and load limits.

This is a preservation and preventative maintenance issue, as inadequate knowledge of element condition prevents proactive actions that may mitigate or prevent further deterioration or future unanticipated failure. This is highly urgency due to the costs associated with failure or major rehabilitation and repair. However, the payoff is uncertain – there will be significant risk associated with this research, as it is possible that improved technologies may be beyond our capabilities at this time.

Scope/Objective: The objective of this research is to improve the current state of inspection technology, or to develop new tools and methodologies to assess the current state of steel prestressing strand, ducts, cables and ropes. Some of these technologies will be focused on determining current condition; others may be focused on identifying active corrosion or conditions favorable to corrosion.

Research Proposed:

The research will entail at least the following:

- Perform a synthesis study to evaluate the existing state-of-technology for inspecting and characterizing prestressing strand, ducts, cables and rope
- Collect information from other industries (e.g., offshore, nuclear) on inspection technologies that they use for similar structures and components
- Develop a research plan for improving existing or developing new technologies that show promise for providing better evaluation of the condition of these elements
- With project manager approval, conduct the research to improve or develop new technologies, and validate them in field trials
- Document the work and provide guidance on the appropriate application of the improved or new technologies in the field

Proposed Deliverables:

1. Guidance on the appropriate application of the improved or new technologies for providing better evaluation of the condition of prestressing strand, ducts, cables and rope

Potential Partners: AASHTO, NCBC

Cost and Duration: \$2,000,000 42 Months

Implementation: Delivery of guidelines to the field; workshops, demonstrations and training courses.

Superstructures # 05

Title: High-Durability Coatings and Sealer Materials for Structural Concrete

Background:

- Premature deterioration of concrete structural components is a national problem.
- Today's designs and materials have higher durability than previous generations; however, HPC and ECR have not completely solved the durability issue given the demands for increased life span of bridges (100 years).
- Advanced protective coating systems have been proven to provide concrete structures in other heavy industries with extended life, both in new construction and maintenance applications. (There are also aesthetic benefits.)
- Little to no effort has been applied to technology transfer and performance assessment of coating systems for concrete bridge systems.
- Traditional thin-film sealer materials continue to be used; however, industry has provided materials with significantly higher durability, and impending environmental issues may limit the availability of traditional sealers in the future.
- Identification of specific bridge components (such as beam ends, pier caps, and parapets) that would particularly benefit from coating application is needed.

This is an issue of national scope. The average age of the concrete bridge inventory is reaching the point that many bridges require intervention. The increased volume of new and rehabilitated concrete structures means that this maintenance burden will build over time. There are currently no highly effective verified methods for rehabilitation of deteriorated concrete that provide acceptable service life extension.

Scope/Objective: Provide coatings-based solutions for service life extension of concrete bridge structures.

Research Proposed:

The following tasks would be required:

- Task 1. Synthesize existing performance data and experience for industrial concrete coatings.
- Task 2. Develop performance data relative to bridge-specific applications for systems that have been proven in other industries.
- Task 3. Define common bridge components that would benefit from the application of protective coatings.
- Task 4. Develop guidance for use of protective coating and sealer materials in new construction and maintenance applications to enhance the long-term durability of concrete bridge structures.

Task 5. Develop and verify test methodologies for qualification of high-performance coating materials for concrete.

Proposed Deliverables:

Guidance on the use of protective coating and sealer materials in new construction and maintenance applications to enhance the long-term durability of concrete bridge structures.

Potential Partners: AASHTO, NCBC

Cost and Duration: \$350,000 2 Years

Implementation: Delivery of guidelines to the field; workshops, demonstrations and training courses

Title: Preservation of Concrete Highway Bridge Substructure Units by Preventing or Delaying the Initiation of Active Corrosion of the Steel Reinforcement

Background: Many of the bridges in the national inventory have substructures for which active corrosion has not yet initiated but can be anticipated prior to completion of the anticipated service life. There exist in a number of exposure environments and the corrosion can result from a variety of causes. Application of existing surface treatments prior to chlorides achieving a critical concentration at the steel depth may reduce ingress of this aggressive species and thereby extend service life. Such treatments are likely to be effective for a relatively brief time compared to the desired service life. Information is lacking, however, regarding the effective life of these alternatives and a time frame for reapplication.

Scope/Objective: Develop guidance for highway agencies to use technologies that prevent or delay corrosion initiation and enhance the long-term durability of concrete bridge substructures

Research Proposed:

The following tasks would be required:

- Task 1. Identify existing and consider new technologies to prevent or delay corrosion of steel reinforcing in concrete
- Task 2. For the different options that are identified, both physical and electrochemical, develop a life cycle schedule for application and reapplication (if needed) that relates properties of the protective system to condition of the substructure and environmental conditions
- Task 3. Identify test methods to evaluate and define performance of each option.
- Task 4. Identify the timeliness and frequency of applying the technologies and their life expectancies in environments of varying aggressiveness

Task 5. Identify initial and life-cycle costs of each technology

Proposed Deliverables:

1. Report on existing and consider newly developed technologies to prevent or delay corrosion of steel reinforcing in concrete

2. Report on test methods to evaluate and define performance of each option.

3. Report on timeliness and frequency of applying the technologies and their life expectancies in environments of varying aggressiveness; initial and life cycle costs of each technology

Potential Partners: AASHTO, NCBC, NACE

Cost and Duration: \$400,000 2 Years

User Community: Bridge designers, bridge management and maintenance engineers

Implementation: Distribution of reports

Title: Preservation of Concrete Highway Bridge Substructure Units by Controlling the Corrosion Rate of the Steel Reinforcement Once Corrosion has Initiated

Background: Many of the bridges in the national inventory have substructures for which active corrosion is ongoing and are experiencing deterioration, such as cracking, delaminations, and spalling. These exist in a number of exposure environments and the corrosion can result from a variety of causes. It is known that once corrosion has initiated, physical mitigation techniques such as patching, coatings, and sealers are no longer effective and electrochemical options such as cathodic protection and electrochemical chloride extraction are the only viable alternatives. Improved methods are needed to facilitate the ease with which such systems are installed and costs reduced.

Scope/Objective: Develop guidance for highway agencies to use technologies that reduce the corrosion rate to extend the service life and enhance the long-term durability of concrete bridge substructures.

Research Proposed:

The following tasks would be required:

- Task 1. Identify technologies to reduce the corrosion rate of steel reinforcing after it initiates and identify the advantages and disadvantages of each alternative.
- Task 2. Identify the timeliness and frequency of the different intervention options and their life expectancies in environments of varying aggressiveness
- Task 3. Identify initial and life-cycle costs of each technology
- Task 4. Develop a manual that identifies the long-term corrosion control system monitoring and maintenance requirements that are the bridge owner's responsibility subsequent to installation of each of the identified technologies.

Proposed Deliverables:

1. Report on technologies to reduce rate of corrosion after initiation including guidance on timeliness and frequency of intervention plus initial and life cycle costs

2. Manual on monitoring and maintenance of corrosion control system

Potential Partners: AASHTO, NCBC, NACE

Cost and Duration: \$300,000 18 Months

User Community: Bridge management and bridge maintenance engineers

Implementation: Distribution of report and manual; workshops and training courses

Title: Development of a High Performance Galvanic Anode

Background: Galvanic anode CP systems for protecting steel in concrete are relatively simple and easy to maintain compared to impressed current ones. However, performance may be less than adequate in high current demand applications. Such performance is limited by properties of the existing anodes. Identification of one or more new anodes with higher driving voltage and current output could overcome this limitation. Development of one or more such anodes could leapfrog present technology similar to what was done with development of mixed metal impressed current anodes.

Scope/Objective: Significantly improve the performance of galvanic CP systems by developing higher potential, higher current output anodes

Research Proposed:

The following tasks would be required:

- Task 1. Review the literature of existing galvanic anodes and galvanic CP systems for protecting steel in concrete
- Task 2. Explore options for identifying higher performance galvanic anodes
- Task 3. Conduct experiments to evaluate performance and service life in environments that are likely to be encountered by bridges throughout North America
- Task 4. Verify expected performance with field verification

Proposed Deliverables:

1. Report on high performance galvanic anodes

Potential Partners: AASHTO, NCBC, NACE

Cost and Duration: \$600,000 3 Years

User Community: Bridge maintenance engineers

Implementation: Distribution of report.

Title: Substructure Preservation Decision Matrix to Address Corrosion Issues of the Steel Reinforcement of Concrete Bridge Substructure Elements

Background: Corrosion of reinforced concrete bridge elements is a pervasive problem throughout the country. This attack can take a variety of forms and have a range of significance depending upon element type and environment. A decision making protocol is needed to assist bridge owners in identifying the most appropriate option for corrosion prevention and/or control that is tailored to variables applicable to the structure or element of concern. Such a protocol should be based upon the assessed condition of the structure or element and identify the appropriate corrosion control methods there from

Scope/Objective: Develop a strategic decision matrix on when and what corrosion mitigation preservation strategies to take to prolong the service life of in-service highway bridge substructures

Research Proposed:

The following tasks would be required:

- Task 1. Identify the existing technologies that prolong the service life of highway bridge substructure elements and the conditions for which each applies
- Task 2. Develop corrosion evaluation methods and condition rating guidelines for highway bridge substructure elements
- Task 3. Develop a decision tree of preservation strategies of differing substructure elements considering present condition, aggressiveness of the exposure, and life cycle cost of each path alternative

Proposed Deliverables:

- 1. Manual on corrosion evaluation methods
- 2. Report on decision tree of preservation strategies of differing substructure elements

Potential Partners: AASHTO, NCBC, NACE

Cost and Duration: \$450,000 2 Years

User Community: Bridge maintenance engineers

Implementation: Distribution of report and manual; workshops and training courses

Title: Preservation of steel bridge piles by preventing corrosion

Background: Steel pilings are a critical element for many bridges in the inventory. Corrosion of the steel and loss of section is a potential cause of bridge failure.

Steel piles in abutments can be exposed by settlement of embankments, consolidation of underlying strata, and erosion. This exposes them to oxygen, moisture and chlorides in roadway runoff, which can result in corrosion and significant section loss. In the areas where this can occur, there is typically limited or no access for inspection and, if required, mitigation. There may be other locations in highway structures that also have limited accessibility but may be subject to moisture, chlorides and the resulting corrosion. Techniques developed to address the steel pile concerns may also have applicability for these details.

Unexposed piles may also corrode in aggressive soil environments such that assessment of the extent of corrosion and lost load bearing capacity is difficult to define.

Residual capacity is determined by the remaining cross section and remaining life is a function of this and the exposure conditions. A methodology is needed to, first, assess the present condition of such piles, second, project remaining life and, third, identify technologies as to how this might be extended.

If steel abutment piles lose load carrying capacity due to corrosion, it would be extremely difficult and costly to restore foundation support. Preventing corrosion of piles in new bridges and mitigation of corrosion in existing piles at an early stage is a very cost effective means of preserving this critical structural element.

Scope/Objective: Develop one or more methods to determine the condition of and remaining service life of in-service steel piles (exposed & unexposed) in environments of varying aggressiveness and identify methods to preserve such piles.

Research Proposed:

The following tasks would be required:

- Task 1. Critically review the literature and DOT records regarding present methods that are being employed to identify and address steel piling corrosion issues
- Task 2. Identify non-disruptive methods by which physical condition of steel piles and present corrosion rate can be estimated and, if feasible, determined for different types of soil
- Task 3. For different exposure to different types of aggressive soils, identify methods for reducing corrosion rate of in place steel piles and extending service life

Task 4. Develop methods for mitigating or preventing further corrosion in piles exposed by settlement of embankments, consolidation of underlying strata, or erosion

Proposed Deliverables:

1. A report documenting methodologies for identifying, assessing and mitigating/preventing corrosion in steel piles

Potential Partners: AASHTO, Deep Foundations Institute, NACE

Cost and Duration: \$500,000 3 Years

User Community: Bridge designers, bridge maintenance engineers

Implementation: Distribution of the report plus workshops and training courses

Selection # 01

Title: Implementation of Preservation Practices on Highway Bridges by State DOTs

Background: Nationwide our bridge inventories are aging. Currently the FHWA maintains the NBI that contains information on the condition of more than 590,000 bridges and culverts located on public roads within the US. In 2006 according to the NBI there are approximately 154,000 structurally deficient or functionally obsolete bridges representing some 26% of the inventory. This represents some 88,849,630 square meters in bridge deck area on deficient bridges.

In the coming years this number is likely to increase due to a number of factors including: a) increasing traffic demand, b) continued bridge aging and deterioration, and c) limited funds. There is a need to a) maximize the benefits of systematic preventive maintenance, b) assess the cost effectiveness of current maintenance and improvement strategies, and c) examine preservation procedures that lead to improved operational performance of highway bridges.

Over the last 30 years the Congress has provided approximately \$77.6B in Highway Bridge Program Funds to the States and local agencies through the Federal Bridge Program. The current funding program is based on deficient bridges. Although Congress has introduced flexibility to use these funds for preservation it is not adequate to address all of the bridge needs. Bridge preservation is necessary to preserve and protect this investment. Bridge preservation practices must be identified by their technical characteristics and economical benefits.

Currently the top priority of State DOTs is bridge rehab and replacement. It will be cost effective nation wide to focus on bridge preservation and extend the useful service life of highway bridges. The information gathered under this study would enable DOT officials to develop and fund preservation programs.

Scope/Objective: Produce a list of bridge preservation actions which can be considered by the responsible owner as alternative options toward life cycle preservation strategy. Collect evidence that demonstrates the benefits of preservation activities and actions.

Researched Proposed:

The proposed research would involve studying the state of preservation practices on highway bridges. The following tasks would be required:

- Task 1. Define bridge preservation and how it needs to be funded and properly implemented on an agency wide basis.
- Task 2. Survey State DOTs and determine the following: a) current maintenance activities including preservation; b) who's performing preservation and maintenance activities; c) number of bridges maintained / preserved; d) annual budget or funding; e) Identify performance measures along with cost/benefit (life cycle) for employing preservation actions.

- Task 3. Compile responses from Task 2 and identify best practices, strategies and funding levels per bridge.
- Task 4. Determine the state of bridge preservation and maintenance practice for each DOT. Establish benchmarks and performance measures and use to rate each DOT in terms of status related to each DOT.

Proposed Deliverables:

1. A report documenting current status of bridge preservation programs nationwide and recommended performance measures

Potential Partners: AASHTO

Cost and Duration: \$300,000 2 Years

User Community: Bridge management engineers, bridge maintenance engineers

Implementation: Distribution of the report

Selection # 02

TITLE: Develop a Framework for documenting Bridge Preservation Activities

BACKGROUND: Information regarding existing or proposed bridge preservation activities (BPA) is lacking. The proposed framework will establish a structure for formatting, retaining and supplying such information to bridge owners. The information should include actions taken, prior and resulting conditions, impact on local communities (disruption and enhancements), first costs, and projected benefits. The proposed research will provide a framework for analyzing bridge preservation activities (BPA). It will also provide a method for comparing various bridge preservation activities. Ultimately it will be a tool for budget allocation and selecting projects.

OBJECTIVE: Purpose of the data is to support cost analysis of preservation actions, and analyze the effectiveness of activities. Additionally, the framework will provide a foundation for performance evaluation of preservation activities.

RESEARCH PROPOSED:

The proposed research would involve developing data base framework for documenting bridge preservation activities.

The following tasks would be required:

- Task 1. Survey State DOTs regarding existing highway bridge preservation and rehabilitation practices. Identify key information that is essential for analyses.
- Task 2. Develop data base framework categorizing preservation activities, conditions and how the information would go into a data base.
- Task 3. Recommend a procedure for establishing and regularly updating the information.
- Task 4. Compare life cycle performance of alternative preservation actions (real or hypothetical). Comparisons should refer to specific structural types.

Proposed Deliverables:

- 1. Data base framework categorizing preservation activities
- 2. Report on Life cycle Performance

Potential Partners: AASHTO

Cost and Duration: \$500,000 3 Years

User Community: Bridge management engineers and bridge maintenance engineers

Implementation: Distribution of data base format and report

Performance # 01

Title: Quantify the Information Necessary to Guide Bridge Preservation Decisions.

Background: Bridge Preservation is a systematic proactive effort to significantly extend the service life of a bridge or bridge elements, usually at least possible cost. Many transportation departments may have a significant amount of largely empirical data on experiences with bridge preservation and have developed conclusions on the effectiveness of bridge preservation based on those experiences. However, few systematic studies have been done to measure, evaluate and document the short and long term results and effects of bridge preservation actions. No attempts have been made to gather and collate high quality data, properly analyze the data and draw conclusions about the costs, effectiveness, and longevity of the preservation action. It is difficult to examine such issues as how long is the service life of the bridge/bridge element extended or what effect do the various, commonly used preservation actions have on the life cycle costs of bridges. Most conclusions reached by bridge practitioners are on the basis of intuition or simple common sense backed up by some experience. It is difficult to translate these conclusions into coherent and convincing arguments that will persuade legislatures and agency upper management to support and adequately fund aggressive and well planned programs of bridge preservation.

The collection of the data necessary to support analysis of the effectiveness and economics of bridge preservation activities should be addressed in a logical sequence starting with short term studies of existing data to future data collection that is targeted at specific elements of performance of bridge preservation actions.

This problem should be studied in 3 phases:

Scope/Objective

Phase I: Determine what aspects or results of bridge performance are of most importance to different levels of a transportation department and to various road users and which methods of bridge preservation should be studied as contributors to the chosen aspects of bridge performance. Identify and define quantifiable and measurable metrics that can be used to analyze the effectiveness and cost implications of a bridge preservation program.

Phase II: Use existing information on bridge preservation actions and programs to analyze existing data and draw conclusions on effects and benefits of bridge preservation actions. Compare these conclusions to those that currently are based on experiences and practices at various agencies in the US.

Phase III: Use experimental studies to collect specific types of data that are needed to evaluate the various benefits of specific, commonly used bridge preservation actions. Use the research quality data to refine and improve the understanding of the effects of bridge preservation actions

Research Proposed:

The following tasks would be required:

Phase I

- Task 1. Determine what aspects or results of performance of bridge preservation actions are most important, useful and feasible to evaluate.
- Task 2. Define the metrics that can be used to measure the chosen aspects of performance; and identify methodologies for measurement.
- Task 3. Produce an interim report that documents these metrics and communicates them to various groups with different interests in maintaining a bridge infrastructure at a high level of performance. These would include legislators, agency upper management, bridge maintenance managers, BMS practitioners, and the public.

Phase II

- Task 1. Identify and collect existing data and information on bridge preservation actions from data already stored in various formats at transportation departments. Organize data and information on:
 - Types of actions that are classified (by the agencies) as bridge preservation, preventive maintenance and/or maintenance actions
 - Guidance on selection, timing and application of the treatments
 - Frequency of application of treatments
 - Effectiveness and longevity of the treatments
- Task 2. Analyze the data and draw preliminary conclusions on performance of various bridge preservation actions under differing site and usage conditions. Compare these preliminary conclusions to commonly held conclusions or opinions on effects and benefits of bridge preservation actions that are based on experiences and practices at various agencies in the US. Verify/modify or disprove existing estimates of benefits that are ascribed to bridge preservations and programs
- Task 3. Develop recommendations on the best methods for measuring or estimating performance and benefits
- Task 4. Produce an interim report that documents the conclusions based on existing data

Phase III

Task 1. Define specific types of data needed to evaluate the various benefits of commonly used bridge preservation actions; determine the existing gaps in available data and describe approaches or methodologies to collect the necessary data

- Task 2. Verify/modify or disprove existing estimates of benefits that are ascribed to bridge preservations and programs.
- Task 3. Develop recommendations on the best methods for measuring or estimating performance and benefits
- Task 4. Develop and communicate summaries of the benefits and strategies for implementation of bridge preservation actions and programs to bridge practitioners, agency upper management, and legislators

Proposed Deliverables:

- 1. Interim report documenting performance metrics
- 2. Interim recommendations on the best methods for measuring or estimating performance and benefits
- 3. Final recommendations on the best methods for measuring or estimating performance and benefits

Potential Partners: AASHTO, State DOTS, Transportation Authorities, FHWA (LTBP Program)

Cost and Duration:

Recommended Funding:	Phase I	\$150,000
	Phase II	\$225,000
	Phase III	\$750,000
Research Period:	Phase I	12 months
	Phase II	18 months
	Phase III	60 months

User Community: State DOTS; Transportation Authorities;

Implementation: Distribution of reports

Performance # 02

Title: Develop Deterioration Models that Account for the Performance of Preservation Actions in Bridge Management Systems

Background: The most widely used bridge management system (BMS) is AASHTOWare[™] Pontis. This BMS is views deterioration as probabilistic rather than as deterministic processes and automatically updates previous deterioration predictions as more cycles of historic inspection data are input. Pontis defines two or more "feasible actions" that may be applied to a bridge element depending on condition state data, costs and level of improvement resulting from the action. These actions include a "do nothing" option and one or more actions that span the spectrum from maintenance to major rehabilitation to replacement. If the "do nothing" option is taken, there is no improvement in the condition state data and the projected deterioration curve will remain the same; on the other hand, if another (improvement) action is taken, the results will presumably be reflected in improvements in future condition state data and the deterioration curve will be recalculated. However, many preservative actions would not result in improved data as determined by the inspector in a visual inspection. This is a weakness in the current system in that it does not account for bridge preservation actions; i.e., it cannot evaluate the impacts and costs of actions that are proactive and preservative in nature instead of reactive to a deteriorated condition.

Scope/Objective: To study the performance of various bridge preservation actions and develop deterioration models that account for the performance of preservation actions in bridge management calculations.

Research Proposed: The following tasks would be required:

- Task 1. Identify the preservation treatments most commonly used on bridges.
- Task 2. Conduct studies to develop deterioration models or otherwise determine, estimate, or elicit from expert opinion the probabilities of changes in condition states on elements that have received a preservation treatment.
- Task 3. Establish new CoRe elements that represent elements that have received preservation treatments and define condition states, transition probabilities and feasible actions

Task 4. Produce a final report

Proposed Deliverables:

A report describing CoRe elements that can be used to incorporate bridge elements with commonly used bridge preservation treatments in bridge management systems such as AASHTOWareTM Pontis.

Potential Partners: AASHTO

Cost and Duration: \$300,000 2 Years

User Community: Bridge management engineers, bridge maintenance engineers, bridge inspectors, etc.

Implementation: Implemented through enhancements to bridge management systems, workshops, training courses,

APPENDIX B – TABLES RANKING ALL PRESERVATION STATEMENTS

		Pavement Preservation Needs Statements	Weighted	
<u>Rank</u>	Needs Statement #	<u>Title</u>	Importance + <u>Priority</u>	
1	Construction 02	Performance Related Specifications (PRS) for Pavement Preservation treatments	2.24	
2	Design 02	Determining Pavement Preservation Treatment Lives and Related Pavement Life Extension	2.15	
3	Design 01	Determine the Economic Benefits of Pavement Preservation Strategies	2.13	
4	Contracting Methods 03	Development of Model Specifications and Testing Requirements for Pavement Preservation Contracting Methods	1.86	
5	Performance 03	Quantify Performance and Benefits of Various Pavement Preservation Treatments and Develop Pavement Preservation Treatment Performance Models	1.85	
6	Asset 01	Development of a Process for Estimating the Remaining Service Life (RSL) for Transportation Infrastructure	1.77	
7	Construction 07	QA/QC Guidelines for Pavement Preservation Projects	1.77	
8	Performance 04	Quantifying the Benefits of Pavement Preservation Treatments	1.75	
9	Materials 07	"Triggers" for the Timing of Surface Treatments	1.70	
10	Contracting Methods 02	Performance Measures and Contracting Methods for Pavement Preservation Treatments	1.69	
11	Asset 06	Data and Performance Requirements Needed to Incorporate Pavement Preservation into Asset Management Systems	1.67	
12	Materials 02	Acceptance Criteria for Surface Treatments	1.62	
13	Design 03	Validate a Methodology for Determining Optimal Timing of Pavement Preservation Treatment Applications	1.59	
14	Performance 05	Factors Affecting Pavement Preservation Treatment Performance and Expanded Treatment Selection and Design Guidance	1.57	
15	Asset 03	Adaptable National Guidelines to Identify the <i>Right</i> Pavement/ <i>Right</i> Time/ <i>Right</i> Treatment	1.51	
16	Construction 05	Pavement Preservation: Contractor/Agency Training and Certification	1.51	
17	Materials 01	Mechanical Binder Properties to Predict Surface Treatment Performance	1.43	
18	Materials 05	Performance Grading System for Asphalt Emulsions	1.40	
19	Performance 02	Development of Distress Identification System for Pavement Preservation Treatments	1.34	
20	Construction 04	Pavement Preservation Contractor Qualification Program	1.19	
21	Asset 04	New Technologies to Determine Preservation Indicators	1.18	

Table B-1 - Top Pavement Preservation Priorities Rated by Combined Importance & Priority

22	Performance 06	Guidelines for Pavement Preservation	1.17
23	Asset 08	Convincing the Stakeholders: Communications and Institutional Issues	1.12
24	Contracting Methods 01	Analysis and Synthesis of Pavement Preservation Contracting Methods	1.11
25	Design 07	Integration of Pavement Preservation with a Pavement Management System (PMS)	1.08
26	Asset 02	Improved Decision Making Through Effective Transportation System Preservation (TSP)	1.07
27	Design 06	Integrating Pavement Preservation into the Design Process	1.07
28	Construction 03	Improving the Timeliness of Acceptance Testing Results	1.04
29	Construction 01	Development of Innovative Pavement Preservation Products, Equipment & Construction Methods	1.01
30	Materials 06	"Triggers" for the Timing of Surface Treatments	1.01
31	Design 04	Develop Appropriate Pavement Preservation Treatments and Practices for Urban Areas	
32	Materials 04	Cost-Effectiveness of Quality Aggregates	0.91
33	Asset 05	Evaluate the Safety Aspect of Pavement Preservation	0.90
34	Asset 07	Integration of Transportation System Preservation (TSP) into the Asset Management Framework	0.80
35	Materials 03	Appropriate Installation Geometry for Crack Treatments	0.71
36	Design 05	Framework for a Coordinated Approach to Pavement Preservation Process from an Agency Perspective	0.68
37	Performance 01	Synthesis: Pavement Preservation Data Sources	0.65
38	Construction 06	QA/QC Guidelines for Pavement Preservation Projects	0.40

Table B-2 - Top Bridge Preservation Priorities Rated by Combined Importance & Priority

		Bridge Preservation Needs Statements	Weighted
<u>Rank</u>	Needs Statement #	<u>Title</u>	Importance + <u>Priority</u>
1	Superstructures 04	Improved Inspection Techniques for Steel Prestressing Strand, Cables, and Ropes	2.54
2	Performance 01	Quantify the Information Necessary to Guide Bridge Preservation Decisions	2.11
3	Decks & Joints 01	Best Practices for Preserving Bridge decks	2.06

4	Selection 01	Implementation of Preservation Practices on Highway Bridges by State DOTs	2.04
5	Substructures 01	Preservation of Concrete Highway Bridge Substructure Units by Preventing or Delaying the Initiation of Active Corrosion of the Steel Reinforcement	1.87
6	Asset 07	Evaluation, Analysis, and Documentation of Successful Bridge Preservation Practices	1.79
7	Substructures 02	Preservation of Concrete Highway Bridge Substructure Units by Controlling the Corrosion Rate of the Steel Reinforcement once Corrosion has Initiated	1.74
8	Superstructures 03	Performance Assessment of Existing Concrete Structure Corrosion Prevention/Mitigation Technologies	1.72
9	Selection 02	Develop Bridge Design Guidelines to Enhance Constructability and Maintainability	1.66
10	Performance 02	Develop Deterioration Models that Account for the Performance of Preservation Actions in Bridge Management Systems	1.65
11	Substructures 04	Substructure Preservation Decision Matrix to Address Corrosion Issues of the Steel Reinforcement of Concrete Bridge Substructure Elements	1.62
12	Asset 03	Development Of A Process For Estimating The Remaining Service Life (RSL) Of Bridge Components And The Overall Bridge System Based On Observable Data	1.57
13	Decks & Joints 03	Determine the Recommended Practice and the Life-Cycle Cost Savings for Using Sealers to Preserve Concrete Bridge Decks	1.39
14	Decks & Joints 02	Determine the Recommended Practice and the Life-Cycle Cost Savings for Using Thin Overlays to Preserve Concrete Bridge Decks	1.27
15	Decks & Joints 04	Determine the Recommended Practice and the Life-Cycle Cost Savings for Preserving Superstructure and Substructure Elements Through the Use and Maintenance of Watertight Joints	1.25
16	Asset 02	Establishment of Uniform Terminology and Definitions for Transportation System Preservation	1.23
17	Asset 01	Development of a bridge preservation process framework ensuring a standardized repeatable process for bridge preservation	1.09
18	Superstructures 05	High-Durability Coatings and Sealer Materials for Structural Concrete	1.05
19	Asset 06	Modeling Early Bridge Deterioration and Prevention	1.00
20	Asset 05	Better Direct and Indirect Cost Models for Bridge Management Systems	0.91
21	Substructures 03	Development of a High Performance Galvanic Anode	0.83
22	Superstructures 01	Development of a test for assessment of performance of weathering steel	0.82
23	Asset 04	Evaluation of the AASHTO Commonly Recognized Elements (CoRe), Ten Years of Data	0.77
24	Superstructures 02	Development of Procedures for Preservation of Weathering Steel Bridges	0.72
25	Substructures 05	Preservation of Steel Bridge Piles	0.63

		Pavement Preservation Needs Statements	
<u>Rank</u>	Needs Statement #	<u>Title</u>	Weighted Importance + <u>Priority</u>
1	Design 02	Determining Pavement Preservation Treatment Lives and Related Pavement Life Extension	2.79
2	Design 01	Determine the Economic Benefits of Pavement Preservation Strategies	2.71
3	Construction 02	Performance Related Specifications (PRS) for Pavement Preservation treatments	2.63
4	Performance 03	Quantify Performance and Benefits of Various Pavement Preservation Treatments and Develop Pavement Preservation Treatment Performance Models	2.63
5	Performance 04	Quantifying the Benefits of Pavement Preservation Treatments	2.58
6	Asset 01	Development of a Process for Estimating the Remaining Service Life (RSL) for Transportation Infrastructure	2.50
7	Contracting Methods 03	Development of Model Specifications and Testing Requirements for Pavement Preservation Contracting Methods	2.50
8	Construction 07	QA/QC Guidelines for Pavement Preservation Projects	2.50
9	Materials 07	"Triggers" for the Timing of Surface Treatments	2.47
10	Materials 02	Acceptance Criteria for Surface Treatments	2.45
11	Design 03	Validate a Methodology for Determining Optimal Timing of Pavement Preservation Treatment Applications	2.45
12	Asset 06	Data and Performance Requirements Needed to Incorporate Pavement Preservation into Asset Management Systems	2.45
13	Performance 05	Factors Affecting Pavement Preservation Treatment Performance and Expanded Treatment Selection and Design Guidance	2.45
14	Asset 03	Adaptable National Guidelines to Identify the Right Pavement/ Right Time/ Right Treatment	2.39
15	Contracting Methods 02	Performance Measures and Contracting Methods for Pavement Preservation Treatments	2.32
16	Materials 01	Mechanical Binder Properties to Predict Surface Treatment Performance	2.29
17	Construction 05	Pavement Preservation: Contractor/Agency Training and Certification	2.29
18	Performance 02	Development of Distress Identification System for Pavement Preservation Treatments	2.26
19	Performance 06	Guidelines for Pavement Preservation	2.21
20	Materials 05	Performance Grading System for Asphalt Emulsions	2.21

Table B-3 - Top Pavement Preservation Priorities Rated Solely by Importance

21	Construction 04	Pavement Preservation Contractor Qualification Program	2.18
22	Design 04	Develop Appropriate Pavement Preservation Treatments and Practices for Urban Areas	2.16
23	Asset 04	New Technologies to Determine Preservation Indicators	2.13
24	Design 06	Integrating Pavement Preservation into the Design Process	2.13
25	Design 07	Integration of Pavement Preservation with a Pavement Management System (PMS)	2.13
26	Asset 08	Convincing the Stakeholders: Communications and Institutional Issues	2.13
27	Contracting Methods 01	Development of Model Specifications and Testing Requirements for Pavement Preservation Contracting Methods	2.11
28	Construction 03	Improving the Timeliness of Acceptance Testing Results	2.11
29	Construction 01	Development of Innovative Pavement Preservation Products, Equipment & Construction Methods	2.08
30	Asset 02	Improved Decision Making Through Effective Transportation System Preservation (TSP)	2.08
31	Materials 06	Performance-Graded Aggregate System for Pavement Preservation Surface Treatments	2.05
32	Asset 05	Evaluate the Safety Aspect of Pavement Preservation	1.95
33	Asset 07	Integration of Transportation System Preservation (TSP) into the Asset Management Framework	1.92
34	Performance 01	Synthesis: Pavement Preservation Data Sources	1.84
35	Materials 04	Cost-Effectiveness of Quality Aggregates	1.84
36	Design 05	Framework for a Coordinated Approach to Pavement Preservation Process from an Agency Perspective	1.82
37	Materials 03	Appropriate Installation Geometry for Crack Treatments	1.74
38	Construction 06	Advanced Equipment for Improved Pavement Preservation Treatments	1.42

		Bridge Preservation Needs Statements	
			Weighted
<u>Rank</u>	_ Needs Statement #	<u>-</u> <u>Title</u>	Importance + <u>Priority</u>
1	Superstructures 04	Improved Inspection Techniques for Steel Prestressing Strand, Cables, and Ropes	2.84
2	Decks & Joints 01	Best Practices for Preserving Bridge decks	2.69
3	Performance 01	Quantify the Information Necessary to Guide Bridge Preservation Decisions	2.59
4	Selection 01	Implementation of Preservation Practices on Highway Bridges by State DOTs	2.47
5	Selection 02	Develop Bridge Design Guidelines to Enhance Constructability and Maintainability	2.47
6	Substructures 02	Preservation of Concrete Highway Bridge Substructure Units by Controlling the Corrosion Rate of the Steel Reinforcement once Corrosion has Initiated	2.44
7	Performance 02	Develop Deterioration Models that Account for the Performance of Preservation Actions in Bridge Management Systems	2.41
8	Substructures 01	Preservation of Concrete Highway Bridge Substructure Units by Preventing or Delaying the Initiation of Active Corrosion of the Steel Reinforcement	2.38
9	Superstructures 03	Performance Assessment of Existing Concrete Structure Corrosion Prevention/Mitigation Technologies	2.38
10	Substructures 04	Substructure Preservation Decision Matrix to Address Corrosion Issues of the Steel Reinforcement of Concrete Bridge Substructure Elements	2.38
11	Asset 07	et 07 Evaluation, Analysis, and Documentation of Successful Bridge Preservation Practices	
12	Decks & Joints 04	Determine the Recommended Practice and the Life-Cycle Cost Savings for Preserving Superstructure and Substructure Elements Through the Use and Maintenance of Watertight Joints	2.31
13	Asset 03	Development Of A Process For Estimating The Remaining Service Life (RSL) Of Bridge Components And The Overall Bridge System Based On Observable Data	2.31
14	Decks & Joints 02	Determine the Recommended Practice and the Life-Cycle Cost Savings for Using Thin Overlays to Preserve Concrete Bridge Decks	2.22
15	Decks & Joints 03	Determine the Recommended Practice and the Life-Cycle Cost Savings for Using Sealers to Preserve Concrete Bridge Decks	2.22
16	Asset 02	Establishment of Uniform Terminology and Definitions for Transportation System Preservation	2.13
17	Superstructures 05	High-Durability Coatings and Sealer Materials for Structural Concrete	2.03
18	Asset 01	Development of a bridge preservation process framework ensuring a standardized repeatable process for bridge preservation	2.00
19	Asset 06	Modeling Early Bridge Deterioration and Prevention	1.91

Table B-4 - Top Bridge Preservation Priorities Rated Solely by Importance

20	Asset 05	Better Direct and Indirect Cost Models for Bridge Management Systems	1.88
21	Superstructures 01	Development of a Test for Assessment of Performance of Weathering Steel	1.84
22	Substructures 03	Development of a High Performance Galvanic Anode	1.81
23	Asset 04	Evaluation of the AASHTO Commonly Recognized Elements (CoRe), Ten Years of Data	1.78
24	Superstructures 02	Development of Procedures for Preservation of Weathering Steel Bridges	1.75
25	Substructures 05	Preservation of Steel Bridge Piles	1.75

APPENDIX C – BALLOTS AND RANKING GUIDELINES

FHWA-AASHTO TRANSPORTATION SYSTEM PRESERVATION R&D PROJECT

TO: ALL PARTICIPANTS OF THE PAVEMENT PRESERVATION R&D WORKSHOPS

PHOENIX, AZ ORLANDO, FL DALLAS, TX

FROM: JOHN M. HOOKS

SUBJECT: BALLOT ON PAVEMENT PRESERVATION R&D NEEDS STATEMENTS

DATE: AUGUST 3, 2007

As a participant in one of the subject workshops you have assisted the FHWA and AASHTO to identify critical needs for research and development related to pavement preservation. You are now being asked to help FHWA and AASHTO prioritize those needs. Please read the brief instructions below and then use the attached materials to complete your rating of the needs statements.

The workshops at Phoenix and Orlando, attended by a total of 92 persons, yielded a total of 63 draft needs statements. At a subsequent workshop in Dallas, attended by 20 persons, the statements were reviewed, edited and merged if appropriate. There are now 40 needs statements under consideration and they are grouped according to the following topics:

Asset Management	AM	Materials	MT
Design	DE	Construction	CN
Contracting Methods	СМ	Performance	PF

The ballot has a separate table for each of the six topics and the statements are identified by number (e.g. AM 01) plus title. A seventh table at the end of the ballot will be used for step 4 of the following instructions. A sample ballot is attached for your further assistance.

The 40 needs statements are provided in the attached 2 documents; one has full content; the other has only #, Title, Background & Scope/Objective.

Instructions for Completion of the Ballot

- 1. For each of the six topics, review the needs statements and then rate the statements as follows:
- 2. **Importance Index:** For each of the needs statements listed, pleases assign an index value that reflects your evaluation of the importance of performing the study. Use the following index of values:

A - Very Important B - Important (not urgent) C - Of Little Importance

- 3. **Priority Ranking:** Rank the statements within each topic from 1 through N, where "N" is the number of statements in the topic. Assign a value of 1 to the statement you would fund as the highest priority, a value of 2 to the next highest priority and so on until assigning a value of N to the lowest priority in the topic.
- 4. Finally, complete Table # 7 at the end of the ballot. Considering only the six statements to which you have assigned a priority value of "1", place these statements, using the statement #, from highest priority to lowest.

Pavement Preservation R&D Needs - Sample Ballot

<u>#</u>	Importance Index (A, B, or C)	Priority Ranking (1 thru 8)	Brief Title
AM 01	В	4	Development of a Process for Estimating the Remaining Service Life (RSL) for Transportation Infrastructure
AM 02	В	5	Improved Decision Making Through Effective Transportation System Preservation (TSP)
AM 03	С	8	Adaptable National Guidelines to Identify the <i>Right</i> Pavement/ <i>Right</i> Time/ <i>Right</i> Treatment
AM 04	А	1	New Technologies to Determine Preservation Indicators
AM 05	С	7	Evaluate the Safety Aspect of Pavement Preservation
AM 06	В	3	Data and Performance Requirements Needed to Incorporate Pavement Preservation into Asset Management Systems
AM 07	В	6	Integration of Transportation System Preservation (TSP) into the Asset Management Framework
AM 08	А	2	Convincing the Stakeholders: Communications and Institutional Issues

Table # 1 - ASSET MANAGEMENT

Table # 2 - DESIGN

<u>#</u>	Importance Index (A, B, or C)	Priority Ranking (1 thru 9)	Brief Title
DE 01	А	3	Determine the Economic Benefits of Pavement Preservation Strategies
DE 02	А	2	Determining Pavement Preservation Treatment Lives and Related Pavement Life Extension
DE 03	А	1	Validate a Methodology for Determining Optimal Timing of Pavement Preservation Treatment Applications
DE 04	В	4	Develop Appropriate Pavement Preservation Treatments and Practices for Urban Areas
DE 05	С	7	Framework for a Coordinated Approach to Pavement Preservation Process from an Agency Perspective
DE 06	В	5	Integrating Pavement Preservation into the Design Process
DE 07	С	8	Integration of Pavement Preservation with a Pavement Management System (PMS)

DE 08	В	6	Develop Pavement Preservation (PP) Strategies and Practices for Urban Areas	
DE 09	С	9	Integration of Pavement Preservation (PP) into the Pavement Design Process	

Table # 3 CONSTRUCTION

<u>#</u>	Importance Index (A, B, or C)	Priority Ranking (1 thru 8)	Brief Title				
CN 01	А	4	Development of Innovative Pavement Preservation Products, Equipment & Construction Methods				
CN 02	А	3	Performance Related Specifications (PRS) for Pavement Preservation treatments				
CN 03	В	5	Improving the Timeliness of Acceptance Testing Results				
CN 04	В	6	Pavement Preservation Contractor Qualification Program				
CN 05	А	2	Pavement Preservation: Contractor/Agency Training and Certification				
CN 06	С	7	Advanced Equipment for Improved Pavement Preservation Treatments				
CN 07	А	1	QA/QC Guidelines for Pavement Preservation Projects				

Table # 4 MATERIALS

<u>#</u>	Importance Index (A, B, or C)	Priority Ranking (1 thru 8)	Brief Title			
MT 01	В	5	Mechanical Binder Properties to Predict Surface Treatment Performance			
MT 02	А	2	Acceptance Criteria for Surface Treatments			
MT 03	С	7	Appropriate Installation Geometry for Crack Treatments			
MT 04	С	6	Cost-Effectiveness of Quality Aggregates			
MT 05	В	3	Performance Grading System for Asphalt Emulsions			
MT 06	В	4	Performance-Graded Aggregate System for Pavement Preservation Surface Treatments			
MT 07	A	1	"Triggers" for the Timing of Surface Treatments			

Table # 5 CONTRACTING METHODS

<u>#</u>	Importance Index (A, B, or C)	Priority Ranking (1 thru 8)	Brief Title		
CM 01	А	2	Analysis and Synthesis of Pavement Preservation Contracting Methods		
CM 02	А	1	Performance Measures and Contracting Methods for Pavement Preservation Treatments		
CM 03	В	3	Development of Model Specifications and Testing Requirements for Pavement Preservation Contracting Methods		

Table # 6 PERFORMANCE

<u>#</u>	Importance Index (A, B, or C)	Priority Ranking (1 thru 6)	Brief Title			
PF 01	А	2	Synthesis: Pavement Preservation Data Sources			
PF 02	В	4	Development of Distress Identification System for Pavement Preservation Treatments			
PF 03	В	5	Quantify Performance and Benefits of Various Pavement Preservation Treatments and Develop Pavement Preservation Treatment Performance Models			
PF 04	А	1	Quantifying the Benefits of Pavement Preservation Treatments			
PF 05	С	6	Factors Affecting Pavement Preservation Treatment Performance and Expanded Treatment Selection and Design Guidance			
PF 06	В	3	Guidelines for Pavement Preservation			

YOUR TOP 6 PRIORITIES

	<u>Highest</u>	<u>2nd Highest</u>	<u>3rd Highest</u>	4 th Highest	5 th Highest	<u>6th Highest</u>
	<u>Priority</u>	<u>Priority</u>	<u>Priority</u>	<u>Priority</u>	<u>Priority</u>	<u>Priority</u>
Write in Needs Statement #	MT 07	DE 03	AM 04	PF 04	CN 02	CM 02
FHWA-AASHTO TRANSPORTATION SYSTEM PRESERVATION R&D PROJECT

TO: ALL PARTICIPANTS OF THE BRIDGE PRESERVATION R&D WORKSHOP

@ DALLAS, TX, MAY 22 - 23, 2007

FROM: JOHN M. HOOKS

SUBJECT: BALLOT ON BRIDGE PRESERVATION R&D NEEDS STATEMENTS

DATE: AUGUST 3, 2007

As a participant in the subject workshop you have assisted the FHWA and AASHTO to identify critical needs for research and development related to bridge preservation. You are now being asked to help FHWA and AASHTO prioritize those needs. Please read the brief instructions below and then use the attached materials to complete your rating of the needs statements.

The workshop at Dallas, attended by a 46 persons, yielded a total of 28 draft needs statements. After further review, these were edited and merged if appropriate. There are now 25 needs statements under consideration and they are grouped according to the following topics:

Asset Management	AM	Substructures	SB
Decks & Joints	DJ	Selection	SE
Superstructures	SP	Performance	PF

The ballot has a separate table for each of the six topics and the statements are identified by number (e.g. AM 01) plus title. A seventh table at the end of the ballot will be used for step 4 of the following instructions. A sample ballot is attached for your further assistance.

The 25 needs statements are provided in the attached 2 documents; one has full content; the other has only #, Title, Background & Scope/Objective.

Instructions for Completion of the Ballot

- 5. For each of the six topics, review the needs statements and then rate the statements as follows:
- 6. **Importance Index:** For each of the needs statements listed, pleases assign an index value that reflects your evaluation of the importance of performing the study. Use the following index of values:

A – Very Important B – Important (not urgent) C – Of Little Importance

- 7. **Priority Ranking:** Rank the statements within each topic from 1 through N, where "N" is the number of statements in the topic. Assign a value of 1 to the statement you would fund as the highest priority, a value of 2 to the next highest priority and so on until assigning a value of N to the lowest priority in the topic.
- 8. Finally, complete Table # 7 at the end of the ballot. Considering only the six statements to which you have assigned a priority value of "1", place these statements, using the statement #, from highest priority to lowest.

<u>#</u>	Importance Index (A, B, or C)	Priority Ranking (1 thru 8)	Brief Title
AM 01	С	7	Development of a bridge preservation process framework ensuring a standardized repeatable process for bridge preservation
AM 02	А	1	Establishment of Uniform Terminology and Definitions for Transportation System Preservation
AM 03	В	5	Development Of A Process For Estimating The Remaining Service Life (RSL) Of Bridge Components And The Overall Bridge System Based On Observable Data.
AM 04	А	3	Evaluation of the AASHTO Commonly Recognized Elements (CoRe), Ten Years of Data
AM 05	А	2	Better Direct and Indirect Cost Models for Bridge Management Systems
AM 06	С	6	Modeling Early Bridge Deterioration and Prevention
AM 07	А	4	Evaluation, Analysis, and Documentation of Successful Bridge Preservation Practices

 Table # 1 - ASSET MANAGEMENT

Table # 2 - DECKS & JOINTS

<u>#</u>	Importance Index (A, B, or C)	Priority Ranking (1 thru 9)	Brief Title
DJ 01	В	4	Best Practices for Preserving Bridge decks
DJ 02	А	1	Determine the Recommended Practice and the Life-Cycle Cost Savings for Using Thin Overlays to Preserve Concrete Bridge Decks
DJ 03	В	3	Determine the Recommended Practice and the Life-Cycle Cost Savings for Using Sealers to Preserve Concrete Bridge Decks
DJ 04	А	2	Determine the Recommended Practice and the Life-Cycle Cost Savings for Preserving Superstructure and Substructure Elements Through the Use and Maintenance of Watertight Joints

 Table # 3
 SUPERSTRUCTURES

<u>#</u>	Importance Index (A, B, or C)	Priority Ranking (1 thru 8)	Brief Title
SP 01	А	3	Development of a Test for Assessment of Performance of Weathering Steel
SP 02	В	5	Development of Procedures for Preservation of Weathering Steel Bridges
SP 03	А	1	Performance Assessment of Existing Concrete Structure Corrosion Prevention/Mitigation Technologies
SP 04	А	2	Improved Inspection Techniques for Steel Prestressing Strand, Cables, and Ropes
SP 05	В	4	High-Durability Coatings and Sealer Materials for Structural Concrete

Table # 4 SUBSTRUCTURES

<u>#</u>	Importance Index (A, B, or C)	Priority Ranking (1 thru 8)	Brief Title
SB 01	А	1	Preservation of Concrete Highway Bridge Substructure Units by Preventing or Delaying the Initiation of Active Corrosion of the Steel Reinforcement
SB 02	В	3	Preservation of Concrete Highway Bridge Substructure Units by Controlling the Corrosion Rate of the Steel Reinforcement once Corrosion has Initiated
SB 03	А	2	Development of a High Performance Galvanic Anode
SB 04	В	4	Substructure Preservation Decision Matrix to Address Corrosion Issues of the Steel Reinforcement of Concrete Bridge Substructure Elements
SB 05	С	5	Preservation of Steel Bridge Piles

Table # 5-SELECTION

<u>#</u>	Importance Index (A, B, or C)	Priority Ranking (1 thru 8)	Brief Title
SE 01	А	1	Implementation of Preservation Practices on Highway Bridges by State DOTs
SE 02	В	2	Develop Bridge Design Guidelines to Enhance Constructability and Maintainability

 Table # 6
 PERFORMANCE

<u>#</u>	Importance Index (A, B, or C)	Priority Ranking (1 thru 8)	Brief Title
PF 01	А	1	Quantify the Information Necessary to Guide Bridge Preservation Decisions
PF 02	А	2	Develop Deterioration Models that Account for the Performance of Preservation Actions in Bridge Management Systems

YOUR TOP 6 PRIORITIES

	<u>Highest</u>	<u>2nd Highest</u>	<u>3rd Highest</u>	4 th Highest	<u>5th Highest</u>	<u>6th Highest</u>
	<u>Priority</u>	<u>Priority</u>	<u>Priority</u>	<u>Priority</u>	<u>Priority</u>	<u>Priority</u>
Write in Needs Statement #	AM 02	SB 01	PF 01	DJ 02	SP 03	SE 02

Thank You for Your Very Valuable Assistance!

APPENDIX D – DATA FROM COMPLETED BALLOTS

	PAV	EMENT PRESER	RVATION PRIOF	RITY RANKING	S	
PAVEMENTS			PRIORITY	RANKING		
Statement #						
Asset	1	2	2	Л	5	6
Management	<u> </u>	<u>~</u>	<u> </u>	<u> </u>	<u>5</u>	<u>u</u>
AM 01	4	3	2		3	
AM 02	3	4	0		Ι	1
AIM 03		1	2			I
		1				1
AM 05			1			1
	2		I			4
AM 08	3		1	1	1	
AIVI 08	2		1			
Design	1	2	3	4	5	6
DE 01	4	1	—	6	1	—
DE 02		7	2		2	2
DE 03		1	1			
DE 04						
DE 05		1				
DE 06	2				1	
DE 07				1		
Construction	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>
CN 01		1				
CN 02	1	4	6	2		2
CN 05						
CN 05	1		1	2	1	
CN 05		2	3	1	2	
CN 06						
CN 07				5	1	
			-			-
Materials	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>
MT 01	1	2	1	2	1	1
MT 02	2		3	1		
MT 03	1					
MT 04						
MT 05	1		1	3		
MT 06					2	
MT 07	3	1	1	4	1	3

Contracting Methods	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>
CM 01		2		1		4
CM 02		1	1	1	4	3
CM 03		1		1	9	4
Performance	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>
PF 01	1	1				1
PF 02		2	1		2	1
PF 03	1	2		1	1	2
PF 04	3		1	1	2	2
PF 05			1			2
PF 06	1	1	2	1		1

Pavements		Ratino	<u> </u>				F	Rank				
Statement #	"A"	"B"	"C"	1	2	3	4	5	6	7	8	
Asset					1		1			1		
Management										4	2	20
AM 01	23	11	4	16	5	3	0	2	4	0	2	38
AM 02	12	17	9	5	4	1	4	5	/	10	2	38
AM 03	22	9	/	4	8	8	3	/	1	ა ი	4 5	30 20
AM 04	13	17	8		4	/	12	2	4	с 5	D Q	20 20
AM 05	11	14	13	0	5	5	4	4	1	2	0 2	20 20
	20 5	10	о О	0	0	0	9	з 7	10	5	2	38
	5 17	25	0	т Б	4	4	4 2	, o	10	3	8	38
	. 14	15	304	38	4 38	4 38	∠ 38	0 38	4 38	38	38	<u>304</u>
Desian			001			00	00	00	50	30	55	
DE 01	28	9	1	11	13	5	4	2	1	2		38
DE 02	31	6	1	14	12	3	1	1	6	1		38
DE 03	19	17	2	4	6	11	8	5	3	1		38
DE 04	11	22	5	2	1	6	3	9	6	11		38
DE 05	6	19	13	1	2	3	6	5	6	15		38
DE 06	13	17	8	4	1	5	7	9	7	5		38
DE 07	14	15	9	2	3	5	9	7	9	3		<u>38</u>
	_		266	38	38	38	38	38	38	38		266
Construction												
CN 01	11	19	8	1	5	6	5	7	7	7		38
CN 02	27	8	3	20	6	5	2	2	2	1		38
CN 03	12	20	6	1	6	3	4	13	7	4		38
CN 04	16	13	9	3	8	3	9	1	8	6		38
CN 05	17	15	6	5	5	13	5	7	2	1		38
CN 06	2	12	24	1	0	0	2	7	11	1/	_	38
CN 07	23	11	4	7	8	8	11	1	1	2		38
			266	38	38	38	38	38	38	38		266
Doucements	Patino			Dan	k							
Statement #	"A") "D"	" C "	1	N Э	2	4	F	4	7	Q	
Matorials	A	D	C			3	4	5	0	,	0	
MT 01	17	15	6	7	1	7	0	5	1	5		38
MT 02	10	17	2	6	4 0	, 7	6	1	0	0		38
MT 02	7	14	ے 17	1	2	, 2	4	13	Ŕ	8		38
MT 04	, 10	12	16	2	7	5	5	3	6	10		38
MT 05	15	17	5	- 6	5	8	7	7	2	3		38
MT 06	12	16	10	2	- 7	4	3	5	- 11	6		38
MT 07	21	13	5	14	4	5	4	4	1	6		<u>38</u>
			266	38	38	38	38	38	38	38		266

Tally Sheet Pavement Preservation

Contracting Methods						-				
CM 01	16	10	12	5	12	21				38
CM 02	16	18	4	15	15	8				38
CM 03	23	11	4	18	11	9				<u>38</u>
			114							114
Performance										
PF 01	9	14	15	2	2	2	8	3	21	38
PF 02	15	18	5	6	7	6	3	15	1	38
PF 03	27	8	3	10	12	3	6	3	4	38
PF 04	23	14	1	9	10	4	8	4	3	38
PF 05	20	15	3	4	5	17	5	7	0	38
PF 06	14	18	6	7	2	6	8	6	9	<u>38</u>
			228	38	38	38	38	38	38	228

BRIDGES			PRIORITY	RANKING		
Statement #						
Asset						
Management	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>
AM 01	3	1				1
AM 02	1		2			
AM 03	4	1	3	1		1
AM 04	1					
AM 05	1			1		
AM 06	2				1	
AM 07	4	1	1	3	1	
Decks & Joints	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>
D&J 01	2	3	5	4	2	
D&J 02			1		1	1
D&J 03	1	2	1		1	1
D&J 04	1	2	1		2	
Superstructure	1	2	2	4	F	,
S	<u> </u>	<u>∠</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>0</u>
SP 01	1					1
SP 02						_
SP 03	3	1	1	1		2
SP 04	3		1	3	1	1
SP 05	1	4	4	3	1	2
	1	2	2	A	F	/
Substructures	<u> </u>	<u>∠</u>	<u>3</u>	<u>4</u>	<u>0</u>	<u>o</u>
SB 01	1		1	3	1	
SB 02		2	1	2	1	1
SB 03	1	1	1			1
SB 04		2		2	1	3
SB 05			1			3
	1	2	2	A	F	/
Selection	<u> </u>	<u>∠</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>0</u>
SE 01	2	3	5	2	6	4
SE 02		1	1	2	3	
	1	^	2	A	F	,
Performance	<u>1</u>	2	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>
PF 01	1	5		2	3	3
PF 02		3		1	4	7

BRIDGE PRESERVATION PRIORITY RANKINGS

			Tally Di	luge Fi	eseiva						
Bridge		Rating				R	ank				
Statement #	"A"	"B"	"C"	1	2	3	4	5	6	7	
Asset											
wanagement	11	10	11	4	2	0	0	7	-	5	່ວວ
AM 01	10	10		4	3	8	Ú	/	5	5	ວ∠ ວວ
AM 02	12	12	8	4	6	4	6	3	4	C 4	32
AM 03	1/	8	/	9	4	5	/	2	1	4	32
AM 04	8	9	15	1	4	4	3	3	8	9	32
AM 05	7	14	11	2	2	4	7	5	8	4	32
AM 06	5	19	8	3	4	2	7	6	6	4	32
AM 07	18	8	6	9	9	5	2	6	0		32
			224								224
Decks & Joints											
D&J 01	24	6	2	17	5	5	5				32
D&J 02	10	19	3	3	9	14	6	_			32
D&J 03	12	15	5	5	12	9	6	_			32
D&J 04	14	14	4	7	6	4	15				<u>32</u>
	14		128								128
Superstructure											
SP 01	5	17	10	1	2	6	17	6			32
SP 02	3	18	11	1	5	4	7	15			32
SP 03	17	10	5	9	11	6	3	3			32
SP 04	27	5	0	19	10	2	1	0			32
SP 05	7	19	6	2	4	14	3	9			<u>32</u>
			160								160
Substructures			_								
SB 01	14	16	2	10	15	3	3	1			32
SB 02	15	16	1	8	10	7	6	1			32
SB 03	3	20	9	1	1	13	8	9			32
SB 04	17	10	5	11	6	5	5	5			32
SB 05	5	14	13	2	0	4	10	16			<u>32</u>
			160								160
Selection			_			[
SE 01	18	11	3	21	11						32
SE 02	18	11	3	11	21						<u>32</u>
			64								64
Performance											
PF 01	23	5	4	20	12						32
PF 02	15	15	2	12	20						<u>32</u>
			64								64

Tally Bridge Preservation

APPENDIX E – TECHNICAL PANEL

Transportation System Preservation R&D Technical Panel

(B & P) = Bridge & Pavement Pavement Specialty

(B) = Bridge Specialty

(P) =

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DRAFT REPORT

A LITERATURE REVIEW OF RECENT PAVEMENT PRESERVATION RESEARCH

PRESERVATION RESEARCH ROADMAP

Prepared for: The Foundation for Pavement Preservation 8613 Cross Park Drive Austin, Texas 78754

Prepared by: The National Center for Pavement Preservation 2857 Jolly Road Okemos, Michigan 48864

For use by:

Engineering & Software Consultants, Inc. 21165 Whitfield Place, Suite 202 Sterling, VA 20165

&

Federal Highway Administration 1200 New Jersey Avenue, SE Washington, DC 20590

November 17, 2006

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ASSET MANAGEMENT	
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INTRODUCTION

The National Center for Pavement Preservation (NCPP) has been contracted by the Foundation for Pavement Preservation (FP²) to perform a literature search and review which would delineate and accurately characterize recent and on-going research related to pavement preservation. This work constitutes the initial phase of the FHWA-sponsored <u>Transportation</u> <u>Preservation Strategic Research and Development Road Map</u> project (DTFH61-05-D-00017), and is intended to provide the basis for the identification of research and development needs of stakeholder agencies and pavement practitioners.

OBJECTIVE

The goal of the literature search is to provide the foundation upon which general topic areas of pavement preservation research and development will be established. Proposed research topic areas will be subjected to critical review, and a subset selected for further exploration as white papers.

METHODOLOGY

The literature review made extensive use of previous, recent, and similar works by Peshkin and Hoerner (1), Gransberg and James (2), Lemer (3), and the FP² (4). On-line searches were performed at the Transportation Research Board (TRB) <u>Research in Progress</u> website (<u>http://rib.trb.org/</u>), the TRIS electronic library (<u>http://ntlsearch.bts.gov/tris/index.do</u>), the NCPP reference collection (<u>http://www.pavementpreservation.org</u>), and using various commercial search engines. The results of the literature review presented herein are not exhaustive, but do include representative and typical examples of recent preservation-related research efforts.

For clarity, information collected on recent and on-going research activities has been systematically classified according to one or more of the following eight (8) general topic categories:

- 1. Treatment performance;
- 2. Treatment timing;
- 3. Treatment selection;
- 4. Life-extending benefits;
- 5. Cost effectiveness;
- 6. Construction techniques / best practices;
- 7. Materials selection; and,
- 8. Specifications and warranties.

SUMMARY OF RECENT RESEARCH

Table 1 presents a summary of representative and recent preservation-related research which was gleaned from the literature. Each research source has been classified according to one or more of the topic categories referenced previously. An initial assessment of the collected literature shows that the bulk of the recently performed research has concentrated on the area of treatment performance and to a somewhat lesser degree, treatment selection.

Although warranty programs have been adopted to varying degrees by Michigan, California, and Arizona, little actual research was uncovered which would assess the effectiveness or benefits of such programs. Moreover, specifications research was generally found to take the form of what are essentially treatment performance characterizations, which were subsequently used to develop recommendations for specifications, rather than research on the effectiveness of existing specifications.

Research in the area of materials selection was comparatively scant. Indeed, Peshkin (2005) notes that mix design and materials selection are largely considered to be more of an art than science (1), and hence are difficult to quantify. Some literature was found which dealt with the evaluation of treatment performance with respect to specific product brands – usually crack or joint sealing / filling products.

Although "Best Practices" syntheses are fairly common for specific treatments such as chip seals, these studies typically consist of literature reviews of published agency and practitioner experiences, and rarely deal with innovative or experimental construction practices. Within this context, a number of agencies have developed experientially-based internal guidelines for the application of various surface treatments. However, research which correlates long-term treatment performance with construction methods is relatively scant.

Much of the published literature either draws upon the analysis of historical data such as that collected for inclusion in the Long-Term Pavement Performance (LTPP) database, or makes extensive use of "experience-based" (i.e., subjective and empirical) pavement performance results. Thus, much of the preservation-related research is arguably lacking in quantitative rigor (36), and results from different studies can sometimes appear contradictory. This is likely due in large part to the significant number of variable design and construction factors which are known or suspected to govern treatment performance outcome.

A preponderance of the recently published literature on preservation deals primarily with treatment applications designed for flexible pavements – chief among these being chip seals, HMA overlays, and crack sealing. Research in the area of rigid pavements has generally focused on the effectiveness, or lack thereof, of joint sealing, although some information was found pertaining to dowel-bar retrofits, diamond grinding, and the placement of asphalt overlays atop concrete pavements.

Start Year	Type(s)	Lead Agency or Researcher	Description	Source(s)
1997	T.S.	Iowa DOT	Guidelines for slurry seals, chip seals, and microsurfacing.	(1)
1999	T.S., L.E.	Michigan DOT	Guidelines for chip seals, microsurfacing, crack treatment, thin overlays, PCC treatments (FDR, spall repair, dowel bar retrofit).	(1)
1999	T.S.	Texas DOT	Microsurfacing guidelines.	(1)
2001	T.S.	Ohio DOT	Covers crack sealing, chip seals, microsurfacing, PCC restoration, thin inlays and overlays.	(1)
2004	T.S., C.E.	Wei and Tighe	Preventive maintenance decision trees based on cost-effective analysis for roadway network.	(5)
2005	T.S.	FP^2	Treatment selection matrix (pocket guide).	(6)
2003	T.S., T.P.	CALTRANS	MTAG treatment selection matrix based on roadway and environmental parameters includes relative performance.	(7)
2001	T.S.	New Mexico DOT	Treatment selection decision guidelines.	(1)
2003	T.S.	Zimmerman and Peshkin	Integration and tracking of preventive maintenance treatments with pavement management systems.	(8)
2004	T.S., C.E.	Arizona DOT	Study which was used to upgrade existing PMS so that cost effectiveness could be determined and used in preservation strategy development.	(1)
2002	T.S.	Smith and San Francisco MTC	Evaluation of PMS-preservation treatment integration techniques.	(9)
2002	T.S.	Zimmerman et al. and South Dakota DOT	Research on impact of maintenance activities on condition indices, appropriate trigger values, reset values, guidelines.	(10)
2002	T.S.	Washington State TRAC	Research on incorporating maintenance management into existing Washington DOT PMS.	(1)

Table 1: Representative Pavement Preservation Research

Start Year	Type(s)	Lead Agency or Researcher	Description	Source(s)
2002	T.T.	Arizona DOT	National study to research use of spray applied sealers, rejuvenators, and binders, with respect to proper timing.	(1)
2003	C.E.	Labi and Sinha	Study on cost-effectiveness of various maintenance strategies for different pavement types.	(11)
2004	T.P., C.E., T.T.	Colorado DOT	Development of procedures to show when and how to use various treatments based on performance, cost, and timing.	(1)
2003	M.S., SP.	CALTRANS	Multi-state research involving the evaluation of existing and new test methods, constructability indicators, etc. Development of guidelines and specifications. Includes two pilot projects. Includes slurry seal / microsurfacing.	(1)
2003	M.S., SP.	North Carolina DOT	Research aimed at evaluating currently utilized mixture characteristics of surface treatments, particularly with respect to aggregate gradations. One goal is to modify existing specs.	(1)
2003	M.S.	Oklahoma DOT	Identification of materials and procedures which can be used to repair PCC pavements and bridges.	(1)
1998	T.P.	Morian et al. and FHWA	Included the analysis of LTPP data after 5 years of services. Treatments examined included crack sealants, chip seals, slurry seals, and thin HMA overlays.	(12)
1999	T.P.	Eltahan et al.	Analysis of LTPP SPS-3 data collected in the Southern Region which focused on life expectancy and the affects of original pavement condition. Examined crack sealing, chip seals, slurry seals, and thin HMA overlays.	(13)
2002	T.P.	Hall et al.	NCHRP project which analyzed all available SPS-3 data to date to assess the effectiveness of crack sealing, slurry seals, chip seals, and thin HMA overlays, and the influence of these treatments on IRI, rutting and fatigue cracking.	(14)
2003	T.P.	Chen et al. and Texas DOT	Analysis of data collected from 14 Texas-based SPS-3 sites to investigate the effectiveness of chip seals, crack seals, slurry seals, and thin HMA overlays. Performance was measured with respect to the Texas DOT distress rating system.	(15)

Start Year	Type(s)	Lead Agency or Researcher	Description	Source(s)
1999	T.P.	Smith and Romine	Extensive long-term research project dealing with crack sealing and filling techniques. Performance evaluated with respect to climate, traffic, pavement type, and crack spacing	(16)
1996	Т.Р., С.Е.	Ponniah and Kennepohl	Ontario's experience with crack sealing and flexible pavements includes assessment of cost-effectiveness.	(17)
1999	T.P.	Michigan DOT	Evaluation of Michigan's Capital Preventive Maintenance Program, including crack sealing, chip seal, microsurfacing, and thin HMA overlays.	(18)
2001	T.P.	Colorado DOT	Evaluation of three chip seal test sections in Colorado, which included examination of a standard chip seal, chip seal with fog seal, and a lightweight chip seal.	(19)
2001	T.P.	Wade et al. and South Dakota DOT	Evaluation of chip seals and sand seals on high volume / high speed roadways.	(20)
1997	T.P.	Center for Transportation Research & Education	On-going Iowa study designed to develop guidelines for thin maintenance surfaces (chip seals, slurry seals, and microsurfacing).	(21)
2001	T.P.	Hanson	Evaluates the performance of thin bonded HMA overlays, correlating with the materials and construction procedures used.	(22)
2003	T.P., C.E.	Washington DOT	Evaluation of Novachip constructability, performance, and cost effectiveness for use on low volume roads in Washington state.	(23)
2000	T.P.	Texas DOT	On-going research project geared toward documenting the performance and cost-effectiveness of cold-pour emulsion crack sealants in comparison to hot-poured sealants.	(1)
2005	T.P.	AASHTO and NCPP	Evaluation of flexible and rigid pavement crack and joint sealant performance from test sections constructed in each of the AASHTO environmental climate zones.	(1)
1997	C.E.	Arizona DOT	Long-term, on-going study to examine the cost-effectiveness of maintenance treatments, including sealers and rejuvenators.	(1)
2002	T.P.	University of Utah and Utah DOT	Performance and life of seal coats, particularly chip seals.	(1)

Start Year	Type(s)	Lead Agency or Researcher	Description	Source(s)
2006	T.P.	Maine DOT	Evaluation of the performance of two microsurfacing test projects.	(1)
2003	T.P., C.E.	North Dakota DOT	Evaluating the performance and cost-effectiveness of microsurfacing when used to fill ruts and depressed transverse cracks. Includes test section which uses an overlay for comparison.	(1)
1991	T.P.	Evans et al.	Long-term, nationwide study (SHRP H-106) which evaluated joint and crack sealing materials placed in different joint configurations, for rigid pavements.	(24)
1991	T.P.	Smith et al.	The effectiveness of joint sealing and resealing in PCC, from data collected as part of LTPP SPS-4.	(25)
2003	T.P.	Minnesota DOT	Investigation into the effectiveness of longitudinal edge joint sealing on PCC pavements in Minnesota, and its ability to reduce the ability of water to enter the pavement system.	(26)
1997	T.P.	Shober	Evaluation of the influence of crack and joint sealing on PCC pavement performance in Wisconsin.	(27)
2000	T.P., C.E.	Hand et al.	Synthesis of research performed since the late 1980's on the performance and cost-effectiveness of crack and joint sealing in both flexible and rigid pavements.	(28)
2001	T.P., C.E.	WA, CA, MN, and TX DOT's	Multi-state study into constructability, life, performance, and cost effectiveness of dowel-bar retrofit techniques.	(29)
1999	T.P., L.E.	Rao et al.	National study which examined the performance and life extending benefits of diamond grinding conducted at 60 test sections completed in 18 states, previous data collected from 133 other test sections, and SPS-6 data.	(30)
1997	T.P.	Missouri DOT	Research covering the use of diamond grinding on new PCC pavements, and its affects on long-term performance.	(31)
2000	T.P.	Missouri DOT	Evaluates the effectiveness of using undersealing and diamond grinding in combination.	(32)
2002	SP.	Arizona DOT	On-going research project which is evaluating the use of warranties on chip seal projects.	(1)

Start Year	Type(s)	Lead Agency or Researcher	Description	Source(s)
2006	B.P, SP.	NCHRP and Colorado State University	Identification of factors influencing emulsion chip seal design and construction through the synthesis of existing research. Includes development of guidance manual and specs.	(33)
2005	B.P., T.P.	Gransberg and James, and NCHRP	Research consisting of an extensive literature review and agency / practitioner survey to develop chip seal best practices, and appropriate performance measures.	(2)
2004	T.P.	Lemer and NCHRP	Synthesis of literature and agency / practitioner surveys to characterize the benefits of preventive maintenance.	(3)
2001	T.P., T.S., C.E., SP., M.S., T.T.	FP ² and FHWA	Problem statements developed from the 2001 Workshop held in Sacramento, CA, covering various aspects of pavement preservation treatments and preventive maintenance.	(4)
2006	B.P.	Gransberg	Correlates chip seal performance ratings with construction practices to develop a slate of best practice guidelines.	(34)
2006	T.P.	Lee et al.	Research presents a new testing protocol to evaluate the performance of bituminous surface treatments using the third-scale Model Mobile Loading Simulator.	(35)
2005	B.P., C.E.	Montana DOT	On-going study designed to synthesize information on the state of the practice in pavement preservation with respect to treatment selection and performance, and cost effectiveness	(36)
2004	T.P., C.E., M.S.	Montana DOT	Crack sealant performance and cost-effectiveness in Montana.	(37)
2004	T.P., T.T., C.E.	Colorado DOT	On-going evaluation of surface treatments over time under varying environmental conditions. The goal is to produce guidelines for applying preventive maintenance treatments.	(38)
2002	T.P.	Ohio DOT	On-going evaluation of the effectiveness of thin HMA overlays on improving ride and condition performance.	(39)
1993	C.E.	SHRP	Study in-progress which is utilizing literature and on-going research to examine the cost-effectiveness of various preventive maintenance treatments.	(40)

Start Year	Type(s)	Lead Agency or Researcher	Description	Source(s)			
2006	T.P.	North Carolina DOT	On-going research into the performance of polymer-modified emulsions used in asphalt surface treatments.	(41)			
2001	T.P.	Nevada DOT	In-progress study examining the performance of crack sealants, including crack propagation, bumps caused by crack sealants beneath overlays, and the safety of hot-applied products.	(42)			
2005	C.E.	Labi and Sinha	Examines the cost-effectiveness of life-cycle preventive maintenance for various bituminous pavement types.	(43)			
2004	L.E.	Bausano et al.	Life extending benefits of preventive maintenance treatments.	(44)			
2004	T.T.	Peshkin et al.	Methodology for determining the optimal timing of preventive maintenance treatments to both flexible and rigid pavements.	(45)			
2003	T.T., T.S., C.E.	Zimmerman and Peshkin	Integrating preventive maintenance activities into a PMS to improve project selection and cost efficiency.	(46)			
2004	T.P., T.S.	Lee et al.	Investigation of relationship between roughness and distress to aid in selecting preventive maintenance smoothing treatment.	(47)			
<u>Research</u> B.P. – Be	<u>Research Type Key:</u> T.S. – Treatment Selection; T.P. – Treatment Performance; T.T. – Treatment Timing; SP. – Specifications; B.P. – Best Practices; C.E. – Cost Effectiveness; M.S. – Material Selection; L.E. – Life Extension.						

PRESERVATION RESEARCH NEEDS

The discussion of preservation research needs contained herein has been formulated using a combination of the data gaps identified in the existing literature, coupled with recommendations for future work contained within these references. The goal of this discussion is to better define major areas of future research which are recommended for more in-depth investigation via the development of appropriate white papers. Once developed, these white papers will form the basis of discussions during two future practitioner workshops, from which detailed problem statements will ultimately be developed.

Peshkin and Hoerner (2005) have categorized the research needs identified in their study as follows:

- Materials selection and mix design;
- Selection of treatments and treatment strategies;
- Construction;
- Treatment performance;
- Specifications; and,
- Policies and training (1).

Peshkin generally defines a "research need" as existing where significant gaps are evident between the research needs identified by their practitioner survey, and the focus of past and ongoing research delineated during their literature review. Additionally, Peshkin has provided a priority ranking for each identified research need (i.e., low, medium, or high) using a combination of survey respondent rankings and the authors' own subjective evaluation (1). A brief discussion is provided in the following subsections for the highest ranking needs identified by Peshkin. The current literature review employs a modified version of the Peshkin study's "needs" list and consists of the following:

- Materials (selection and mix design);
- Design (treatment selection, timing);
- Construction (innovative methods, QA/QC, best practices);
- Treatment Performance (including life extension, cost-effectiveness);
- Contracting Methods (specifications, warranties, selection);
- Asset Management (PMS integration); and
- Policies, training and public relations.

For convenience, clarity, and consistency, topics and ranking discussions have been subdivided according to each of the categories presented above.

<u>Materials</u>

Peshkin has identified three primary topic areas of interest with respect to materials selection and mix design procedures:

1. Documenting the effectiveness of crack and joint sealing materials;

- 2. Improving mix design methods for thin surface treatments; and
- 3. Developing best practices for the use of PCC materials in preventive maintenance (1).

Of these three topics, Peshkin ranks the second as being a "medium" priority need, while rating the first and third as "low". In general, Peshkin notes that practitioners have indicated very little interest in PCC materials research, preferring instead to focus on processes related to the application of thin surface treatments on bituminous pavements (1). Moreover, although the Peshkin study indicates that a strong interest remains in the evaluation of crack and joint sealants, the current literature review finds a sizable number of completed and on-going studies in this area, which may suggest that interest may soon diminish as the results of recent research are compiled and become widely disseminated.

Although not addressed by the Peshkin study, on-going work at the NCPP on behalf of FHWA Federal Lands Highway Division (FLHD) indicates emerging interest concerning the use of polymer modifiers in asphalt emulsions (48). Indeed, the recently completed NCPP literature survey and initial industry peer review have revealed a sizable research gap with respect to the cost-benefit, applications, and specification of polymer modifiers. Moreover, the NCPP study has found that there is currently very little consensus on either appropriate performance testing protocols, or, the most representative method of asphalt residue extraction (48). During the current literature review, comparatively few examples of recent research were identified with respect to polymer modified emulsions, although work on polymer modified binders was considerably more plentiful.

<u>Design</u>

The Peshkin study finds that research covering the selection of preservation treatments, treatment timing, and related economic cost-benefits (i.e., design), garner the greatest interest among pavement practitioners and stakeholder agencies. Highway agencies in Arizona, California, Kansas, Iowa, Maryland, Michigan, Montana, Ohio, South Dakota, Texas, and Washington State have all engaged in recent research to develop methodologies to select appropriate preservation treatments (1). Several of these agency studies have also attempted to find the best means to integrate preventive maintenance treatment tracking into their pavement management systems. Other recent studies have focused on the creation of treatment selection algorithms, such as decision trees or matrices.

Specific topic areas meriting a high priority ranking which were highlighted by the Peshkin study include the following:

- 1. Enhancement or development of treatment selection guidelines;
- 2. Optimal timing of preservation treatments;
- 3. Economic benefits of preservation treatments; and
- 4. Integration of preventive maintenance into existing PMS's (1).

With respect to the fourth topic area, the current literature review treats the matter of PMSpreservation treatment integration as an asset management issue which is addressed separately and presented later in this document. Although there has been significant research conducted in the area of treatment selection, established guidelines have been found to vary widely. This has lead to some confusion within state agencies on the best selection methodology to use. Thus, Peshkin advises that research in this area should focus on the advantages and disadvantages of the various treatment selection methods. Evidence gathered from the current literature review further indicates that research into treatment selection methods should also consider the impacts of environmental factors, traffic volumes, and motorist delays.

Peshkin finds that about half of the survey respondents in that study indicated that they are not currently optimizing the timing of preservation treatments – often opting for a reactive rather than proactive approach. Similarly, on-going reviews of state pavement preservation programs also indicate that a majority of the 20 agencies appraised thus far currently utilize a "worst-first" approach (49). In this regard, agencies are particularly interested in tools that can assist them in determining the optimal timing for preventive maintenance treatments, as well as aiding with project selection.

Many stakeholder agencies report considerable difficulties in justifying pavement preservation to their state legislatures and public stakeholders (1) (49). The primary source of this problem is a general lack of data which clearly show the economic advantages of the preventive maintenance philosophy. Lacking proof of the demonstrable economic benefits of preservation, many pavement practitioners find that convincing the general public and upper management that preservation treatments should be applied to pavements in good condition is an uphill battle. As a result, preventive treatments are often applied in a reactive fashion to roads which are in poor condition. This translates into poor treatment performance, and reinforces the notion that preservation is an ineffective technique. For this reason, future research into this topic area is ranked as a high priority.

Construction and Best Practices

The Peshkin study highlights three principal topic areas related to preservation treatment construction:

- 1. Construction factors affecting treatment performance;
- 2. Innovative treatment construction techniques; and
- 3. Development of best practices manuals (1).

Peshkin ranks the first two topic areas as low priorities, and the third as medium. While Peshkin opines that future interest in new construction practices appears significant, the authors conclude that current priorities among practitioners are comparatively low. However, work by Gransberg and James (2005) concludes for example, that significant research is needed in the area of chip seal design and construction methods (2). Moreover, the 2001 <u>Research Problem Statement</u> <u>Workshop</u> identified several research needs in the area of construction, including QA/QC practices, standardized field sampling methods, and construction training and certification (4). Similarly, other work by Gransberg (34), Gransberg and James (2), and Cuelho (36) underscores

the importance and value of establishing correlations between long-term treatment performance and the construction methods used.

It is well-accepted among pavement practitioners that one of the leading causes of premature failure in thin surface treatments is improper construction. Indeed, this fact is the driving force behind current efforts in the public and private sectors to introduce some form of preservation contractor certification and training (4). Thus, it would appear that while some stakeholder agencies may not see the immediate need for research, future attention to the validation and development of treatment construction practices and training should receive a much higher priority than they have to date. Proper construction represents the cornerstone of a successful preventive maintenance treatment, and such success is essential in achieving greater acceptance and support for the preservation philosophy. Therefore, it is recommended that a high priority be assigned to conducting construction-related research, particularly in the areas of correlating construction practices with performance, and in the synthesis of best practices. However, because many U.S. practitioners have yet to fully assimilate existing proven construction techniques; and because a significant body of successful practices already exists in countries such as New Zealand, Australia, and the U.K (2).; it is suggested that research on new and innovative construction methods should merit a much lower priority.

Treatment Performance

As Table 1 illustrates, there is a considerable body of recent research in the area of preservation treatment performance. The survey and literature review performed by Peshkin are in general agreement with this observation, and it has been further noted that the effect of preventive maintenance treatments on pavement performance garners the highest ranking of all the research topics examined (1). Moreover, the Peshkin study reveals that roughly half of the agencies surveyed do not currently track the performance of preventive maintenance treatments. However, on-going work being conducted by the NCPP estimates that this percentage may actually be significantly higher (49).

Peshkin notes that while several responding agencies reported failures with specific preventive treatments, only one agency reported that these failures were due to poor project selection (1). Yet paradoxically, approximately 65% of the Peshkin survey respondents also reported applying preservation treatments to pavements in fair, poor, or very poor condition (1) - a fact which appears to belie the suggestion that treatment failure is generally not due to poor project selection.

The Peshkin study has identified the following five (5) primary topic areas under the category of treatment performance research:

- 1. Construction and monitoring of treatment test sections;
- 2. Tools to measure pavement and treatment performance;
- 3. The impact of treatments on functional performance parameters such as noise, ride, and friction;
- 4. Treatment impact on pavement performance; and
- 5. Appropriate treatment performance measures (1).

Peshkin rates all of the topic areas above as having a high priority, with the exception of the third which the authors rate as medium.

While several studies were found during the current and Peshkin literature reviews which focused on the longevity of preservation treatments, few were located which dealt with the impact on overall pavement performance measures such as extended service life. Because quantification of extended pavement service life is essential in assessing cost-effectiveness and performance, this topic should be given a high priority. In addition, since the magnitude of service life extension is highly dependent upon the condition of the underlying pavement to which a preservation treatment is applied, it is recommended that the impacts of treatment timing on performance also be integrated into these studies.

Peshkin notes that because preservation treatments are often applied to pavements with varying degrees of functional problems, research into the ability of these treatments to correct functional deficiencies should receive at least medium priority (1). Such work would be productive in identifying the benefits and limitations of various preservation treatments, and would also provide insight into issues related to treatment timing and project selection.

Research is also needed to establish representative performance criteria for preventive maintenance treatments such as pavement deterioration rate, reducing water infiltration, crack mitigation, etc. (i.e., other than functional characteristics). Peshkin recommends this topic be assigned a high priority.

Finally, because the construction and monitoring of pavement test sections represents perhaps the best known and most widely accepted method for assessing field treatment performance, it is recommended that future studies emphasize its use. In this regard, Peshkin recommends that much of this work be performed at the local level by agencies which do not have much experience with pavement preservation (1). The advantage in such an approach is that the potential effectiveness of certain treatments, when applied in a given area, can perhaps be more accurately gauged when using local material and contracting sources under a characteristic set of environmental and traffic conditions. The disadvantage is that the extrapolation of very localized studies to other geographical areas may prove problematic or impractical. In addition, local research efforts may not possess the financial resources to construct a sufficient number of test sections needed to engender widespread confidence in the accuracy and representativeness of the results. Thus, it is further suggested that pavement test section construction and monitoring programs should be coordinated to the extent practical, on a national and/or regional level.

Contracting Methods

Very few literature sources were identified during the current study which pertained to the development or evaluation of treatment specifications. No references were identified which evaluated the effectiveness of warranty polices. Results of the Peshkin survey further indicate a comparatively low interest in contracting methods research among practitioners, although several agencies did indicate that their specifications require improvement, and a few others expressed some interest in warranties (1). On-going work by the NCPP suggests that existing specifications covering the use of polymer-modified emulsions are generally inadequate, in that they typically fail to define or capture optimal performance or best practices for the treatments which utilize them (48). The NCPP has also found that considerable uncertainty exists as to the best way to specify, test, and ensure the quality of polymerized emulsion, and that there is a widespread sentiment that performance-based specifications are needed. Similarly, work by Gransberg and James indicates a need for the development of performance and end-product specifications to improve the quality of chip seals (2). Others have recommended the broad development of performance and warranty specifications to cover a variety of treatment applications (4).

Paradoxically, Peshkin states that very little interest was identified among highway agencies in moving from method specifications to either performance specifications or warranties for preservation treatments (1). Yet a number of recent best practices syntheses stress the important role of performance-based specifications in successful preventive maintenance programs (2) (4) (50). Moreover, method-based specifications may stifle innovation, and have the additional effect of shifting the burden for a treatment's success from the contractor to the owner agency. Given these factors, it is recommended that research on treatment-targeted performance-related specifications (PRS) be given a medium to high priority.

<u>Asset Management</u>

Peshkin observes that the integration of preservation into pavement management touches issues ranging from treatment timing and selection, to the evaluation of cost-effectiveness and extended service life (1). Recently conducted appraisals of the pavement preservation programs of 20 state highway agencies by the NCPP, clearly indicate that few have made little more than the most rudimentary efforts to track preservation treatment performance in their pavement management systems (49). Without effective PMS tracking of preventive maintenance treatments, it is not practical to determine their life-extending benefits or cost-benefit performance. Thus, this topic merits a high priority for future research, particularly since the experientially-derived data which would be derived from this practice would provide a solid basis for justifying the expansion of preservation programs to state legislators and agency upper management.

Policies, Training and Public Relations

The practitioner survey conducted by Peshkin and Hoerner (1), work by Gransberg and James (2), Lemer (4), and the pavement preservation appraisals conducted by the NCPP (49) have all revealed a number of key issues related to agency policy and public relations:

• Justification of the benefits and cost-effectiveness of preservation to elected officials, agency management, and the general public;

- Agency structural issues related to establishing a formal preservation policy, a working and effective definition of preservation and preservation treatments, a dedicated preservation budget, and the designation of a preservation champion;
- Dealing with the obstacles to preservation as well as the negative pressures exerted by industry, trade groups, and public perceptions;
- Establishing a mechanism through which the benefits of preservation can be communicated to the community via the media.

Similarly, several issues were identified which relate to agency and industry training needs, including:

- The need for a formal contractor certification program;
- Training of agency technicians and inspectors;
- Education related to the basics of preservation and the types of treatments;
- Preservation strategy and project selection;
- Design and construction of preventive maintenance treatments;
- Disseminating best practices to facilitate implementation.

While the development of methods to deal with public relations issues cannot readily be defined as "research" per se, it does represent an important outcome or end-product of a productive preservation research program. For instance, by integrating preservation with pavement management, agencies can begin to track the cost effectives and life extending benefits of treatments, and these data can then be used to justify and promote expanded preservation programs to decision makers. Conversely, the establishment of a clear preservation policy and the training of maintenance forces are necessary preliminary steps in ensuring the implementation of a successful preventive maintenance program.

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APPENDIX G – WORKSHOP ATTENDANCE LISTS

G-1 PHOENIX, AZ, FEBRUARY 4 – 6, 2007 PAVEMENT PRESERVATION NEEDS

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Church	Wes		95 West 1100 North	North Salt Lake City	UT	84054- 2624	801-397-7600	wchurch@semgrou plp.com	SemMaterials
Connor	Billy	Director, Alaska University Transportation Center	Arctic Engineering Research Center, Room 234A Duckering, PO Box 755900	Fairbanks	AK	99709- 5399	907-474-5552	ffbgc@uaf.edu	University of Alaska at Fairbanks
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Eller	Gerry	Executive Director	8613 Cross Park Drive	Austin	ТХ	78754	1-866-862-4587	fppexdir@aol.com	Foundation for Pavement Preservation
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Peshkin	David	Vice President	Executive Towers West III, 1400 Opus Pl, Suite 905	Downers Grove	IL	60515	217.398.3977	dpeshkin@pavemen tsolutins.com	Applied Pavement Technology, Inc.
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G-2 ORLANDO, FL, FEBRUARY 24 – 26, 2007 PAVEMENT PRESERVATION NEEDS

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Birdsall	Rod	Market Development	3900 Forest Glen Blvd #101	Naples	FL	34114- 3580	413-687-2208	rbirdsall@allstatesasphalt.c om	All States Asphalt
Buckingham	Michael	President	1595 Frank Road	Columbus	ОН	43223	614-276-5501	mikeb@strawserinc.com	Strawser Incorporated
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Denehy	Edward	Civil Engineer	Transportation Maintenance Division	Albany	NY	12232- 0337	518-457-6914	edenehy@dot.state.ny.us	New York State Department of Transportation
Dickerson	Candace	Conference Coordinator	21165 Whitfield Place, Suite 202	Sterling	VA	20165	703-421-3020	cdickerson@escinconline.c om	Engineering & Software Consultants, Inc.
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Estakhri	Cindy	Associate Research Engineer	Texas Transportation Institute, Texas A&M, TAMU 3135	College Station	TX	77843- 3135	979-845-9551	c-estakhri@tamu.edu	Texas Transportation Institute
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Shatnawi	Shakir		1120 N Street, Mail Stop 31	Sacramento	CA	95814	916-227-5706	shakir_Shatnawi@dot.ca.g ov	California Department of Transportation
Shields	Todd	Pavement Preservation Engineer	IN DOT, 100 N Senate Ave, N901	Indianapolis	IN	46204	317-233-3345	tshields@indot.in.gov	IN DOT, Division of Highway Operations, Office of Traffic Engineering
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Last Name	First Name	Title	Street Address	City	State	Zip	Phone	Email	Affiliation
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Testa	Dean		3610 SE 28 th Street	Topeka	KS	66605	785-220-7679	dean@ksdot.org	Applied Pavement Technology, Inc.
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Watson	Dennis	Manager, Asset Management	12th Floor, 215 Garry St.	Winnipeg	MB	R3C3 Z1	204-945-5173	dennis.watson@gov.mb.ca	Manitoba Transportation
Wood	Tom	Engineering Specialist	1400 Gervais Ave.	Maplewood	MN	55109	651-366-5573	thomas.wood@dot.state.m n.us	Minnesota Department of Transportation
Yildirim	Yetkin	Director	The University of Texas at Austin, Dept. of Civil Engineering	Austin	ТХ	78712	512-232-1845	yetkin@mail.utexas.edu	Texas Pavement Preservaton Center, The University of Texas at Austin
Zhou	Haiping	Principal Engineer	4704 Roseville Road, Suite 108	North Highlands	CA	95660	916-332-5552, ext. 227	hzhou@mactec.com	MACTEC

G-3 ARLINGTON, TX, MAY 22 – 23, 2007 BRIDGE PRESERVATION NEEDS

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APPENDIX H – PAVEMENT PRESERVATION WHITE PAPERS

H-1 ASSET MANAGEMENT AND PRESERVATION

Mr. John O'Doherty National Center for Pavement Preservation

Mr. Larry Galehouse National Center for Pavement Preservation

1.0 Introduction

Private companies view their instruments of production—that is, manufacturing and distribution facilities--as depreciable assets. As facilities are used in production, they gradually lose their value. Losses of value are reported as depreciation costs on companies' balance sheets, ending only when residual values reach zero. When they perceive inefficiencies, companies usually pinpoint the problem and find ways to improve. In the past, road agencies generally did not view roads, bridges, and related appurtenances as assets in the business sense and did not generate the information necessary to evaluate the development of infrastructure asset value. Today, road agencies are coming to realize the advantages of managing assets and modifying their operations accordingly.

As they begin to make their transition to a more formal model of asset management, agencies are realizing the difficulties of adapting private enterprise models to the public sector. This is particularly true when attempting to optimize operations in a public setting because of the myriad constraints (political and other) and ambiguities associated with defining objectives.

Consequently, agencies have tended to concentrate on physical conditions, when economics and cost-effectiveness must also be considered.

2.0 Summary of Current Practice

Highway engineers and other technical professionals with backgrounds and training in materials, design, construction, maintenance, etc., have tended to see the highway infrastructure as a series of independent physical links, each of which must be designed, constructed, and maintained as physical conditions and resources permit. In contrast, planners and economists are less concerned with individual segments and tend to focus on aggregations of segments functioning as a network. Moreover, their interest in the network is long term, extending over multiple budgetary periods.

When dealing with budgets, agency officials tend to rely heavily on past experience, partly because they have difficulty in accurately calculating budgetary needs and also due to the uncertainty associated with budgeting in the public sector political environment. Faced with such constraints, agency officials often make the safe political decision of fixing the worst facilities until their scarce resources are exhausted. Thus, they tend to focus on the present and

deal with their networks at the project level. Unspent budgets would be lost, so there is an incentive to "spend it all!"

Modern management theory has shown that highly complex operations such as geographically dispersed highway agencies can be managed most cost-effectively and rationally at the network level using a horizon of multiple time periods. Indeed, powerful long-term asset management tools, including true optimization techniques exist at the network level. Unfortunately, few agencies are aware of or willing to use these tools. This lack of use is not caused by inadequate research.

In managing their roads at the project level, agencies face two sets of imponderables, viz., when to undertake physical corrections based on physical or engineering criteria, and what thresholds to adopt based on public acceptability. How good is good?

3.0 Key Challenges

Key challenges exist at both the highway project and network levels. Some of these challenges involve bringing existing tools to the attention of agency managements and convincing them of the advantages of using them. There are many existing management systems available for agencies' use, and information from these systems can be linked to allow for trade-off analyses and better decision-making. It is important that agencies ensure that the right data necessary for engineering and economic analysis are collected accurately. These challenges can be solved without additional research.

Other challenges involve extending the state of the art in areas of uncertainty and these challenges would benefit from additional research. Some of these unknowns are at the project level while others are at the network level or both levels.

While the conventional wisdom indicates that preservation treatments and programs are beneficial, little hard quantitative conclusions are available in this area. What are the economic benefits and cost-effectiveness of such treatments and programs? Should user costs be considered in such calculations? These questions are applicable at both consideration levels.

At the project level, little definitive understanding of the benefits and costs of individual preservation treatments is known. Many variables affect this outcome, particularly design, materials, workmanship, traffic, and climate. Moreover, few agencies have collected sufficient longevity and cost information to constitute adequate databases for use with modern Pavement Management Systems (PMSs). The common currencies of PMSs are asset condition indicators such as Remaining Service Life (RSL). But even here, there is a need for clarification. It is possible to distinguish between a physical RSL and an economic RSL. Engineers tend to think of RSL as an indicator of a pavements remaining physical life, whereas planners would think of remaining economic life. What is the relationship between these alternative indicators? Are they equivalent? If not, what are the differences? When does an asset's RSL reach zero? The generally accepted answer is when the asset's replacement / reconstruction is the only

economically feasible alternative. What would be the appropriate technique to determine this point in time? Can we improve the way we calculate RSL¹?

At the network level, agency managers are faced with the daunting challenge of allocating their scarce resources between pavements, bridges, and other associated appurtenances such as traffic control devices, drainage structures, etc. They typically solve this problem by relying on past experience to guide their initial allocations and being prepared to re-allocate resources should the need arise. This problem could be greatly alleviated by harmonizing common denominators and asset condition indicators of Bridge Management Systems (BMSs) such as AASHTO's Pontis, and PMSs. Such a harmonization would render the problem amenable to a technically efficient solution using well established operations research (OR) techniques².

An additional challenge may be found in the application of tried and proven OR techniques to optimize the management of highway networks. While many agencies already have substantial quantities of network data and sophisticated PMSs (with OR capabilities) are available, there is still a policy gap resulting from a failure to fully utilize these capabilities.

4.0 Conclusions and Recommendations

Contacts with state and other highway agencies indicate that few departments have fully implemented, comprehensive asset management systems. Many agencies are very interested in the area and would welcome assistance in starting / improving their systems.

Transportation asset management is practiced widely in Australia, New Zealand, and the United Kingdom. In New Zealand, the National Asset Management Steering (NAMS) Group has created a manual titled "*International Infrastructure Management*", which has become an industry standard in New Zealand and Australia.

We recommend that, with the concurrence / cooperation of NAMS, a research project be initiated to adapt the manual to U.S. conditions and offer it to highway agencies to assist them in their asset management efforts.

We further recommend that, in view of the highway system's vital importance to the nation's economy, security, and quality of life, the federal role in encouraging and facilitating asset management be reinforced and continued.

At the network level, we recommend that research be undertaken in the following two areas:

¹ In practice, most agencies do not use RSL as an indicator but instead, rely on Pavement Serviceability Ratings (PSRs) or the International Roughness Index (IRI). Since physical RSL and economic RSL are not necessarily equivalent, agencies find it more politically expedient to work with policy threshold PSR / IRI levels. In most states, the problem of choosing capital projects is complicated by the existence of other decision variables, some of which outweigh pavement condition. Accordingly, in these cases, the recommendation of a PMS merely determines a candidate roadway's eligibility for evaluation of these other factors which dictate a program's final composition.

² While many State DOT's are competent in OR techniques, their practical application is constrained by the need to substantially improve data collection and adjust inter-program priorities.

- 1. Investigate the feasibility of harmonizing common denominators and asset condition indicators to optimize resource allocation.
- 2. Establish standardized linkages between collected network data such as performance, condition, cost, etc., and the mathematical formulations of OR algorithms that could be used to optimize network management.

There are several other more detailed areas where research could be useful to assist asset management practitioners. More understanding is needed in the area of RSL and other asset condition indicators. More accuracy is needed in the calculation of these indicators because decisions involving the allocation of vast resources will come to depend on them. Unanswered questions include the relationships between present policy variables and the results of economic analysis. It would also be highly desirable to be able to link asset physical condition to economic replacement thresholds and levels of cost-effectiveness.

We further recommend research to establish multi-regional baselines through economic analysis. These baselines would be very useful to agencies starting or improving their asset management programs.

Finally, research would be useful in the area of budget allocation, particularly innovative adjustments that could encourage preservation.

References

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H-2 DESIGN OF PAVEMENT PRESERVATION ACTIVITIES/PROJECTS

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1.0 Introduction

An important part of a successful pavement preservation program includes design considerations for pavement preservation projects. The key issue is placing "the right treatment on the right road and the right time". Pavement preservation needs to be applied on good pavements or on pavements with only minor distress. Pavement Preservation treatments do not increase the structural capacity of the pavement. There may be cases when the pavement condition is too good or too bad for pavement preservation or may have structural or drainage deficiencies. The design considerations of a preservation program can include many factors, but the most important include the following:

- Strategy selection- it is important that a process be in-place to determine which treatment should be placed on a given pavement. Several factors can affect this decision:
 - Roadway conditions-this includes the types and amount of distress as an indicator of structural support issues and the trigger values used to select an appropriate treatment. Pavement preservation treatment life is greatly influenced by the condition of the pavement on which the treatment is placed. Other factors to consider in the selection process include ride, skid, and noise issues, but these issues are covered in another paper on surface conditions. Pavement preservation is not appropriate for all pavements. For example, poor drainage can contribute to certain distress types inappropriate for pavement preservation treatments.
 - Types and level of traffic-This will have an impact on the type of treatment to be used. Some treatments may not be suited for urban areas or high volume roads. Consideration should also be given to future traffic levels or potential functional changes of the roadway.
 - Climatic factors-different treatments may not be appropriate in certain climatic conditions. Also the adequacy of the pavement's drainage system could play a role in the selection of the treatment.
 - Constructability issues- quality of contractors and nighttime construction can also influence the selection of the treatment. The windows of opportunity are becoming shorter and shorter particularly in urban and environmentally sensitive areas.
 - Treatment costs- the cost of treatments will vary considerably and can influence the final selection.

- Funding issues- dedicated funding is needed to have a successful pavement preservation program. Without adequate funding, the treatments are often not placed at the right time. Though this may not specifically be part of the design process, it can affect the selection of strategies.
- Cost analysis- once potential treatments have been identified, it is necessary to analyze and evaluate the economics of the feasible options and compare them with the do nothing or rehabilitation options. They should be compared in terms of agency and user costs and extended life resulting from the treatment. A life cycle cost analysis (LCCA) procedure tailored to pavement preservation for comparing various preservation and rehabilitation alternatives should be conducted to evaluate the best strategies for keeping the road in good condition for its design life while minimizing the impact to its users.
- Treatment timing- part of the design process is to incorporate strategies at various intervals in the expected life of the pavement. An important consideration is to determine the optimum timing for each of the pavement preservation treatments used by an agency. To determine the optimal timing, performance standards for various treatments need to be established, and to be reliable these need to be representative of the environment in which the treatments are to be used. Collecting the right data at a reasonable cycle is crucial to the success of this effort. Timing will be influenced by the existing pavement conditions, climatic factors, materials properties, and traffic loading as well as agency resources and funding limitations.

Other design issues such as mix design, performance related testing, and materials design are covered in other papers.

2.0 Background

Why is this area important?

It is important to have a process for selecting the most appropriate pavement preservation treatments for a given project. The steps in any process should include the following;

- Assessing the existing roadway conditions-this includes evaluating the level of pavement distress and other surface conditions, the traffic, drainage, and climatic conditions. All of these factors can influence the treatment to be used.
- Determine feasible options- the feasibility is determined by the treatment's ability to address the functional (ride, skid) and surface condition (type and extent of distress) of the pavement. Pavement preservation treatments by definition will not impart a structural improvement to the pavement, but they will delay the structural degradation of the pavement by sealing water from the underlying structure. At this stage, the purpose is to determine what treatments might work for a given situation. Availability of quality contractors and materials for each feasible treatment should also be considered at this time. If quality contractors or materials are not available for a given treatment, the treatment should probably not be used. The risk of early failure is just too great.
- Analyze and compare the feasible options- these should be compared in terms of life extension of the existing pavement resulting from the pavement preservation treatment. A

life cycle cost analysis (LCCA) or other economic evaluation tool should be conducted to evaluate the most cost effective strategy to be used for a given situation. The cost effectiveness of pavement preservation treatments is extremely important to agency managers. They want to know whether the pavement preservation treatments used within their agencies are cost effective. Without good information on the expected life extension to be attained using a given treatment, determining cost effectiveness is not possible.

Agencies also need better information on the optimum timing for a treatment. Work reported in NCHRP Report 523 provided a framework for optimum timing of treatments, but needs to be field evaluated.

What sorts of issues are known to be hindrances to preservation?

One of the major concerns facing agencies is the quantification of the benefits of pavement preservation. To accomplish this, there is a need for the following information:

- Performance data on treatment life and life extension as functions of the existing pavement condition for all treatments. This can only be obtained from a pavement management system (or a pavement performance database) that incorporates information on key pavement preservation activities.
- An improved approach for establishing the cost effectiveness for pavement preservation treatments and comparing these strategies with the traditional pavement rehabilitation methods. We need to show, using actual performance data, that pavement preservation practices do provide a good return on the investment to the agency. Future highway usage patterns also need to be considered. Unexpected increases in traffic volume and weight can destroy otherwise good treatments.
- Documented information on the benefits of pavement preservation. For example what are the cost savings (both to the agency and the user) and the corresponding improvements to the overall network condition when using pavement preservation techniques? Many times only anecdotal information is available to demonstrate these benefits.
- The lack of quality contractors and materials leads to variable performance for many of the treatments, and can make agencies less likely to use some treatments.
- Lack of integration of all the agency elements for preserving pavements (programming, design, construction, maintenance) makes it difficult to document all the benefits of pavement preservation treatments.
- Lack of confidence of the State DOTs in using treatments that are not familiar to them and the lack of performance related tests and specifications for most pavement preservation treatments.

What existing literature/ research have already been applied?

Several efforts have been published and applied to varying degrees including:

• Work on strategy selection done for the foundation for pavement preservation (FOUNDATION FOR PAVEMENT PRESERVATION) and several state DOTs. Much

of this was summarized in a FOUNDATION FOR PAVEMENT PRESERVATION report by Hicks, Peshkin and Seeds, but it needs to be updated.

- Work on optimal timing of treatments reported in NCHRP Report 523 still needs followup using field projects.
- Work on strategy selection and treatment life done by Caltrans in the development of the Maintenance Technical Advisory Guides (MTAG) for flexible and rigid pavements. However, little has been done to document the effect of existing pavement condition on treatment life or pavement life extension.
- Work on cost effectiveness of pavement preservation vs. traditional pavement rehabilitation treatments-ISAP paper by Scholz, Moulthrop, and Hicks dated 2002. This effort is just a start. There is a need to better document the cost effectiveness of pavement preservation treatments

Other notable research efforts are summarized in the National Center for Pavement Preservation (NCPP) report titled "A Literature Review of Recent Pavement Preservation Research" dated November 17, 2006.

3.0 Issues

The design area should be an integral part of any successful pavement preservation program. Some of the questions which need to be explored in more detail at this workshop are discussed below. We need answers to these questions in order to advance pavement preservation throughout the industry.

How does the design topic relate to preservation programs?

- o Design elements are an important part of pavement preservation programs.
- All agencies should have a process for strategy selection for both flexible and rigid pavements.
- Economic analyses should be a part of the strategy selection process once suitable treatments are selected.
- The cost benefits and improvements to the road network must be documented to a much better extent. We cannot continue to rely on anecdotal information.
- Optimal timing of treatments still hasn't been fully addressed.
- Number of applications of a given or mixed treatment that can be applied before rehabilitation is needed. We don't want to over apply treatments such that their effectiveness is diminished.
- Valid justification for delaying rehabilitation, reconstruction and replacement in pavement preservation programs is needed

How do research and information gaps in the design area present obstacles to the implementation of pavement preservation programs?

• The most important issue for most agencies is whether pavement preservation treatment is cost effective compared with pavement rehabilitation.

- Without documented information on the expected life extension from applying pavement preservation treatments, it is difficult to document the benefits of pavement preservation programs.
- Variable performance of many of the treatments is a major cause of concern by agencies. The reasons for the variable performance have to be addressed.
- In preparing economic analysis, there may be a need to establish different analyses periods for pavement preservation cost studies when comparing them with rehabilitation projects.

4.0 Summary

Several studies haven been completed which deal with research needs for pavement preservation. These include:

- FHWA workshop on Pavement Preservation Research Needs, Sacramento CA, June 20-12, 2001
- NCHRP Project 20-07, Task 184, "Pavement Preservation Practices, Research Plans, and Initiatives", Final report to TRB, May 2005
- National Center for Pavement Preservation, "A Literature Review of Recent Pavement Preservation Research, Preservation Research Roadmap", Draft report prepared for the Foundation for Pavement Preservation, November 17, 2006
- National Center for Pavement Preservation, "Pavement Preservation Program Technical Appraisal", On-going FHWA sponsored project, 2006
- Caltrans Pavement Preservation Strategic Planning Meeting, Sacramento, CA August 28-29, 2006

In all these reports, specific research needs have been identified. Some have been completed, while others simply lacked the needed funding to permit the work to be undertaken. This section summarizes some important research needs in the design area and identifies the steps needed to draft project statements for this area.

- Potential research projects
 - Determining what pavement attributes to measure to assist agencies in selecting pavement preservation activities
 - Identifying the proper timing for pavement preservation treatments
 - Determining threshold limits (or trigger values) for pavement preservation activities
 - Determining expected treatment lives and/or life extension as a function of existing pavement conditions for the various pavement preservation treatments
 - o Development/enhancement of treatment selection guidelines
 - Development/enhancement of a process for evaluating cost effectiveness of treatments compared with rehabilitation
 - Developing the optimal timing for treatments-verification of NCHRP study using field projects
 - Developing appropriate pavement preservation treatments for urban areas

- Integrating preventive maintenance and pavement management
- Steps to be considered to develop research needs- This section is likely similar for all of the whitepapers
 - Identify the problem
 - Develop specific objectives for the study
 - o Identify important work tasks
 - Identify the expected deliverables
 - Identify the level of effort and costs needed to do the work and the time needed to get it done
 - Identify an implementation plan for the project

Two example project statements from the FHWA Research Needs workshop in 2001 are included in Appendix A.

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H-3 QUALITY CONSTRUCTION OF PAVEMENT PRESERVATION ACTIVITIES/PROJECTS

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1.0 Introduction

When maintenance or pavement preservation projects are being administered, constructed, and inspected we often hear: "It is just a maintenance project." While the results are expected to benefit the existing pavement, the perception is that the project is not really that important. Because there is little glamour in "maintenance" projects, contractors and Agency inspectors look on these projects as "not really important projects" and as "fill in work". There could be nothing further from the truth. The necessity to perform "simple" maintenance activity projects correctly cannot be over emphasized.

2.0 Background

Reviewing the history of pavement preventative maintenance projects, we find most preventative maintenance actions were performed utilizing the Agency's own maintenance forces. The primary goal of these maintenance actions was to keep the subgrade dry. With the limited resources available, the principal actions selected were crack sealing and chip seals.

As additional paved surfaces were constructed, there was more work than what Agency maintenance forces could accomplish. Agencies had to contract out parts of the work and a new industry was born--"Maintenance Activity Projects". However, there were no specific specifications or standards for maintenance activity projects. Most often the contracts were let using existing construction specifications with a few minor modifications.

Demands by users and conditions changed and will continue to change. There are considerably more lane miles of pavement in existence today than just a few years ago. Like anything that wears out over time, the pavement surfaces will require maintenance to extend their life and retard deterioration. New products and processes have been developed to improve the effectiveness of the selected contract action. To properly produce these new products and processes requires a "Specialized Contractor" with a trained crew working together with a trained quality control inspector.

3.0 Agency Issues

From a construction contract administration point of view, one must ask: "What needs to be accomplished in the construction, inspection, and contract administration area of pavement preservation projects?" There are different challenges in preventative maintenance projects than in new construction. When looking at areas affecting construction of maintenance activity or pavement preservation projects, one must remember the duties and responsibilities often overlap.

What changes could Agencies make to enhance the quality of construction projects?

Agencies must make changes in how they view maintenance and pavement preservation activities, in particular.

- Maintenance and pavement preservation activities cannot be considered as just a fill in or minor project but rather must be considered as an important Agency program on par with Capitol Improvement Projects.
- Though not a construction problem, the need to have dedicated funding for Pavement Preservation Projects exists. Contractors will not invest their resources developing new materials and processes if they see no long term opportunity to recoup their investment.

With dedicated funding and a formal preservation program, the Agency sends the message that pavement preservation is important to the Agency as it is included as one of the Agency's major programs.

What can be done if Contractors specialized in pavement preservation type projects are not available?

Agencies should investigate and evaluate the benefits of developing and/or requiring (prequalifying) specialized contractors to perform pavement preservation projects. A change in the way most Agencies do business may be required.

- Agencies and contractors could form contractor development partnerships. To date, governmental and private contractors working together developing new products and processes at the project level is very limited.
- Other than the DBE program, helping to develop a new Contractor's line of business is not done.
- Agencies do not know how to accomplish joint development, what tools may be required, and whether there are changes to existing laws that must be considered.

Information or guidelines on "How to" move into this new arena would be a benefit to Agencies.

Could quality be improved if Agencies required warranties?

Some Agencies may look at the idea of warranties as a way to improve the quality of pavement preservation projects.

- Though this concept sounds good and may work in some situations, one must question whether it is adaptable for all preventative maintenance activities.
- The contractor should only be expected to warranty the work the contractor actually performs on the existing surface rather than having to warranty the work performed and the existing pavement structure.

- The contractor has no control of the Agency-selected pavement treatment but could be expected to assume accountability for the existing pavement at a designated level of service.
- If the contractor must assume the risk for existing pavement or for failed or near-failing surface layers below the driving surface, the pavement preservation project may become cost prohibitive due to the risk involved.

A complete look at warranties for pavement preservation would provide a valuable tool for Agencies to consider.

Can Agencies improve their image and relationship with the user?

Most highway user surveys indicate users do not want to be inconvenienced by construction or reconstruction of existing pavements. Agencies, Contractors, and Inspectors must understand and deliver the products and services users demand.

- Users want work to be done when they have no need for the section of highway requiring work.
- Users demand projects be completed faster and last longer. The "get in, stay in, get out, stay out" mantra especially applies to pavement preservation projects.
- When no work appears to being accomplished, such as when materials are being cured, the user only sees their road as being removed. Thus a need to develop construction methods or materials that reduce curing times without decreasing pavement longevity.

In order to improve the Agency image there is a strong need to provide information to the public as to why the Agency is performing preservation projects and what the Agency expects from such projects.

- The public may understand the principal of preventative maintenance as they change oil in their vehicles or know they must paint the house to preserve their investment; however, the public perceive a pavement as lasting forever.
- When driving, users cannot see the surface distress and will not be able to see potential failure from structural distress.
- The concept of working on good roads while others are in a failed condition is even more difficult for users to understand.

While this educational element may not be perceived as construction, effective public knowledge will reduce conflicts between the public and the Agency or contractor when the work is actually underway allowing the contractor and inspector to concentrate on producing a quality project. Knowing how to implement effective methods for delivering this information would be a positive benefit for the Agency.

What can be done to improve traffic flow considering pavement preservation projects are done on existing roadways and traffic operations are a continuous problem?

By their very nature, pavement preservation projects affect traffic. Providing real-time traffic information to the user and general public will lessen user pressure on the Agency and the Contractor.

• Users knowing the real delay time and reasons for the delay are calmer and more cooperative, allowing the inspection forces and contractor to remain focused on delivering a quality product rather than handling public complaints.

• Expecting delays, users may find alternate routes thereby reducing the amount of traffic involved.

Having information available on how to effectively inform users of traffic delays would be beneficial to the Agencies.

4.0 Contractor Issues

What can a contractor do to improve quality?

Often when a maintenance activity contract is put out for bids, an existing Contractor decides he could accomplish the work using his existing equipment and forces. The work is attempted with an existing crew who do not understand the importance of or what is expected of a pavement preservation project.

- The need exists for the Contractor to have "specialized trained crews" to perform preservation work.
- The need exists to develop specialized equipment for the various pavement preservation projects.
- The requirement for work to be accomplished rapidly, efficiently, and often during night time hours or weekends requires specialized training.
- With training materials available contractors could accomplish needed training in house, using professional trainers, using industry developed programs, or in conjunction with the contracting Agency.
- Depending on Agency requirements a form of trained crew certification or specific crew member certification could be implemented.

To assist contractor crews, the need for a short course training manuals for pavement preservation activities (for both instructors and participants) exists to provide expertise and uniformity.

Is the contractor at the Agency's mercy, because the Agency provides the quality control?

The real question becomes: "Should contractors be required to perform their own quality control activities rather than relying on the Agency to provide quality control?" In general the contractor rather than the Agency should be doing its own quality control.

- QC/QA plans have been developed for some areas of construction, (HMA pavements, PCCP pavements, Bridge construction), resulting in a more uniform product being delivered.
- Corrections are made quickly as the Contractor's test results can be used to take corrective action instantly.
- QC/QA plans require time to be developed; the need exists for these to be developed if such plans do not exist for pavement preservation activities.

A generically developed QC/QA program for pavement preventative maintenance activities could provide the basis for Agencies and individual contractors to aid in the development of their own QC/QA programs.

How can we overcome the attitude of contractors and Agency personnel who do not seem to care about the product being delivered?

One ingredient often missing is the need for the Contractor's personnel to want to perform quality work. Quality cannot be inspected or forced into the final product but must come from a desire to provide quality work especially at the project level.

- The use of trained crews should be a step in the right direction.
- An overall "TEAM" concept must be accepted by everyone working on the project. The projects and processes of the future will require everyone involved knowing and understand the importance of their job as well as what the other team members (contractor personnel, QC/QA technicians, and inspectors) contribute to the project.
- The need to accept, understand, and buy into the partnering concept could help alleviate this problem.

Finding ways to make the team concept a part of the project goal without making it a contract requirement is an area deserving investigation.

5.0 Inspection and Quality Control Personnel Issues

What changes in inspection and QC/QA personnel need to be made to improve the quality of constructing pavement preservation projects?

The future inspector must understand both the overall importance of how the preventative maintenance project fits into the Agency's highway system and how the pavement preservation product or process functions.

- Though the head of the Agency or Contractor's owner may want and demand quality workmanship, the only personnel capable of delivering a quality product are the Contractor's and Agency's personnel working together on the project.
- It is not enough to know how to run and report a specific test; instead, inspectors must also know why the test is important and how it affects overall quality including the affect on the Agency life cycle cost.
- Inspectors will need to demand that the work be accomplished as intended meeting all of the specifications.
- Agency inspectors will require the same specialized training as required of Contractor's crews.
- Training for Quality Control personnel, Inspectors, and Contractors' Crews could be undertaken simultaneously. This fits in with the concept of "Partnering" as both parties would learn and understand what each needs to do to accomplish the goal of a quality project.
- The overall quality of the project is in the hands of the "TEAM" actually performing the work.

Knowing "How to" get both parties working in harmony would be a major achievement and benefit to quality construction.

What could construction inspectors and contractor quality control personnel use to make better decisions during construction?

There is a need for rapid tests as well as an ability to evaluate new products and processes presently under developed.

- Preventative Maintenance projects are constructed at rates measured in miles per day rather than months or seasons. Entire projects may be completed in a matter of days.
- If it takes a couple of days to determine out-of-specification materials are being produced, twenty to fifty percent of the project may have been completed.
- Rapid tests with real-time results for both new and existing materials must also be developed to ensure the correct products are being delivered to the work.
- The test results and indicators need to almost be instantaneous in order for corrections to be made timely.
- Many new products work in theory showing very positive results in the laboratory; unfortunately, the actual performance will not be known until the products have been in place for a number of years facing real traffic and environmental conditions.

Work in the areas of accelerated evaluation and development of rapid tests providing real time results has the potential to improve the quality of pavement preservation projects.

6.0 Potential Research Topics

Proposed research must result in materials, products, or processes that can be easily implemented by Agencies and Contractors. Though they are called research topics, the topics may better be characterized as "tools" to help improve the overall quality of pavement preservation projects.

Potential research could include:

Developing and/or certifying "specialized contractors or individual crew members" performing pavement preservation projects.

- Jointly (Agencies and private contractors) developing new products and processes, which may also lead to developing a new line of business for an existing highway contractor or new contractors.
- Examining the way warranties may be used to improve the quality of construction and effective pavement life.
- Determining methods to help the traveling public understand why Agencies may be working on good roads while others are allowed to deteriorate.
- Determining effective methods to get real-time traffic or potential travel delay information to the road user when a preventative maintenance activity is underway.
- Developing training manuals for both contractor and Agency personnel to use in either joint or individual training activities. The topics could range from planning methods to how and why a product works.
- Developing generic QC/QA programs for pavement preservation activities to be used as a format for contractors to develop Agency specific QC/QA programs.
- Investigating ways to incorporate the partnering concept into the contract without making it a contract requirement.

- Developing construction methods or products to reduce curing times to an absolute minimum, thus returning the surface to the user quicker.
- Developing tests (for new and existing materials or products) that can be done rapidly and produce results that can be used to make adjustments immediately.

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H-4 MATERIALS for PAVEMENT PRESERVATION ACTIVITIES/PROJECTS

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1.0 Introduction

The purpose of this paper is to establish the framework for the development of research problem statements that address the impact of materials selection on the performance of preventive maintenance treatments. Because most preservation treatments are structurally thin (i.e., < 25 mm) and must adhere to an existing pavement surface under widely varying traffic loading and environmental conditions, the quality of the materials used in construction is critical to their life span and long-term performance.

Thin surface treatments such as chip seals and micro-surfacing are generally comprised of >90% aggregate, and as such, their utility is prescribed in large part by the physical properties of the stone used, like abrasion resistance, durability, and skid-resistance (friction properties). While most agencies tend to utilize locally available aggregate sources which may be less than ideal, others seek ways to determine when importing higher quality aggregate from distant sources may prove more economical in the long-term due to increased life span and improvements of overall performance.

Binder quality is of equal importance to aggregate quality, and can be impacted by the base crude stock used, and the batching and handling procedures employed during formulation (e.g., especially in emulsions). Moreover, the use of additives such as polymer modifiers or crumb rubber can significantly affect pavement properties like stone retention, temperature susceptibility, safety, and noise. Ultimately, the bonding capacity of the binder used in thin surface treatments is critical in ensuring adequate adhesion of the aggregate to the substrate or underlying pavement surface.

Defining appropriate testing protocols to determine material properties has proven to be somewhat problematic with respect to the reproducibility of results and the degree it represents the actual field performance. For example, research has shown that the most prevalent emulsion residue extraction methods generally do not accurately reproduce the structure and performance of field-placed emulsion-based treatment applications. Yet the more representative techniques generally require a lengthy (and costly) extraction process which often discourages their use.

2.0 Summary of Current Practice

Recent reviews of the research literature reveal comparatively little effort in the area of materials selection, mix design, and materials testing (1) (2). To date, most of the available research has focused on evaluating the performance of crack and joint sealing/filling products, and to a lesser degree, the development of improved mix design methodologies. Nationwide surveys of pavement practitioners have similarly revealed a high level of interest in the study of crack and joint sealant material performance, and methods of sealant product selection (2).

Although the evaluation of the impact of aggregate quality on treatment performance does not generally appear to rate as a high priority for most agencies, the high incidence of premature treatment failure, performance problems, and motorist dissatisfaction would suggest that this is an area which warrants increased scrutiny. For example, the chief cause of early chip seal failure is excessive early stone loss. While stone retention problems can be caused by poor construction practices; improper aggregate selection and/or preparation, and the failure to use a polymer modifier have also proven to be significant causative factors.

Research also indicates that in "cold" treatments which utilize asphalt emulsions, considerable confusion exists among practitioners as to the best testing methods and parameters to use to evaluate long-term performance. While many agencies use a subset of the Superpave grading system to evaluate emulsion residues, some practitioners maintain that an entirely new grading system is needed, while others have proposed collections of modified testing procedures based to varying degrees upon Superpave.

Little is generally known by most pavement professionals about the influence of the composition of the base crude stocks used in hot and cold applied asphalts on long-term treatment performance and constructability. For example, ratios of asphaltenes to maltenes can vary significantly based upon the source of the crude stock and the refining processes used. Because asphaltene dispersion is dependent upon maltene content, higher asphaltene to maltene ratios may lead to poorer asphaltene distributions and thus, may be less amenable to proper emulsification. Similarly, asphalts with a marginally balanced ratio of asphaltenes to maltenes may exhibit compatibility problems if crumb rubber is added to the binder, since rubber tends to preferentially absorb maltene components.

3.0 Key Challenges

On-going reviews of the various state agencies' pavement preservation programs reveal that most will default to using local aggregate sources on the basis of cost and availability, rather than quality and long-term performance (1). This practice is believed to be primarily rooted in the fact most pavement practitioners simply do not fully understand the impact of aggregate quality on treatment life and performance. In the absence of quantitative data on the impact of aggregate quality on the life cycle costs and life-extending benefits of surface treatments, agency practitioners possess no method of determining when it might be economically advantageous to import higher cost, high quality aggregate from distant sources instead of opting to use poor quality but lower cost local materials. Similarly, little is understood about how to determine when an aggregate is "good enough" or "too poor" for a given treatment application.
Lacking the fundamental tools to justify the increased material and transportation costs to their management, agency practitioners have little choice but to use potentially inferior aggregate sources. This problem has been further exacerbated by the widespread depletion of quality aggregate sources in many areas, and the acquisition of others by hot mix interests who may prevent access to supplies on less profitable preservation projects through the use of cost-prohibitive pricing practices.

Aggregate "cleanliness" is widely understood to influence binder adhesion and cohesion in thin surface treatments. Many agencies will utilize a high-float emulsion in cases where the percentage of fines passing the #200 sieve exceeds about 1% but is less than 5%. However, the potential benefits of binder pre-coating in dealing with dusty aggregates are generally not well understood by many pavement practitioners. While some recent research indicates that pre-coating may also be beneficial when using even clean aggregate (for example, in chip seals), information on the cost-benefit relationship of the practice is scant. Thus, without supporting quantitative data on the cost-effectiveness of pre-coating, many agencies choose to avoid the practice altogether.

Recent research has shown that aggregate shape, texture, and angularity can significantly impact thin treatment performance. However, most state specifications fail to directly relate the most appropriate and representative methods for measuring these parameters. Moreover, uncertainty often exists on the appropriate specification limits for these parameters for the various surface treatments to ensure optimal performance. Guidance is needed on selecting the appropriate aggregate grading methods for quality control, and on the influence of particle physical parameters on various aspects of treatment performance and longevity.

Although a wide variety of emulsion types are available on the market, confusion often abounds on which types should be used and for which application scenarios. Many industry sources often recommend using only CRS-2P or HFRS-2P for most seal coats, yet numerous agencies report using literally a dozen or more different emulsions in their preservation projects with little understanding as to the benefits or drawbacks of using one emulsion over another. Moreover, for thin treatments such as chip seals, additional uncertainty exists as to whether hot applied binders are preferable to emulsions, and if so under what conditions? Indeed, currently available cost and performance data are not sufficient to support the use of cost-benefit analysis in binder selection.

Research on latex and crumb rubber additives and other polymer modifiers, indicates that improved performance and longevity are possible when these compounds are added to either hot or cold applied asphalt binders. Little data are available however on the proper methodology for polymer dosing, or for assessing when polymer content is optimal. When is the added cost of polymer warranted and effective? What are the best polymer types to use?

Additionally, there exists considerable debate on the nature and type of specifications which should be used for polymer modified binders. Most emulsion and polymer suppliers prefer performance-based specifications, since material and method specs are viewed as restrictive and stifling to innovation. However, many state highway agencies continue to specify polymer types and contents, and in some cases, even modification methods. Suppliers insist that if given a free-

hand, they can design modified emulsions to meet almost any reasonable specification. The problem in this regard however, arises when an agency seeking to develop a performance-based specification sets out to define what parameters are important in predicting true field performance, and how best to test and evaluate those parameters.

There are often widely differing testing protocols employed to verify the quality and performance of materials used in preventive maintenance treatments. While some agencies find success with common methods, others may find they provide only marginal value. For instance, while the LA Abrasion test is widely accepted by many agencies for measuring abrasion resistance and toughness, those located in extreme cold weather states such as Alaska have found that the Nordic Ball Mill Test is far more appropriate for their prevailing climate conditions and the widespread use of chains and studded snow tires. Guidance is often sought by the pavement practitioner on which tests are best suited to the environs, traffic, and loading conditions prevalent across their roadway network, but existing research into these areas tends to be sparse and disjointed.

4.0 Conclusions & Recommendations

Perhaps the most significant challenge facing preservation practitioners with respect to materials use is developing a better understanding of the cost-benefits associated with selecting one material component over another. This issue is particularly poignant when considered in regards to the screening and selection of appropriate aggregate sources. Presently, insufficient quantitative data exists which would permit agency decision makers to determine whether to utilize a local aggregate source, or to incur the additional expense of importing aggregate from distant locations. Moreover, understanding the material parameters that impact performance, and devising reliable methods of measuring those parameters are critical components needed to facilitate this process.

Guidance is needed by state agencies to determine:

- What type(s) of emulsion to use and for which application types
- When to use polymer additives and how to determine optimal polymer content
- What materials testing methods best represent field performance, and how/when should these methodologies be adapted for extreme environs or traffic conditions
- What are the potential costs, benefits and limitations of aggregate pre-coating
- When is an aggregate "good enough" or "too poor" for a given application
- Methodologies for optimally selecting treatment materials based upon road type, conditions, and the degree and types of underlying pavement distress
- What are the best methods of determining aggregate particle morphology, and what are the appropriate ranges for physical parameters such as angularity, shape, and texture that will ensure optimal performance
- The advantages and disadvantages of using a hot binder versus an emulsion for given surface treatments
- Development of appropriate performance specifications
- How best to correlate materials laboratory testing with treatment field performance

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H-5 CONCRETE PAVEMENT PRESERVATION

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1.0 Introduction

The Pavement Preservation Concept:

"Pavement preservation, as defined by the FHWA, is a program employing a network level, long-term strategy that enhances pavement performance by using an integrated, cost-effective set of practices that extend pavement life, improve safety and meet motorist expectations (FHWA, 2005)"¹. This definition clearly breaks preservation into three outcomes; (1) pavement life extension, (2) improved safety, and (3) consumer satisfaction. In addition, it also defines how the process needs to be accomplished; (1) through a long term, network level approach and (2) using integrated, cost-effective practices. The FHWA clearly had the wisdom to realize the importance of defining the outcomes and processes involved.

By defining pavement life extension, the FHWA has distinguished between treatment life and pavement-life extension. That is, it is not uncommon to refer to pavement preservation strategies in terms of treatment life, such as 3-5 years. However, if the treatment does not extend the existing pavement life, the service life of the treatment is inconsequential since it is not a cost-effective treatment. This is a very important concept to embrace, particularly during times of funding shortfalls when the worst first strategy often times gains momentum.

Improved safety is often considered addressed through pot hole or spall repair but its meaning needs to be much more comprehensive. Motorists place their trust in agencies to provide safe and comfortable roadways. When a motorist begins a journey, there are expectations that the pavement conditions will ensure proper operation of the vehicle for all environmental and operational conditions. This can only be assured when safety is a managed and distinct portion of any pavement preservation activity.

Consumer satisfaction is best achieved through smooth roadways and minimizing maintenance and construction delays. Road roughness has been the measurement of choice for assessing roadway conditions and correlates best to consumer satisfaction. Few motorists can relate to pavement distresses such as cracking or surface defects. At most highway speeds, the driver is often unaware of the surface condition of the roadway except for its roughness level. Similarly, construction and maintenance delays need to be held to a minimum whenever and where ever possible. In addition to requiring an outcome-based result, the FHWA also defines the minimal process necessary to adequately provide a functional preservation system. Since most agencies have independent processes addressing the cradle-to-grave activities of a pavement network, it is critical that they be integrated and involve long term network level assessment and feedback. For example, an agency might have one group design the roadway either geometrically or structurally while other groups construct the project, test the project, maintain it over time leaving others responsible for collecting/assessing pavement performance data and deciding when to allocate funding for preservation treatments. While oftentimes these functions can be accomplished by fewer groups, it points to the imperative of having an integrated process that relies on actual pavement performance data collected on the network from cradle to grave. Only through this type of integrated approach can cost-effective treatments be developed and implemented.

The FHWA's Pavement Preservation definition also includes the use of the terms "long term" and "cost-effective" which both should imply life cycle cost analysis (LCCA) approaches. This is the only reasonable approach to ensuring that resources are properly utilized and the roadway investment managed adequately. However, to properly conduct LCC analysis, an agency needs to have performance data, construction costs and as-built data to define the actual performance of the various strategies and their associated costs. If this data isn't readily available, then the LCC approach is relegated to no more than a cosmetically improved anecdotal approach.

The traditional pavement preservation approach oftentimes uses the Fram Oil filter slogan of "Pay me now or pay me later" to emphasize the preservation concept. This approach is often linked to the classic performance/investment curve shown in Figure 1; where it is indicated that investments made during the preservation period are significantly more cost effective than investments during the resurfacing or reconstruction portion of the performance curve.



Figure 1: Typical Pavement Performance Curve and Maintenance/Rehabilitation with Time (Ref 1)

This approach, albeit conceptual, infers all pavement types/strategies perform similarly. Unfortunately, this is an over simplification that can lead to anecdotal approaches when adequate engineering data/analysis are not available.

One additional implication of the FHWA requirement of "long term" is the selection of preservation strategies A-priori. That is, for the designated life cycle analysis period, an agency or owner must designate the respective treatments from cradle to grave to define the "expected" performance/investment curve shown in Figure 1. However, except in very few instances, once the LCCA analysis is completed and the strategy selection made, no future funding is programmed to accomplish the "planned" preservation strategies. The agency or owner, simply defers the funding, strategy selection, and decisions to future organizations and conditions.

This approach makes it difficult to provide feedback between design, maintenance, and actual performance since the conditions upon which the design was selected may or may not occur in the future. This is also probably why the FHWA includes the terms integrated and cost-effective. Historically, few agencies/owners have developed a holistic approach to accomplish this.

2.0 Summary of Current Practice

Concrete Pavement Preservation (CP²):

Traditionally, concrete pavement has been utilized in urban areas with high traffic volumes where long life pavements are warranted to reduce delays and congestion associated with construction and maintenance activities, or on roadways which sustain heavy traffic loadings due to commercial vehicles.

 CP^2 is a series of engineered techniques developed over the past 40 years to manage the rate of pavement deterioration in concrete streets, highways and airports. CP^2 is a non-overlay option used to repair areas of distress in concrete pavement without changing its grade. This rational, preventive procedure restores the pavement to a condition close to or better than original and reduces the need for major and more costly repairs later. Benefits of CP^2 include:

- CP² addresses the causes of pavement distress, minimizing further deterioration. Covering the distress with an overlay does not correct the cause of the distress. Eventually the distress manifests itself again, usually as a larger, more expensive problem. This fundamental difference makes CP² more effective and less costly than other treatment options.
- CP² costs less and lasts longer than other treatment options. Georgia has used CP² extensively for nearly 40 years, sometimes as many as three times on the same road. Georgia has found that CP² is a cost competitive option when compared to overlay treatment options.
- CP² is quicker and causes less traffic disruption. Since CP² maintains the existing grade, features such as curbs, gutters, bridge clearances, approach slabs and roadside appurtenances do not need adjustment. Furthermore, CP² repairs only those areas that need improvement, such as the driving lane or the keel section of a runway. This

accelerates the entire construction process, requires fewer traffic control measures and causes less traffic disruption.

- CP² preserves the safety of concrete pavement. Concrete surfaces do not deform and typically maintain their drainage characteristics for the life of the pavement. This is especially important at intersections or other locations where traffic is starting, stopping and turning. Furthermore, because of their light color, concrete pavements reflect light better than most other pavement surfaces, which improves vision and safety during night and inclement-weather driving.
- CP² can be used to repair a concrete pavement that has been previously overlaid with asphalt. Agencies in the past have overlaid many structurally sound concrete pavements due to roughness and/or lack of friction, both easily corrected by the use of diamond grinding.

Concrete pavement preservation activities consist of slab stabilization, partial or full-depth repair, dowel bar retrofit, cross-stitching of longitudinal cracks or joints, diamond grinding, and joint and crack resealing. A brief description of each of each of these strategies is listed below (ref 1):

- **Slab Stabilization**: A technique to restore support to concrete slabs by filling small voids that develop underneath the concrete slab at joints, cracks, or the pavement edge.
- **Full and Partial-depth Repair:** A technique to fix cracked slabs and joint deterioration by removing at least one portion of the existing slab and replacing it with new concrete.
- **Dowel Bar Retrofit:** A technique of cutting slots in the pavement across the joint or crack, cleaning the slots, placing dowel bars, and backfilling the slots with new concrete. Dowel-bar retrofits link slabs together at transverse cracks and joints so that the load is evenly distributed across the crack or joint.
- **Cross-stitching longitudinal cracks:** A technique to repair cracks that are in low-severity condition. The method adds reinforcing steel to hold the crack together.
- **Diamond Grinding:** A technique that uses diamond blades to grind surface irregularities, such as faulting, slab warping, studded tire wear, etc to create a smooth, uniform surface profile.
- Joint and crack resealing: A technique to minimize the infiltration of surface water and incompressible material into the pavement section.

3.0 Issues

Concrete Pavement Performance Curves

Traditional pavement management or pavement preservation curves are based on conceptual models like the one indicated in figure 1. The same approach is used for both concrete and asphalt pavements. However, the two pavement types are designed differently and perform differently. Figure 2 is an example of another conceptual model used to promote optimum preservation strategies. Again, this is an asphalt based conceptual model and does not lend itself to CP^2 .



Figure 2 Optimum Timing for Pavement Preservation

Concrete pavements last longer and their pavement preservation techniques are generally effective for longer intervals than other pavement materials. Many existing concrete pavements have achieved and exceeded their design life without pavement preservation assistance.

For concrete pavements, the consumer is typically only aware of the pavement's ride qualities or tonal characteristics. Seldom do they associate joint distress or cracking with anything but roughness. The performance model that best depicts this is a roughness curve as shown in Figure 3. The curves presented in Figure 3 represent the roughness progression for the projects studied on the LTPP GPS-3 and 5 sites. The GPS-3 projects represent the plain jointed existing LTPP projects while the GPS-5 represents the existing CRCP projects within the LTPP database. As noted in most of these examples, the roughness performance curves appear quite linear and often times flat, with little change in time. Therefore, to properly develop meaningful pavement preservation strategies, the agencies/owners need to develop realistic performance curves for both the original construction life and subsequent preservation strategies. It should also be noted in Figure 3 that many of these pavements are performing beyond their 20 year design period. Good CP² requires developing models to represent the actual design strategy performance that will occur under the given loading and environmental conditions.

Concrete Pavement Intervention Cycles

Due to concrete pavement's long service record; it has often been easy for agencies/owners to ignore the need for CP^2 . When funding is tight and the worst first principles control, concrete pavement preservation is often overlooked as most agencies recognize that concrete pavements last longer than their design lives. This has allowed agencies to ignore CP^2 and expend preservation funds elsewhere. This has lead to many concrete pavements experiencing little or no preservation.

There is a need to shift the intervention cycle earlier in the performance period, so that pavements can remain smooth and free from dynamic loading. This will increase the ultimate serviceability of the pavement as well as improve consumer satisfaction. However, to

accomplish this, the agency/owner needs to have the data collection and analysis processes required by the FHWA definition discussed earlier in this paper.



Figure 3 IRI Trends for GPS 3 & 5 LTPP Test Sites (From Ref 2)

4.0 Potential Performance Enhancements Resulting from Improved Design/Construction Practices

 CP^2 activities have often been determined after a pavement has been in service for many years as opposed to the earlier notion presented that the preservation strategies should be determined Apriori. The current approach assumes that what ever has occurred in the design, construction, and performance period will manifest itself and be arrested by the selected CP^2 strategy. Although this approach minimizes the risk involved in strategy selection (e.g. 20:20 hindsight), it affords no opportunity to prevent a reduced performance period caused by errors in the design/construction process. Figure 4 indicates plots of Good and Poorly performing projects for the GPS 3 & 5 LTPP sections. As evident in the plots,



Figure 4 for Good and Poorly Performing LTPP GPS 3 & 5 Test Sections (From Ref

2)

there is considerable difference in performance. Well performing pavements have little change while poorly performing pavements exhibit significant performance issues. Therefore, instead of just accepting the differences in performance levels and using CP^2 activities to mitigate their impact, there is a need to identify the features that cause these differences and to attempt to extend pavement performance at the onset (e.g. design/construction process). This is truly the most effective form of pavement preservation.

Another example of how design can affect performance is indicated in Figure 5. For this example it is clear that the use of dowels reduces the performance variability and extends pavement life in some instances. Again, the point of the example is to reinforce the concept of basing the strategy decisions on actual performance data.



Figure 5 Relationships Between Rate of Change of IRI and Pavement Age for GPS-3 Sections (From Ref 2)

Perhaps the most debated design consideration is whether to seal joints or not. Although this activity has been conducted for nearly 60 years or more, strong disagreements still exist as to its

benefits. Many agencies have inadequate data to determine the need for an activity that represents 3-5% of the initial cost and is expensive to conduct as a CP² activity,

5.0 Incorporating Safety into CP² Strategy Selection Processes

Safety has generally been assessed in highway agencies through the use of the ASTM lockedwheel skid trailer. Discrete location tests are conducted at regular intervals, often at milepost locations, using either the ribbed or smooth ASTM test tire. Most of the time, these activities are conducted as part of the agency's pavement data collection effort. Many agencies/owners have trigger values that determine when corrective action is initiated to resolve the friction problem.

Often times, unless a deficient friction value exists, friction improvement is not a preservation activity and the effect of the selected activity on safety is not always properly considered. Since the FHWA preservation definition includes safety as one of the outcomes, there is a need to determine the best way to measure and manage roadway safety. When selecting preservation activities, their impact on safety should be considered.

The majority of the current fleet on the highway is equipped with anti-lock braking systems that prevent locked-wheel skidding accidents. There is a need to improve the current system of safety measurement to a more relevant and technologically advanced measurement system that better relates the pavement condition to today's vehicles.

The Minnesota DOT is a good example of how an organization can improve safety through conscience actions. To improve the surface texture of their concrete pavements, they modified their mix design and provided incentives to contractors for lower water cement ratios. Both of these actions led to improved and longer lasting macro texture and subsequently safer roadways.

6.0 Potential Research Projects

- Establish actual concrete pavement performance curves and CP² strategy effectiveness.
- Determine the most effective intervention cycles for CP² strategies based on actual Life Cycle Cost (LCC) principles.
- Develop awareness of the national network condition and identify the areas of needed CP² activities.
- Identify potential performance enhancements resulting from improved new construction/ design/testing techniques.
- Define the necessary elements of a working pavement management system to responsibly implement and manage CP².
- Develop predictive costing capabilities to better incorporate future costs into LCC based strategy selections.
- Develop guidelines for incorporating safety into CP² strategy selection processes.
- Determine the optimum design life selection and CP² intervention interval selection for improved network level investment decisions.

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Appendix A: Potential Concrete Pavement Preservation Research Topics

Development of a model to determine the stresses between the base pavement and an overlay at the bond plane, the degree of bonding, its' expected life span, and the impact that the bonding that is present has on the thickness of a PCC overlay. The model needs to address the above items for bonded resurfacing overlays and also the incidental bonding that occurs on unbonded overlays.

Preservation strategies for high volume facilities taking into account time of work and frequency of closure.

Research on the required thickness and specific characteristics of effective bond breaking interlayers for unbonded overlays. Materials evaluated should include Hot Mix Asphalt, synthetic materials, and other products that have proven successful.

Realistic determination of life expectancy of preservation methods based on projected traffic volumes and materials used in the original concrete pavement

Determination of the value of different types of fibers in PCC overlays in relationship to extending service life and allowing the joint spacing to be increased

Quantify mix design improvements for thinner PCC overlays, such as use of ternary mixes, in terms of impact on reduced shrinkage, improved bond, and improvements to workability, curing timing/methods, and sawing techniques

Determination of the appropriate window of opportunity, based on cost effectiveness and condition of the underlying pavement, to extend pavement service life through various preservation techniques

Research into the need for surface preparation in advance of bonded PCC overlays that do not use a bonding agent, the changes in bond strength based on the surface preparation and the impact to the design thickness, if any.

Determination of non-destructive test procedure to determine the structural condition and functionality of longitudinal and transverse joints in the underlying pavement as input into the preservation project design process

Determination of the value of continuing maintenance of joint sealers on concrete pavements, including drainable and undrained bases and with and without subdrains.

Determination of road user cost based on the design life of the preservation method

Defining the end of the economic and functional life of a concrete pavement and development of methods to determine the remaining functional life as input into preservation project decisions

Determination of cost effective methods to improve subgrade/subbase pavement support prior to undertaking a preservation project

Determination of optimal saw cut depth on longitudinal and transverse joints on concrete resurfacing projects

H-6 METHODS OF MAINTENANCE CONTRACTING

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1.0 Introduction

Agencies use a number of different approaches to carry out pavement preservation projects. The most common methods are in-house maintenance, in which the work is completed by the agencies own forces, or contract maintenance, in which the agency issues a contract to a private firm to perform the maintenance activity. The approaches that agencies use to decide whether to complete a project in house or to outsource it are beyond the scope of this paper. Instead, the focus of this paper is on maintenance contracting.

Four primary types of maintenance contracts are described. While these apply to many different maintenance activities, and not just pavement preservation, they are each also applicable to contracting for pavement preservation activities. Each of these is briefly described below.

2.0 Method-Based Contracts

In method-based contracts, the owner agency specifies in detail how the work is to be completed and the successful contractor follows the specifications in order to receive payment. For example, a method-based contract might specify the following: the materials and equipment to be used, the application rate, the methods of pavement preparation, and the conditions necessary to open the pavement to traffic.

In a method-based contract, it is presumed that if the contractor follows all of the detailed steps described by the method then he has earned full pay for his efforts. Implicit in a method-based contract is that the contracting agency fully understands and can specify all of the steps in the construction process to ensure the desired performance of the end product. That is, they are reasonably certain that when the contractor follows the "methods" spelled out in the contract documents, the results are predictable. This type of contract also calls for a fairly high level of effort on the part of the agency to monitor that the methods are being followed. In a method-based contract, the contractor has few options on how to perform the work.

Method-based contracts are by far the most common type of contract used for pavement preservation work not done by the agency itself. As such, there is a high degree of familiarity and "comfort" with these contracts. The specifications associated with contracts for preservation

treatments have evolved over many years of use and experience, and as such the contracting agency will have a reasonable expectation that if the treatment is constructed as specified, the outcome will be acceptable.

Potential shortcomings with method-based contracts include that they place more responsibility for good performance with the owner agency than with the contractor, which in turn requires that the agency have a good understanding of the relationship between what is specified and the desired ultimate performance of the product. These contracts also call for a higher level of agency effort to accept the final product, as almost all quality control testing is performed by the Agency. Method-based contracts also can inhibit innovation and improvements on the part of contractors and materials suppliers, as these advancements are only slowly incorporated into revised specifications. Agencies usually need to be convinced of a new product or method before they will develop a specification for it, and this process must be repeated for each agency. As such, the barriers to developing and promoting new products are huge. And as new pavement preservation products, procedures, equipment, and materials are developed, agencies may be slow to permit these improvements to be placed.

3.0 Performance-Related Contracts

This type of contract focuses more on the outcomes of the work than on how the work is performed. In performance-related contracts, measures of the properties of the final product are used to determine whether the contractor has satisfactorily completed the job. For example, under a performance-related contract for chip seals the agency might specify the materials, verify that those materials are used, and measure aggregate embedment, percent retention, or final surface macrotexture, rather than specifying a rolling/embedment sequence.

When a performance-related contract is used for pavement preservation, it implies that the relationships between the contract's performance measures and the desired ultimate performance of the maintenance activity are well established. In some performance-related contracts, payment could be linked to attaining various measures, where exceeding positive measures would result in payment greater than 100 percent, while falling short of the same measures would result in payment less than 100 percent.

Unlike method specifications, the contractor has input into how he will perform the work. Advantages of these types of contracts are that they place more responsibility (i.e., quality control, placement methods, and overall risk) for the desired outcome in the hands of the contractor, As such, the contractor is free to innovate and invent, finding new ways to achieve the same objectives, or perhaps to lower costs or improve performance.

The greatest disadvantage with this type of contract is that it requires the contracting agency to have a very good understanding of the performance measures specified in the contract and the desired long-term performance of the preservation treatment.

4.0 Performance-Based Contracts

A performance-based contract is similar to a performance-related contract, but it places even more control of the materials, means, and methods in the contractor's hands. In such a contract, the agency might specify "a pavement surface with a friction of (some value) for (some time period) or "a surface with less than (some valve) cracks per mile for (some time period)" and let the contractor select the method and materials to achieve the specified performance. Theses types of contracts are being used for fence-to-fence maintenance, as well as for select maintenance activities, but not for pavement preservation.

The advantages and disadvantages of performance-based contracts are similar to those of performance-related contracts. They call for the agency to cede almost complete control to the contractor, but in return they can specify the type of performance that they want and in concept only pay if they get it.

Because true performance-based contracting calls for measurements only on the final product, the agency must accept that the contractor can choose any path to reach the final outcome. As an example, if a contractor is placing a thin overlay under environmental conditions where the agency would typically stop construction (such as low temperatures or very wet surfaces), the contractor could still receive full payment for the final product if it met the performance measures (which might be measures of density, thickness, surface texture, and so on). There is also an increased risk to the agency if the contractor fails and the surety does not cover the actual liability.

5.0 Contracts Which Include Warrantees

A contract including a warrantee (contract warrantee) focuses on the longer-term performance of the maintenance activity. Where payment for the first two types of contracts could occur when construction is completed, with warrantees full payment might not be achieved until one or more years after a treatment has been in service. A contract warranty is differentiated from performance-related contracts or method contracts in that under a warrantee the in-place performance of the pavement is observed for a specified amount of time before the project is accepted. For example, a contract warrantee on a chip seal project might specify as an additional condition that a specific measure of pavement surface macrotexture would still be in place after 1 year of performance as an acceptance condition.

Contract warrantees are very attractive to owner agencies because they focus on the desired outcomes (in terms of longer measures of performance) than do the other contract types. From the agency's viewpoint, they place all of the risk for performance in the hands of the contractor, suggesting that the agency will receive a higher quality product as well. Contract warrantees may also contribute to greater innovation, as the contractor is free to select the means and methods, associated with the treatment placement.

Most contract warrantees cover a time period somewhat less than the intended life of the treatment. For example, while crack sealant might be expected to average 8 years of

performance, a reasonable warrantee might only cover the first 1 year. The reason for this difference is that the warrantee is meant to cover construction deficiencies that are under the contractor's control and not long-term loading or environmental conditions that he can't control. With crack sealant, it is reasonable to expect that if after one year the sealant is firmly in place and retains its desirable properties of resilience and elasticity then the contractor placed the treatment properly.

There are several problems with warrantee contracts for pavement preservation treatments. The agency must have meaningful measures that reflect the desired long-term performance of the treatment. Project selection becomes much more critical as well with warrantees. If the pavement is not a good candidate for pavement preservation, it can be difficult to get qualified bids or to get the desired performance. The potential for increased contract costs are also an agency concern. These contracts are riskier for the contractor, which may translate into higher bid prices.

6.0 Research Needs

No matter what type of pavement preservation contract is used, the goal should be the same: to obtain the desired performance from the treatment application in a cost effective manner. It is believed that in the long run performance-related or warrantee pavement preservation contracts are generally more beneficial to agencies, as they should result in improved treatment performance. Ultimately, that work should be done at the same, or lower, cost to the agency, as cost-saving and performance-enhancing innovations are incorporated into these products. In order for this to happen, good answers to the following questions are needed:

- When should the different contracting methods be used?
- For performance-related contracts, what measures should be used to identify long-term performance?
- For warrantees, what measures should be used for contract acceptance?
- What is a reasonable length of time for warrantees for different treatments?

There is an ongoing study on performance-based contracting that is meant to provide some initial insights on this topic. NCHRP Synthesis of Highway Practice 37-09, *Performance-Based Contracting for Maintenance*, is surveying agency practice and reporting on the following topics:

- Performance standards and relevant measures commonly used to address performancebased contract delivery for different types of maintenance activities.
- How performance levels are established, measured, and evaluated in maintenance contracting.
- Best practices in monitoring and reporting performance-based contract maintenance delivery.
- Costs, benefits, risks, and possible shortcomings of adopting performance-based maintenance contracts.

- Basic elements necessary to initiate performance-based maintenance delivery, including contractor acquisition strategy, evaluation criteria for selection, and pre-qualification processes.
- Contractual provisions such as payment methods, including incentives/disincentives.
- Examples of successful and failed applications in performance-based maintenance contracting.

Where applied to both performance-related, performance-based and contract warrantees for pavement preservation contracting, research on these topics would adequately fill the knowledge gaps. These also describe in general terms the desired end products of the desired research.

The Arizona DOT's study of cost-effective maintenance has also considered measures of the effectiveness of warrantees and performance measures, and this is also being studied for selective surface seals by the Foundation for Pavement Preservation. Ultimately, that type of research needs to be expanded to generate appropriate answers to help public agencies to use these contracting methods. This work has been underway for decades in hot-mix asphalt (HMA) and Portland Cement Concrete (PCC) construction, suggesting that this is by no means a trivial problem.

7.0 Barriers to Implementation

The primary barrier to implementation is that in order to develop good guidelines on performance-related pavement preservation contracts, relationships between short-term measurements and long-term performance need to be established. Even if experiments were in place today to develop these relationships, and it is not believed that they are, at best several years would be required to generate useful results. However, once such relationships begin to be developed, the following more general barriers are likely to remain:

- Performance-based or contract warrantees either will be, or will be perceived to be, more expensive than conventional contracts.
- The risks associated with these types of contracts are on the contractor, so contractors will be opposed to them.
- Such contracts favor large contractors who can afford to provide warrantees and/or withstand delays in receiving payment.

8.0 Required Scale of Effort

The complexity of the steps required to develop widely accepted performance-based specifications and warrantee guidelines for pavement preservation should not be underestimated. As noted previously, such efforts have been underway for several decades for HMA and PCC construction and are still not complete. While the issues associated with developing these improved contracting methods for pavement preservation are perhaps not as complex, there are many more types of treatments, each potentially requiring separate measures of performance and different warrantee requirements.

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H-7 SURFACE CHARACTERISTICS (DRAFT)

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1.0 Introduction

The Surface Texture Continuum:

Pavement surface texture influences many aspects of tire-pavement interaction, including wetweather friction, tire-pavement noise, splash and spray, rolling resistance, and tire wear. Overall pavement surface texture includes the contributions of many surface features with different combinations of texture depth (amplitude) and feature length. These features include the contributions of aggregate texture and gradation, pavement finishing techniques, and pavement wear, to name just a few. Different texture characteristics (i.e., combinations of texture depth and wavelength) have different effects on tire-pavement interactions. Therefore, it is important to be able to classify pavement texture in a way that is useful in interpreting the effect of the texture on pavement performance characteristics.

In 1987 the Permanent International Association of Road Congresses (PIARC) proposed the following categories of pavement surface characteristics based on their amplitude (depth) and wavelength: microtexture, macrotexture, megatexture and unevenness (roughness).² Each of these categories is described in subsequent sections, and the specific influence of each category on tire-pavement interaction is illustrated in Figure 1.



Figure 1 Illustration of PIARC Pavement Surface Characteristics (Reference 3)

Microtexture is defined as texture having wavelengths of 0.0004 in to 0.02 in (1 μ m to 0.5 mm) and vertical amplitudes less than 0.008 in (0.2 mm).² Good microtexture is usually all that is needed to provide adequate stopping on dry pavements at typical vehicle operational speeds and on wet (but not flooded) pavements when vehicle speeds are less than 50 mph (80 kph). When higher vehicle speeds are expected, good microtexture and macrotexture are generally required to provide adequate wet-pavement friction.⁴ Microtexture is not generally considered to be a factor in the development of pavement noise or splash and spray.

- **Macrotexture** refers to texture having wavelengths of 0.02 in to 2 in (0.5 mm to 50 mm) and vertical amplitudes ranging from 0.004 in to 0.8 in (0.1 mm to 20 mm).² Macrotexture plays a major role in the wet weather friction characteristics of pavement surfaces, especially at higher vehicle speeds. Therefore, pavements that are constructed to accommodate vehicles traveling at speeds of 50 mph (80kph) or faster require good macrotexture to help prevent hydroplaning.⁴ In addition to providing wet weather friction, macro-texture is the pavement surface characteristic that has the strongest impact on tire-pavement noise and splash and spray (see Figure 1).
- **Megatexture** comprises texture with longitudinal wavelengths of 2 in to 20 in (50 mm to 500 mm) and vertical amplitudes ranging between 0.004 in to 2 in. (0.1 mm to 50 mm).² This level of texture is typically the result of poor construction practices, local settlements, or surface deterioration. Megatexture can cause vibration in tire walls, resulting in in-vehicle noise and some external noise. It also adversely affects pavement ride quality and can produce premature wear of the vehicle suspension (i.e.,

tires, shock absorbers and struts).⁵

• Unevenness (roughness) is defined as surface irregularities with wavelengths longer than the upper limit of megatexture (> 20 in. [500 mm]). Wavelengths in this range have an impact on vehicle dynamics, ride quality, and surface drainage.⁵ Unevenness does not significantly affect tire-pavement noise.

2.0 Measurement of Surface Texture:

There are several different methods for measuring surface texture, but the results of these methods are sometimes difficult to compare directly (although correlations and conversion equations have been developed). Some commonly used measures and measurement methods are the mean texture depth and the mean profile depth. The mean texture depth (MTD) is a measure that is determined using the traditional volumetric method (commonly referred to as the "sand patch test" or ASTM E 965).

In the past decade, advances in laser technology and computational power have led to the development of systems that measure longitudinal profile at highway travel speeds. The data from these systems can be used to compute the mean profile depth (MPD). ASTM E-1845 provides a more detailed explanation of the computation. Examples of equipment capable of measuring this are the C.T. Meter, inertial profilers, and the Robotex. The CT Meter is a static measurement device, while the Robotex is a slow speed, robotic controlled device. Inertial profilers are typically operated at highway speeds.

3.0 Measurement of Roadway Friction

Four basic types of full-scale devices are most commonly used to obtain direct measurements of pavement surface friction: **locked wheel**, **side force**, **fixed slip**, and **variable slip** testers. All of these devices can be equipped with tires featuring either a "ribbed" tread (one with longitudinal grooves on the tread surface) or a "blank" (smooth) tread. However, measurements obtained using ribbed tires are somewhat insensitive to macrotexture and are mainly influenced by microtexture.⁶

Locked-wheel trailers simulate emergency braking conditions for vehicles without anti-lock brakes by dragging a locked wheel on a pavement wetted with a specified amount of water. The brake is applied and the force is measured and averaged for 1 second after the test wheel is fully locked. Locked wheel testers are usually fitted with a self-watering system for wet testing, and a nominal water film thickness of 0.5 mm is commonly used. An example of this type of trailer is the ASTM locked-wheel skid tester.

Side force testers are designed to simulate a vehicle traveling though a curve. They function by maintaining a test wheel in a plane at an angle to the direction of motion (the yaw angle), while the wheel is allowed to roll freely.¹ Side force is measured perpendicularly to the plane of rotation. The main advantage to this method is that these devices can measure friction continuously through the test section (rather than over 1-second intervals, like the locked wheel devices). Examples of specific side force testing equipment include the MuMeter and the Sideways-Force Coefficient Routine Investigation Machine (SCRIM), both of which

originated in the United Kingdom.

The **fixed** and **variable slip** methods attempt to detect or operate around the peak friction level to simulate a vehicle's ability to brake while using antilock brakes. Fixed slip devices operate at a constant slip (usually between 10 and 20 percent slip) by driving the test wheel at a lower angular velocity than its free rolling velocity) while the variable slip devices sweep through a predetermined set of slip ratios (in accordance with ASTM Standard E 1859).^{1,7} Examples of fixed slip devices include the Grip tester and SAAB Friction Tester. A specific example of a variable slip device is the Norsemeter Road Analyzer and Recorder (ROAR). Fixed and variable slip testing devices have not been widely used on highway pavements in the United States and there is no current ASTM standard for fixed slip testing

In regards to the measurement of pavement friction, it should be remembered that hydroplaning is different from skidding on wet pavement. When hydroplaning occurs, the entire tire footprint is separated from the pavement by a layer of water and the pavement surface texture no longer plays a role in the friction process.

When a rolling tire encounters a film of water on the roadway, the water is channeled through the tire tread pattern and through the surface texture of the pavement. Hydroplaning occurs when the drainage capacity of the tire tread pattern and pavement surface is exceeded and the water begins to build up in front of the tire. This build-up creates a water wedge that can lift the tire off the pavement surface – a condition referred to as "full dynamic hydroplaning." Since water offers little shear resistance, the tire loses its tractive ability and the driver may lose control of the vehicle.

4.0 Measurement of Roadway Noise

Many sources of sound contribute to the overall level of sound that is generated in the highway environment, including:

- ✓ pure vehicle sources (e.g., mechanical sounds from the engine, drive train and exhaust as well as onboard equipment, such as refrigeration units in heavy trucks);
- ✓ aerodynamic effects, such as those that result from the passage of air around the vehicle and through the vehicle (e.g., into radiator and engine air intakes); and
- \checkmark the interaction of vehicle tires and the pavement over which they travel.

The noise produced from tire-pavement interaction is generally the largest individual source at vehicle speeds of more than 20 mph for cars, and more than 30 mph for trucks. Many factors are involved in tire-pavement interaction and the resulting generation of sound, including tire design, size, condition and loading, vehicle speed and pavement texture. If all other factors are held constant, traffic noise levels will vary mainly with the different physical characteristics of the pavement surface, such as porosity, texture, etc. In other words, pavements constructed using different materials but with identical surface characteristics will generate nearly identical sounds when subjected to identical traffic streams.

Outside of the vehicles, overall sound levels depend upon the distance to the sources, the presence of blocking barriers and reflecting surfaces, environmental conditions (e.g., wind direction and speed, temperature, etc.) and many other factors. Inside any given vehicle,

overall sound levels depend upon on the frequencies and levels of sound generated by the different sources and the ability of the vehicle to filter, block or "cancel" those sounds (though insulation, suspension characteristics, etc.).

Measured sound levels, both inside and outside of the vehicle, vary with the measurement approach (including the equipment used, the distance to the source, analysis techniques and other factors). Furthermore, sound measurements do not reflect everyone's perceptions of the noise because people have differing sensitivities to the same pitches and intensities of sound. Traffic noise that is very irritating to some people might not bother others at all. For example, an environment with an overall lower level of sound might be perceived to be louder or more irritating if it contains certain frequencies of sound that are missing from an environment with a higher overall level of sound. Therefore, it's not enough to simply compare total levels of sound to determine the "less noisy" of two pavement textures; frequency content and other factors must also be considered.

5.0 Measurement of Roadway Profile

Roadway profile measurements can be obtained using both low speed and high speed equipment. In the late 1950s, the California Highway Department developed a profilograph to evaluate pavement smoothness during the construction process. A Profile Index (PI) was established so that different roads could be compared and new construction specifications developed. The PI index was established by conducting a network survey of both flexible and rigid pavements and establishing the "threshold" of a good pavement. The threshold value for a good pavement was considered a PI index of seven inches per mile. That specification is still widely used in the construction industry for both flexible and rigid pavement construction.

In the 1960s, General Motors developed an inertial profiler which could measure the true profile of a pavement at a speed of approximately 25mph. With time, technology allowed the development of non-contact profilers, which allowed high speed testing. Today profilers have been developed for both high and low speed testing.

In 1990 the FHWA promoted the use of a standard roughness statistic, the International Roughness Index (IRI), which had been developed by the World Bank. This statistic was established so that a common metric could be used to evaluate roadways from cradle to grave.

6.0 Summary of Current Practice

Safety and Friction

Most agencies in the United States currently measure pavement friction using an ASTM locked-wheel trailer using either a standard ribbed or smooth (blank) tire (in accordance with ASTM E 274 or ASTM E 524, respectively).^{1,8} Testing is typically conducted at discrete distance intervals (such as mile post locations) at some designated time interval (such as annually). Results from this testing are then used within a pavement management system to determine necessary intervention times for safety purposes (e.g. correction of inadequate friction).

In 1980, the FHWA provided guidance to state and local highway agencies in establishing skid accident reduction programs through Technical Advisory TA 5040.17 "Skid Accident Reduction Program."⁹ This document was superseded in June 2005 by TA 5040.36.¹⁰ Neither document provides specific recommended values for minimum or desirable pavement friction test results

In practice, friction values of 30 to 40 (measured using a locked wheel trailer with a ribbed tire) have generally been considered acceptable for interstate highways and other roads with design speeds greater than 40 mph. Lower friction numbers have generally been accepted for pavements with low traffic volumes (e.g., average daily traffic of less than 3,000 vehicles) and traffic speeds less than 40 mph.

NCHRP 1-43 and 10-67 research projects are currently looking at friction guidelines and optimization of pavement texture, respectively.

Noise

Historically, noise mitigation and abatement has occurred through the use of distance or obstructions such as berms or walls. The FHWA established a maximum allowable noise level of 67 dBA for mitigation purposes. States are allowed to establish lower limits but cannot exceed the federal requirement on Federal Aid Projects.

In May of 2005, the FHWA began requiring the use of a new traffic noise modeling procedure called TNM 2.5 (Traffic Noise Model). The use of this new software is required for agencies to conduct noise mitigation analysis during preparation of the environmental impact assessment on federally funded projects. The new methodology replaced the older software, called STAMINA, which was developed in the early 1970s in a four-state study. Since the development of STAMINA, many changes have occurred, including fleet changes on the highways, and significant improvements in both software and noise modeling, enabling a more sophisticated approach to be taken. The new study began by developing a national Reference Energy Mean Emission Level (REMEL) database.

The new TNM software has many advantages over the previous software. For one, it can evaluate the effect of four different pavement categories; Average, Dense-Graded AC; Open-Graded AC, and Portland cement concrete. The average pavement is arrived at by combining approximately 75% dense-graded asphalt pavement results with 25% concrete pavement results. Currently, the average pavement category is the only approved surface type that can be used in modeling. The only exception to this is the Arizona Quiet Pavement Pilot program where surface type effect has been allowed as a noise mitigation strategy.

Roughness

Roughness measurements are typically obtained for two purposes: construction acceptance and system monitoring. For system monitoring, such as with a PMS, high-speed profilers are used almost exclusively with measurements at highway speeds. The measurements are typically obtained continuously over some finite length, such as a mile, and are assigned to a locator such as a milepost location. This allows a PMS system to evaluate the change in properties over time. The International Roughness Index is used almost exclusively for this evaluation.

The data is also obtained to support the FHWA Highway Performance and Monitoring Systems (e.g. HPMS) and the required input for this is the IRI statistic.

Newly constructed pavements are evaluated with both low-speed and high-speed measurement devices. For flexible pavements, the high-speed profiler is more commonly used, although profilographs are still used for construction monitoring. For concrete pavements, the profilograph device and profile index statistic are more common. An increasing number of agencies are replacing the profilograph equipment with light-weight profilers, but they generally still require the measurement index to be the profile index.

<u>Issues</u> Safety

Pavement texture plays an important role in roadway safety issues. There are more than one million deaths and 50 million injuries annually on highways and roads all over the world, with more than 40,000 deaths and 3 million injuries annually in the U.S. alone.¹¹ Research indicates that about 14 percent of all crashes occur in wet weather, and that 70 percent of these crashes are preventable.¹² Two primary causes of wet weather crashes are 1) uncontrolled skidding due to inadequate surface friction in the presence of water (hydroplaning), and 2) poor visibility due to splash and spray. Pavement surface texture characteristics play an important role in both of these safety-related phenomena. Inadequate friction contributes to many accidents in dry weather as well, especially in work zones and intersections, where unusual traffic movements and braking action are common.

It has been reported that 10 percent of wet weather accidents are caused by reduced visibility due to splash and spray (especially at night) and that 15 to 35 percent of wet weather crashes involve skidding.⁴ Research suggests that up to 70 percent of wet weather crashes can be prevented with improved pavement texture/friction.¹³ If wet weather crashes account for about 19 percent of all fatal crashes, improved pavement texture/friction could reduce overall highway crash, fatality and injury rates by 13 percent (i.e., 5600 fewer deaths, 390,000 fewer injuries and 3.25 million fewer accidents in the U.S. each year).

In a 2004 Australian study, macrotexture levels were strongly correlated with crash rates for most of the pavement locations and categories that were studied, particularly at intersections. The lower limits of satisfactory surface texture were determined to be 0.4 and 0.5 mm (measured using laser-based devices), respectively, for two different highways. Crash risks were determined to be 1.8 and 1.9 times higher, respectively, when average macrotexture dropped below these critical values.¹⁴ The authors estimated that 13 to 17 percent of all crashes on the two study highways could be prevented by improving all low macrotexture sites.

A 1999 survey of U.S. highway agencies revealed that only 11 of 42 responding agencies had published minimum acceptable levels for skid resistance.¹ It appears that many highway agencies are reluctant to assign minimum acceptable friction levels for highway pavements because of liability concerns.

It follows that good surface texture can prevent many of these accidents, thereby reducing the number of deaths and serious injuries. Pavement engineers must select surface textures that

reduce the potential for hydroplaning at higher speeds while providing sufficient surface drainage so that splash and spray are minimized. 4

Noise

The current noise mitigation procedures require the use of wayside noise measurement equipment. This testing is both time-consuming and expensive to conduct. As such, there has been recent interest in near field noise measurement techniques, such as On-Board Sound Intensity (e.g. OBSI). Unfortunately there are no current standards addressing this technique. The FHWA and ASTM are both working on standards to alleviate this, but none presently exist.

TNM 2.5 does not allow the designer the ability to use pavement surface type as a noise mitigation strategy. The reason the FHWA does not provide this capability is due to the changing acoustic properties of pavement surfaces over time. Many pavements become noisier over time as a result of surface attrition. These changes in acoustic properties makes it necessary to establish what those changes are and how best to measure them. Currently, the OBSI technique is the de facto standard for measuring acoustic changes over time in the US. However, with no established test procedure, and no standard test tire, there is concern as to the viability of this technique in the near term. In addition, there is presently no way to use OBSI data to modify the TNM REMEL database, which would be necessary to allow the use of pavement surface type as a variable.

Current noise mitigation requirements involve only the dBA level of the noise source. Consumer annoyance is not exclusively related to level alone and a need exists to establish a better annoyance metric than source dBA level.

Profile

The profilograph has served both industries well over the past 50 years, providing improved pavement smoothness and monitoring. However, technology and equipment have evolved such that more meaningful measurement statistics and equipment should be used for both construction acceptance and performance monitoring. Pavement roughness should be measured using profile type equipment with IRI as the roughness statistic. To achieve this, further refinement of the sensors must occur to allow coarse-textured pavements to be measured properly. Currently, many sensors with small foot prints will misrepresent actual pavement roughness. Additional research is needed to overcome this deficiency and to provide improvements in operational conditions, such as unlevel and curved terrain, and pavements with significant color changes.

7.0 Potential Research Projects

- Develop procedures for determining the acoustic performance curves of selected pavements and develop procedures for incorporating them into TNM.
- Promote the use of the International Friction Index as the preferred measurement statistic for friction.
- Evaluate the preferred measurement technique for best assessing roadway safety in terms

of a vehicle fleet that uses ABS braking systems.

- Evaluate methods for providing continuous friction (i.e., safety) measurements instead of discrete location measurements.
- Develop friction/safety standards appropriate to the roadway needs.
- High Speed 3-D texture measurement equipment.
- o Develop Splash/Spray measurement equipment and standards.
- o Development of a better noise annoyance metric.
- o Development of rolling resistance measurement procedures and equipment.
- Development of procedures for predicting noise level and friction levels from texture measurements.

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H-8 PAVEMENT PRESERVATION TREATMENT PERFORMANCE

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1.0 Introduction

Pavement performance is an important element of a program for pavement preservation PP). Evaluation of pavement performance is a critical step for agencies seeking to find better design procedures and more enduring materials. In particular, the effect of preventive maintenance treatments on pavement performance needs to be understood to increase the effectiveness of pavement preservation programs. As it stands, the relationship between performance and treatment is not clear, since the effect of PP treatments on pavement performance has not been well studied.

This paper discusses the concept of pavement performance, factors that affect performance particularly treatments, the role of performance in developing performance specifications, and the importance of training and policy for improving pavement performance. The paper will finally address key issues for applying performance measures in pavement preservation programs. In the conclusion, the paper makes suggestions for future suggested projects related to PP performance.

2.0 Concept of Performance

Performance is basically defined as the durability and longevity, i.e., the amount of maintenance activities required to maintain the required level of service during the design life of a pavement. Performance of a pavement is dependent upon a combination of many things, including construction practices, materials, materials production control (1), traffic loads, climate, and the substrate.

Cost justification is a central factor in performance. Optimal performance is determined, not only by the durability and longevity of a pavement, but by sufficient time to failure or to reconstruction in order to justify the use of any particular methodology or set of materials. Factors that must be taken into consideration include cost of construction, traffic density, environment, and numerous other factors. (2)

Performance is also contingent upon the specific agency context. Performance measures should be defined in response to the goals and objectives of a particular agency, which are directly aligned with its broad goals and mission. To be effective, performance measures should be based upon technically sound data, which is understandable at all levels of the agency, and reflects the needs and interests of users and stakeholders. (3)

3.0 Key Factors Affecting Performance

As previously mentioned, determining the best approach to obtaining optimal PP performance is dependent upon many interrelated factors. Among the most basic factors to be taken into consideration are which treatments, materials, and treatment strategies to use and the optimal time to apply them, and these must be based on the condition of the pavement. Some of the most important factors affecting performance of PP methods are the materials used, including asphalt binder, aggregate, and additives/admixtures. These materials should be evaluated both individually and together to evaluate their potential effect on performance. PP performance is especially sensitive to the materials used in the treatment. Many years of practical experience and laboratory research have demonstrated that slight differences in the composition of materials can result in less satisfactory performance of the treatment or even premature failure.

Asphalt binders play a large part in extending treatment life. The life of a correctly designed asphalt surfacing, placed on a structurally sound pavement, can be greatly affected by the performance of the asphalt binder. The treatment deteriorates if the asphalt binder rapidly hardens with time until it can no longer withstand movement caused by diurnal temperature changes and cracking occurs, or when the bond between the aggregate and the binder fails and stone particles are displaced by traffic. (4)

Superpave performance-graded (PG) specifications are improving the life of binders in specific conditions of climate and traffic. Under the PG specifications, modifiers, such as elastomers, plastomers, fibers, and pulverized rubber are used to produce mixes with greater potential to withstand climatic stresses and to support heavier loads, thus extending pavement performance. However, the PG specifications have not yet been related to pavement preservations techniques. Asphalt binders are in need of PG specifications to better meet the demands of PP.

A shortage of materials puts constraints on achieving an optimal mixture design. An increasing number of restrictions are being placed on certain locally available (sometimes high-quality but inexpensive) aggregates due to environmental and zoning laws. As a result, there is a growing need for recycling existing materials. Pavement cost is decreasing through the introduction of reclaimed asphalt pavement (RAP) into HMA mixes and refinement of recycling methods. However, as a result of these innovations, more extensive laboratory analyses may be required to achieve a satisfactory mix design. The incorporation of RAP and resultant performance of RAP mixtures as well as the inclusion of modified asphalt binders should be studied in more depth (5) with a specific focus on PP treatments.

The choice of treatments and treatment strategies is another key factor effecting performance. PP treatments are evaluated with time to determine their relative performance. The method of measurement, as well as whether one evaluates potential or actual failure modes (e.g., rutting, cracking, raveling) can significantly effect the evaluation of performance (6). The performance of a specific treatment can be difficult to measure, since the same treatment under different pavement conditions will perform differently. (7)

The most common performance measure of PP treatments reported in the literature—life of the treatment—is not the most reliable, since the performance of a particular treatment may not be a

good indicator of how the overall pavement system performed. The extension of pavement life provided by the treatment, on the other hand, may possibly be the most important and the most useful measurement for planning and for pavement management systems. Such a technique must take into account both the life of the treatment and the effects of the pavement condition prior to applying the treatment. (8)

Appropriate timing for the application of a treatment has significant influence on the performance of the treatment and the pavement. It is crucial to identify the optimal time to apply a treatment. Placing a PP treatment on a road after structural damage has appeared may not prove cost effective and, in fact, may cause additional problems, such as faulting, severe cracking, and rutting, while too early of an application will result in an unnecessary expenditure. To determine the most cost-effective time to apply a PP treatment, performance standards and indices (9) need to be established through research, including collection of performance data. These indices should be descriptive of the environment in which the treatments are to be used and should include, not only pavement conditions, climatic data, material properties, and traffic loading, but also agency resources and funding limitations. (10)

Specifications generally call for key materials and construction quality characteristics that have been demonstrated to correlate with long-term performance. Performance-related specifications are based on quantified relationships between characteristics measured at the time of construction and subsequent performance. Typical specifications include sampling and testing procedures, quality levels and tolerances, acceptance or rejection criteria, and payment schedules with positive or negative adjustments. Performance models that predict changes in the anticipated pavement life resulting from different quality levels have been used to quantify the pay adjustments. (11)

Performance-related specifications aim to achieve the best balance between cost and performance and to assure that this balance is attained throughout construction via quantification of the quality level. Such specifications incorporate the best understanding of what determines quality, and they maximize cost effectiveness through a contractual framework. However, new testing techniques and a better understanding of the relationship between fundamental engineering properties and subsequent performance of the constructed product are required to create more accurate specifications. Engineering properties must therefore be quantitatively measured during application of the PP treatment. (11)

Current efforts to develop performance specifications for PP treatments are not sufficient. An increased effort to adopt a broader range of materials and processes used in pavement preservation activities is required. Agencies must be open to new ideas for pavement maintenance in order to advance technologies to meet the demands of their customers. Training and policy issues are particularly important for promoting the adoption of new specifications within agencies and to ensure support and understanding from all vested parties. (7)

Training needs to address the design and construction of preventive maintenance treatments. Courses need to modular in nature so that agencies can select modules of interest to them. Courses should be targeted towards two particular audiences: those unfamiliar with new maintenance techniques and those who need a refresher to improve their PP treatments. The ultimate goal of training programs should be to improve the overall quality of the treatments applied by agencies and to ensure that they serve their purpose in extending the performance of the pavement. (11)

4.0 Applying Performance Measures in Pavement Preservation Programs

The measurement of pavement performance has become fairly well systematized among highway agencies. Agencies have implemented pavement management systems, which utilize field testing and surveys of actual road sections on a periodic basis to monitor performance. In addition, agencies utilize highly effective quality control/assurance programs, which measure material properties considered to be critical to long-term performance. This data is best grounded by pavement performance models, which correlate PMS data to material properties. (12)

However, measuring the effects of various PP treatments on pavement performance is more problematic. As delineated above, measuring the effectiveness of a treatment is a complicated issue that can be biased by the method of measurement. Current surveys of PP treatment performance primarily focus on how long the treatment itself lasts. Problems with this method of measurement include the definition of treatment life (e.g., whether it should be defined as the life of the treatment or the extension in the pavement life) and how to measure the effect of the treatment on actual pavement performance. Further research is required that correlates preventative maintenance activities to pavement performance and expected extension in pavement life. Furthermore, since treatment and pavement performance are dependent on the time at which treatment is applied, the effects of the time of application upon pavement performance should be investigated in conjunction with such studies. (13)

Existing information on the impact of performance on the effectiveness, costs, and benefits of pavement preservation currently suffers from a lack of standardization. Most of the data on the effectiveness of pavement management resides within agencies and comes from observational experience. Nonetheless, transportation agencies can still apply this knowledge and take advantage of the cost effectiveness of pavement management. As previously mentioned, the matter of the cost effectiveness of pavement preservation treatments is far more problematic. Although this is very important information, literature on this issue is limited. An effort to fill in the gaps of information on pavement preservation treatments as well as creating a widely available literature on the cost effectiveness of performance, in general, is necessary, since performance is important to maintenance and rehabilitation activities for overall planning and budgeting purposes. (14)

5.0 Suggested Future Projects

The literature on pavement preservation suggests the following key areas of focus for pavement performance, in order to bolster existing knowledge of performance to improve strategies and techniques for pavement preservation:

• Effects of pavement preservation treatments on pavement performance. As this paper has repeatedly stressed, the effects of various treatments on pavement performance

need to be documented more clearly. Since the effects of a treatment on pavement performance and the performance of a treatment itself are two different things, they should be evaluated separately. To accomplish this in several areas of the US, thorough, standardized measurement techniques are required, which incorporate integrated pavement performance data, including costs, benefits, and effectiveness of preventive maintenance through well monitored tests under different conditions (e.g., climate, traffic, and the treated pavement). The relations between treatment performance and different factors such as traffic, climate, material, and construction also need to be Enhancement of performance through pavement preservation should be evaluated. evaluated through the change in comfort, convenience, safety, and life-cycle cost. Although the specific performance of a preventive maintenance treatment may not be directly transferable from agency to agency or from one geographic region to another, due to differences in the condition of the pavement at the time of treatment application, the current condition of pavement, surface and subsurface drainage conditions, types of materials used, quality of workmanship in applying them, and various other disparities, there is still value to be gained in generalizing such research. One may expect that, if a specific treatment performs well in one location, it will perform equally well in comparison to other treatments in another location with similar conditions, if applied properly at the correct time.

- **Treatment impact on functional performance.** Since preventive maintenance treatments address functional issues, more research is needed to understand the effect of various treatments on functional performance factors (e.g., noise, friction, and smoothness).
- **Optimal timing for treatment.** The proper timing for a treatment is an essential and under-studied factor. The timing of treatment has its own significant effect on pavement performance (too early an application exhausts resources, while too late an application may have an adverse effect on performance). Important questions to consider in this matter include how to best measure timing for treatment and what tools to use for measurement. A sound method should be developed to identify when the application of the treatment is most beneficial. Furthermore, as previously mentioned, this research needs to be incorporated into research on pavement management in general.
- Measurements of performance that better reflect benefits of pavement preservation. Traditional measures of pavement performance, and certainly those most associated with network monitoring as part of pavement management, are closely associated with pavement failure (e.g., cracking, rutting, raveling, faulting). Although there is no consensus on which measures are most meaningful, it is believed that these measures do not always reflect the benefits of pavement preservation treatments. Research is required to determine which performance measures truly identify those performance characteristics that best determine whether their pavement preservation goals are being met.
- **Definition of treatment failure.** The definition of failure is important for the measurement of performance. Even though failures for pavements are well defined, this

is not sufficient in itself for understanding and evaluating performance of pavement preservation treatments. Failure of a pavement and failure of a pavement preservation treatment need to be investigated separately. The definition of failure should include initial cost of the treatment.

- **Construction and monitoring of treatment test sections.** Test sections are among the best tools available to evaluate treatment performance and the effect of treatment performance on pavement performance. While constructing, monitoring, and analyzing the findings from effective test sections is perhaps best done at the local level, nationally coordinated efforts could be used to address particular concerns, such as the effect of pavement preservation treatments on smoothness, safety, and noise.
- **Research on Performance Specifications and Materials.** Since performance specifications balance cost and performance and drive the determination of which methods and materials to utilize, performance-based specifications should be developed for pavement preservation treatments. Research on the latest materials and methods for treatments should be gathered and utilized for the development of performance specifications. Research is needed to provide a better understanding of ideal available construction materials to achieve optimal performance at minimal cost. Asphalt binders are in need of performance-based specifications to better meet the demands of pavement preservation. There is also a need for research in recycled materials and their relationship to performance, since they are now being used more often.
- **Training tools.** Training tools should be developed and related to new findings in the area of pavement preservation performance. Such training should lead to a better understanding of pavement preservation activities, which in turn, should lead to more broad-based support for preventive maintenance. Training should address the latest materials and methods as well as the need for dedicated funds for pavement preservation and management support. As previously mentioned, the training should target both those unfamiliar with preventive maintenance techniques and those who require a refresher.

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APPENDIX I – BRIDGE PRESERVATION WHITE PAPERS

I-1 BRIDGE ASSET MANAGEMENT & BRIDGE PRESERVATION

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1.0 Introduction- Why This Is Important

An important component of the proper care of a single bridge, or a large network of bridges, is a comprehensive bridge preservation program predicated on the strategy of doing "the right treatment on the right bridge at the right time". Many times the most effective preservation strategy is applied on bridges in good condition or ones that have only minor distress. Most of the time, good bridge preservation treatments do not increase the structural or functional capacity of the bridge. Effective preservation strategies are applied on bridges in good condition, or on ones that have only minor distress. In addition to the in-service bridge inventory, an owner must design bridges with sound preservation details that will return low life-cycle costs.

Competition for limited funds requires a change from previous practices where an agency had larger funding sources and replacements and upgrades were commonly perceived as the most feasible action. Now that the funding is tighter, this strategy is too costly. In addition, the administrative and environmental issues associated with the replacement of existing bridges introduce complexities that increase costs and the ability to implement timely projects. These issues are forcing bridge owners to seek new processes to manage their inventory. Although "worst-first" may have been an acceptable policy in the past, modern bridge maintenance practice, the reality of funding constraints, and public expectations, indicate the need for a well-planned preservation program that is pro-active and efficient.

Some key issues in defining a preservation program include:

- Defining the difference between reactive maintenance, preventive maintenance, preservation and rehabilitation.
- Development and definition of bridge preservation strategies.
- Developing deterioration models for the bridge as a whole and for the preservation work.
- Development of bridge management policies that address the interaction of network benefits and needs with individual bridge benefits and needs.
- Paradigm shift from "reactionary" correction to "planned" correction and from "wait and watch" to pre-emptive actions.
- Education of management and technical staff in the process of bridge asset management and life-cycle analysis.

Many of the items outlined above are related to other topics in the bridge asset management field. The focus of this paper is development of a systematic process to implement the most effective action.

2.0 Background

Why is this area important?

Since the cost of construction has out paced the funding for bridges, an alternative process was needed for bridge inventory work prioritization. The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) fueled the need for development of management systems and systematic processes for development of maintenance, repair, rehabilitation and replacement (MRR&R) strategies for the nation's inventory of bridges. This process required integration of several existing processes. The development of a Bridge Asset Management and Bridge Preservation Program can include many factors but the most important are:

- Collecting, processing and updating of data. Data collected must support safety compliance and asset management goals.
- Predicting deterioration. Deterioration prediction needs to follow field observations over time to enable a reliable assessment of the outcomes of policy decisions.
- Identify alternative actions. Apply the appropriate action based on environmental conditions, traffic mix and life-cycle effectiveness.
- Predicting cost. Apply cost models based on standard data available to the asset manager.
- Determining optimal policies. Develop policies that maximize condition and minimize cost over the long-term.
- Performing short and long-term budget forecasting. Determine funding needs in operational accounts as well as capital requirements in the States Statewide Transportation Improvement Plan (STIP) and regional or statewide network long-range plans.
- Recommending programs and schedules for implementation within policy and budget constraints. Development of project budgets and scopes that are aligned with agency scoping and estimating processes.

What sorts of issues are known to be hindrances to preservation?

The integration of these processes reveals several barriers to developing an effective management strategy. These can be summarized following the seven factors discussed above.

• The data collected for bridge management are misaligned between safety compliance and asset management. The two data sets have different objectives and needs. Over the past decade, asset managers have responded by developing specifications for element-level inspections, separating severity from extent of deterioration to improve the utility of data for asset management. Working with this new information has uncovered the need to further describe bridges by separating structural element defects from protection element

defects. In addition, historical maintenance actions are not accounted for in the data collection for future model actions.

- The development of deterioration models has depended on "expert" opinion. As agencies have gained experience with these models, they have found a number of shortcomings in the use of human perceptions of long-duration or unusual deterioration processes. Alternative approaches will be needed to overcome these issues and build more trust in the forecasting capabilities of management systems. Such trust is necessary in order for managers to feel confident in moving away from "replacement-in-kind" approaches to more strategic approaches that use "remaining life" or "life-cycle cost" of an asset with preservation activities.
- The development of preservation treatment alternatives is in its infancy. Most of the action items currently considered are based on past reactionary maintenance activities. They are typically evaluated based on the immediate effect on condition, rather than long-term efficiency. The least-cost action may not return the best long-term life-cycle solution.
- The development of cost models has been one of the elusive parts of the bridge management system. The current bridge inventory element units of measurement are not aligned with internal business processes of an agency. The assumptions that a manager makes to close the gap between the contract and/or maintenance management systems does not align with individual projected project costs. In addition, costs that are captured in most systems are the direct costs associated with construction or maintenance of an element or a group of elements. The capture of soft or indirect costs associated with a project is missing or not aligned with business processes. These costs include items like mobilization and traffic control as well as design and construction engineering costs.
- Optimal policy needs have been driven by initial cost and activity type. Risk and lifecycle cost also need to contribute to optimal policy and need to take into account service and environmental conditions.
- Developing network level budget strategies for long-term planning has been the end product of current bridge management analysis software. The relationship between long-term predicted needs and development of short-term projects has been disjointed. Many practitioners struggle to align the long-term network forecasted needs with the agency's short-term project level plan.
- Development of project scopes and budgets need to fit better with agency business practices and policies.

The culture of an agency can have an effect on the implementation of a management system and preservation program. Several cultural hindrances can be summarized from the following:

- Many agencies have only anecdotal information to demonstrate preservation benefits. For example, what are the cost savings, both to the agency and the user, and the corresponding improvements to the overall network condition when using bridge preservation techniques?
- Cost and benefit outcomes of bridge preservation decisions may be spread among many parts of the agency (e.g. programming, design, construction, maintenance, and overload permitting) and are difficult to integrate.

- Agencies often lack confidence in using unfamiliar treatments and may lack performance related tests and specifications for most bridge preservation treatments.
- Analysis engines are often developed with only budget constraints. Upper management is looking for direction on the question "What level of service can the agency afford?"
- Management acceptance of data from a forecasting system is needed to provide sound short and long-term strategic direction.
- Agencies sometimes lack trained personnel to collect and analyze maintenance and deterioration data.

Issues

There are important linkages between bridge design and preservation decisions. Some of the questions which need to be explored in more detail at this workshop are discussed below. We need answers to these questions in order to advance bridge preservation throughout the industry.

How does the design topic relate to preservation programs?

- Design elements are an important part of bridge preservation programs because they affect the feasibility and efficiency of different preservation approaches.
- All agencies should have a process for strategy selection that is sensitive to material and design-type of bridges.
- Economic analysis should be a part of the strategy selection process once suitable design or treatments are selected.
- The cost, benefits, and improvements to the bridge network must be documented to a much better extent. We cannot continue to rely on anecdotal information.
- Optimal timing of treatments still hasn't been fully addressed.
- Certain preservation treatments have a limited ability to be applied multiple times over a structure's life-cycle before a more expensive rehabilitation treatment is required. The effectiveness and limitations of this sort of repetitive policy need to be studied.
- Valid justification for delaying rehabilitation, reconstruction and replacement in bridge preservation programs is needed.

How do research and information gaps in the design area present obstacles to the implementation of bridge preservation programs?

- The most important issue for most agencies is whether bridge preservation treatment is cost effective when compared with bridge rehabilitation.
- Without documented information on the expected life extension from applying bridge preservation treatments, it is difficult to document the benefits of bridge preservation programs.
- Variable performance of many of the treatments is a major cause of concern by agencies. The reasons for the variable performance have to be addressed.
- In preparing economic analysis, there may be a need to establish different analyses periods for bridge preservation cost studies when comparing them with rehabilitation projects.

- Most new bridges are designed for an arbitrary life span without consideration of future functional requirements at the bridge site. As the bridge ages, the analysis of the remaining functional life of the bridge could influence preservation decisions.
- User cost models for bridges need better definition both for work zones and for ongoing service. The development of such a model could include:
 - Accident user costs
 - Detour cost this is for both parallel bridge and single bridge configurations
 - Traffic Delay costs
 - Vehicle operating costs
 - Time value of money
 - Mobilization
 - Traffic control
 - Contingency
 - Design and Construction Engineering
- There is a need to develop ways of incorporating engineering risk into the analysis action effectiveness. These modeling items could include:
 - o Earthquake
 - o Scour
 - o Flooding
 - Material failure due to fatigue
 - o Overload failure
 - Vulnerability to other natural and man-made hazards

Summary

Several studies and projects have been completed that deal with addressing issues to improve bridge management and bridge preservation. These include:

- FHWA Demonstration Project 71 AASHTOWare Pontis Bridge Management System
- NCHRP 12-28(2) Report 300 BRIDGIT
- NCHRP 12-43 Report 483 Bridge Life-cycle Cost Analysis
- International Technology Exchange Program, "Bridge Preservation and Maintenance in Europe and South Africa"
- NCHRP 18-6(A) Report 558 Manual on Service Life of Corrosion-Damaged Reinforced Concrete Bridge Superstructure Elements
- NCHRP 12-67 Multiple-Objective Optimization for Bridge Management Systems
- NCHRP 14-15, National Database System of Maintenance Actions on Highway Bridges
- National Bridge Investment Analysis System (NBIAS), Federal Highway Administration (FHWA)
- "Reliability-Based Life-Cycle Management Of Highway Bridges" By Dan M. Frangopol, Jung S. Kong, and Emhaidy S. Gharaibeh; Journal of Computing in Civil Engineering, January 2001
- National Bridge Preservation Workshop, St. Louis, MO April 17-18, 2007

In all of these reports, specific research needs have been identified. Some have been completed while others simply lacked the needed funding to permit the work to be undertaken. This section

summarizes some important research needs in the preservation area and identifies the steps needed to draft project statements.

5.0 Potential Research Projects

- Determining what bridge attributes to measure in order to assist agencies in selecting bridge preservation activities.
- Develop performance indices for targeted bridge elements or group of elements in particular reflecting the performance of protective systems.
- Identifying the proper timing for bridge preservation treatments.
- Determining threshold limits (or trigger values) and other warrants for bridge preservation activities.
- Development of deterioration models of bridges in relatively good condition subject to alternative preservation treatments.
- Determining expected treatment lives and/or life extension as a function of existing bridge conditions for the various bridge preservation treatments.
- Development/enhancement of treatment selection guidelines.
- Development/enhancement of a process for evaluating cost effectiveness of treatments compared with rehabilitation.
- Developing the optimal timing for treatments and verification of NCHRP studies using field projects.
- Developing appropriate bridge preservation treatments for urban and rural areas.
- Integrating preventive maintenance and bridge management.
- Estimation procedures for agency and user costs associated with bridge work zones and project development.

Steps To Be Considered To Develop Research Needs

This section is likely similar for all of the white papers:

- Identify the problem.
- Develop specific objectives for the study.
- Identify important work tasks.
- Identify the expected deliverables.
- Identify the level of effort and costs needed to do the work and the time needed to get it done.
- Identify an implementation plan for the project.

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I-2 OVERLAYS AND SEALERS FOR PRESERVATION OF CONCRETE BRIDGE ELEMENTS (DECKS)

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1.0 Introduction/Background

Bridge decks are the most critical element of highway bridges with respect to exposure to traffic, moisture, and roadway de-icing chemicals. Highway users demand bridge decks to be in good condition without potholes, and they expect a smooth ride as they travel across a deck. Users are adversely affected by any preservation or rehabilitation work done to a bridge deck. All of these factors contribute to the need for State Departments of Transportation (DOT's) to develop the most cost effective ways to preserve bridge decks for the longest duration possible by using methods that cause the least overall disruption to traffic.

DOT's undertake many different types of bridge deck preventive maintenance and preservation activities. For the purposes of this paper, preservation maintenance activities include both preventive maintenance activities that prevent further deterioration of a bridge deck (such as washing, crack and concrete surface sealing) and more common preservation maintenance activities that either replace the element or improve its condition (such as spall and delamination repair and overlay placement or replacement).

There are various hindrances that state DOT's face in implementing a quality bridge deck preservation program. Among these are:

- preservation maintenance activities cause user delays on the roadway
- adequate funding is not available for preventive maintenance since funds are allocated to more common preservation maintenance activities that repair advanced deterioration
- research is not readily available addressing the effectiveness of various preservation activities and cost-benefit analysis of various products
- many DOT's do not have dedicated bridge maintenance crews available to perform costeffective bridge preservation activities

2.0 Issue

A bridge deck preservation program relates to overall bridge preservation since a well preserved bridge deck prevents deterioration of underlying bridge elements. Bridge decks deteriorate when

water and chlorides from road de-icing chemicals are able to pass through cracks in the concrete deck and begin to corrode the reinforcing steel. When reinforcement corrodes, the rebar expands and causes spalls in the deck which then allow more chlorides to penetrate to the level of the rebar and the deterioration advances. Bridge decks also deteriorate, but more slowly, when the chlorides permeate through porosity in sound concrete to the level of the rebar.

Bridge deck life can be increased by keeping chlorides from penetrating through deck cracks and through the deck itself by use of crack sealers and concrete surface sealers. Washing bridge decks is one way to remove chlorides before they penetrate the concrete. There are many sealers on the market today that are used by DOT's specifically to seal the bridge deck surface or to seal cracks. These products include silane and siloxane surface sealers and high molecular weight methacrylate and epoxy surface and crack sealers. Among the difficulties faced by DOT's is deciding which of these products are most effective at sealing deck surfaces at various stages of deterioration, which manufacturer's product performs best, and how often crack sealing and concrete surface sealing should be performed.

There have been various studies over the years on the effectiveness of sealers, including a Wisconsin DOT study in 2005, a Minnesota DOT study in 1995, a South Dakota study in 2002, etc. All of these studies show various levels of effectiveness of products. A comprehensive compilation of the studies would help states to identify both the type of product (silane, etc) and material properties and tests that identify the best performers. A comprehensive study would provide data on the long term effectiveness of surface sealing and crack sealing bridge decks and provide a cost/benefit ratio of such application. In the absence of thorough research, it is difficult for DOT's to rationally allocate funding to preventive maintenance activities.

Once a bridge deck deteriorates to the point where the overlay surface is saturated with chlorides and there are areas of delamination, spalling, and repair on the bridge deck, the DOT must take action to either preserve the deck or to let it deteriorate to a condition where replacement is the only option. Preservation activities may include adding a low slump concrete or thin polymer overlay to a bare concrete deck, milling off the in place overlay and replacing it with a new concrete (or bituminous with membrane) overlay, or performing quality repairs on the unsound areas. Again there have been research projects investigating the effectiveness of various deck preservation activities (such as Minnesota DOT 2007 study pending final paper) but more work could be done to compile these studies into a single reference and format useful to bridge preservation decision makers.

3.0 Incorporation of Bridge Deck Preservation into Bridge Management System (BMS)

Bridge deck maintenance comprises a large part of a DOT's bridge program. At this time there is no easy and rational way to incorporate preventive maintenance activities (such as washing and sealing) into a BMS since performing the activity does not improve the condition state of the element. The authors realize there is some work being done to incorporate preventive maintenance activities into a BMS, and additional research should be provided as needed to further the ability for DOT's to show the effectiveness of bridge deck preventive maintenance.

The main topic would be to tie the deterioration rate of elements to preventive maintenance expenditures in various environmental states.

4.0 State of the Practice in Bridge Deck Preservation

In most states preventive maintenance activities such as silane, siloxane, high molecular weight methacrylate, or epoxy concrete surface sealing is not often performed on new bridge decks due to the lack of funding for such work, or due to consideration for user costs related to commute delay while work is performed on a bridge that is restricted or closed. Research is needed to help DOT's identify how concrete surface sealing during or shortly after construction can extend the life of bridge decks by reducing the rate of chloride intrusion into the concrete. User costs for preventive maintenance activities conducted over several days during the first 20 years of a deck life should be compared to user costs for more traditional preservation maintenance repairs conducted over a longer duration, once or twice during the deck life. Bridge deck crack sealing is performed in some states by tracing epoxies or high molecular weight methacrylate directly onto the crack, or alternately by flood coating the deck with the crack sealing materials. This work is usually performed when the bridge deck is still in good to fair condition. Sealing the cracks prevent chloride intrusion, and intuitively is a cost effective measure. After the deck deteriorates to a certain point, crack sealing no longer is effective. Bridge deck washing is performed in some states, but the value added toward extending the life of the bridge deck, joints or drains is not easily quantifiable.

Preservation activities such as placing a new concrete overlay (latex modified concrete, low slump concrete, high performance concrete, etc.) are most often completed after deterioration has occurred and/or chlorides have saturated the upper portion of the in place deck and/or overlay. Thin polymer overlays that are currently used by many state DOT's can be placed directly on the existing bridge deck surface after cleaning. Polymer overlays vary in product type (epoxy, polyester or methacrylate resin based) as well as type of application (chip seal, multi coat or slurry). Membranes and bituminous overlays are also used by some DOT's to provide some protection and provide a smooth ride.

Electrochemical processes can be used to provide sacrificial elements (embedded pucks, spray on materials, etc.) such that reinforcement does not corrode as rapidly.

5.0 Gaps in Knowledge

Conditions that trigger when to apply crack and concrete surface sealers vary from State to State. A comprehensive source providing trigger conditions for the most effective times to perform those activities is warranted. Triggers would include how the condition state of the deck (especially cracked vs. uncracked deck) influences the selected application.

Products such as linseed oil are often used at time of construction in an effort to help seal and cure bridge decks. Linseed oils can adversely limit the penetration of other sealing products for future application. Other sealing products including silanes and siloxanes could be used instead

of linseed oil at contract time. Some silanes and siloxanes contain very high VOC content and therefore are not permitted in many states. The primary function of linseed oil, silane and siloxanes is to make cracks and the porosity of concrete hydrophobic. They do not actually fill or seal the cracks and lose effectiveness over time, due to the environment and traffic. Research is needed to determine their performance level and establish a time when reapplication is appropriate or required.

6.0 Potential Research Projects

- Effectiveness of linseed oil, silanes, siloxanes, high molecular weight methacrylates, and epoxy as concrete surface sealers
- Effectiveness of crack sealing with epoxy, high molecular weight methacrylate, or other materials
- Effectiveness of patching unsound decks versus complete replacement of the overlay
- Application of preventive maintenance activities into a BMS
- Reducing cracking in dense concrete overlays (not a preservation research item, but valuable for extending overall bridge deck life)
- Comparing effective preservation activity needs and life cycle costs for black bar, epoxy bar, and stainless steel bar bridge decks
- Compare the life cycle costs for various types of bridge deck overlay methods

I-3 BRIDGE DECK JOINT PRESERVATION

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1.0 Introduction

The typical bridge deck is made of reinforced concrete, which provides a rigid, impact-resistant, surface that distributes vehicular loads across the superstructure. It also covers and protects critical structural members against surface water which combines with roadway contaminants such as deicing salt. Openings are constructed in the concrete deck to provide a space for thermal expansion and contraction. These deck openings are called deck joints. Unfortunately, they provide a passageway for the water and contaminants to drain from the deck onto the critical structural elements that support the bridge. This drainage accelerates the corrosion of the steel and damage to reinforced concrete elements below the joint.

Earlier joints were not designed to be watertight. They were left open on shorter spans. Steel plates were installed to transition the traffic across the joints on the longer spans. However, water, contaminants and some debris spilled through the space between the plates. Transportation agencies spend billions annually repairing, rehabilitating and replacing bridges because of the damage caused by this drainage. Over the past five decades, the public's bare pavement expectations during winter storms has increased, which has resulted in the increased use of deicing salt. The magnitude and cost of the damage has increased as agencies have increased the use of deicing chemicals.

While there continues to be many older bridges with open deck joints in service today, the joints on newer bridges are filled with a flexible material designed to be watertight. As the technology has advanced, the joints systems have improved. While there are no joint systems that are durable enough to last the life of the bridge deck, it is not uncommon for the newer systems to remain watertight for 15 years if they are properly maintained.

2.0 Joint Types

2.1 Open Joints- Common types of open joints are butt joints; either with or without armor facing, sliding plate joints, and finger joints. These were the first types of joints used on modern bridges. The butt joint is normally used for movement less than 25 mm (1 in), the sliding plate bearing for movement between 25 and 75 mm (1 and 3 in), and the finger or tooth joint for movements above 75 mm (3 in). Open joints have lost favor with most bridge engineers (particularly in those geographical locations that require deicing salts) because they permit salt water and debris to pass through deck openings and damage critical support components.

Drainage systems have been installed under some open joints to collect and carry deck runoff away from a bridge. This prevents salt contamination runoff from damaging critical superstructure and substructure components beneath the deck. The drainage system usually consists of a drainage trough (preferably non-corrosive) placed beneath the joint.

Drainage troughs also have problems. Most are poorly designed. They fill with debris, which allows runoff to overflow and spill on underlying bridge components. Cleaning and flushing is often

difficult and rarely performed often enough to keep the trough open. Many of the older metal types have corroded away, fallen apart or been removed. Today many agencies use flexible troughs, which are made of non-corrosive materials such as fiberglass or neoprene. They are less problematic if designed with the adequate slope so that debris is flushed away; if they are sufficiently accessible to be maintenance friendly; and if runoff from the trough does not spill out on the structure. Unfortunately, these features are difficult to achieve on most existing bridges because of limited space.

2.2 Filled Joints- The basic categories of closed or filled joint system types include field-molded; compression; strip; plug; cushion and modular.

2.21 Field Molded Seal — The field-molded (poured in place) sealer is one of the first type used to make deck joints watertight. Traditionally, it was used on shorter spans where the joint movement is 5 mm (3/16 in) or less. However, newer systems are suggested by manufacturers for larger movements depending on the type of sealant material. This system normally includes a thick, sticky, pourable watertight material placed near the top of the joint as a sealant. A polymer material known as Silicone is probably the most common sealant used today. A premolded filler material (backer rod) is placed under the sealant to prevent it from flowing through the joint. After the sealant molds to the opening, it remains flexible and bonds to the sides of the joint. The earlier poured seal materials were heated asphalt or coal tar products, which did not perform satisfactorily for many transportation agencies. Earlier polymer materials had many of the same problems including debonding, splitting and damage from incompressible debris. Damage to the deck edge also caused the joint sealant to fail. Agencies report that, when installed properly, the newer systems are serving well. As a consequence this type joint is returning to widespread use.

The systems used today, typically, include an elastomeric header with pourable silicone sealer and polyethylene foam backer rod, as joint filler. The silicone is a self-leveling, rapid curing, two-component polymer material. The backer rod is squeezed into the joint to keep the sealant from spilling through the joint opening and to form the shape of the sealer. The silicone sealant is poured in the opening on top of the backer rod. It is important that the joint edges be clean and sound so that the silicone bonds tightly. The thickness of the silicone at the center should be no more than half the joint width. It is important that the bottom of the silicone does not bond to the material below. It performs best if the seal is poured when the ambient temperature (must be above 40° F) is at the middle of the historical range or the joint opening is at the mid-point. Agencies have also had success with elastomeric block out materials to reinforce the edge of the deck.

There are certain advantages to this type seal. Unlike many premolded seals, its performance is generally unaffected by joint walls that are not perfectly parallel or perfectly vertical. It is also relatively easy to repair. If a short portion of the seal fails, it is easy to remove it, clean the walls and quickly refill the joint. This minimizes traffic disruption and work zone hazards. Since short sections of this joint can be replace if damaged it should last many years if maintained properly. This system is preferred by many states for upgrading existing deck joints with poor performing seals.

2.22 Compression Seal – Compression seals rely on a continuous preformed neoprene elastomeric rectangular shaped section compressed into the joint opening for the total width of the bridge deck to accomplish its waterproofing function. Movements from 5 mm to 60

mm (¹/₄ in to 2¹/₂ in) can be accommodated with this type of joint. Open cell compression seals are extruded with a semi-hollow cross section with internal diagonal and vertical neoprene webbing resembling a truss to allow the joint seal to compress freely while providing stability and pressure against the joint face during movement. The joint face may, or may not, be strengthened with armor or polymer concrete material.

Some agencies also use a closed cell (foam) compression seal which accommodates approximately the same range of movement as the open cell. The seal is a low-density closed cell polymer with a "foam-like" appearance. One manufacturer describes their product as cross-linked ethylene vinyl acetate polyethylene copolymer material. This material relies heavily on an adhesive bond to the joint sidewall. In a free state, heat may cause shrinkage, especially if not properly ventilated.

The sides of the compression seal are squeezed together and inserted into the joint using a lubricant that also serves as an adhesive that bonds the seal in place. The compression seal must always be in compression to ensure that it stays in place and remains watertight. Splices should be avoided. Typically, the sides of the joint include an offset or stop bar at the bottom of the seal to hold it in-place.

Compression seals must be sized properly for the actual joint opening range. Joint openings must be constructed properly with a uniform width; vertical sides, no edge spalling and the seal must be set the proper distance below the top of deck. Seals are subject to damage if not installed properly when the temperature is relatively low. Some agencies report that over time, the compression seal experiences a loss of resilience, particularity if the movement range is large.

Generally, the compression seal has a good performance if installed and maintained properly. Agencies report 15 years service life. However, there have been some problems in regions of the country with unusually large temperature ranges. The larger the temperature range the wider distance the seal material has to expand and contract.

2.23 Strip Seal — A strip seal consists of a membrane (gland) of neoprene rigidly attached to a metal facing on both sides of the joint. The material is pre-molded into a "V" shape that opens as the joint width increases and closes as the joint width decreases. The joint can accommodate movements up to 100 mm (4 in). These seals are watertight when properly installed. Under the best conditions the life of a strip seal tends to be longer than other joint seals. However, splices in the membrane should be avoided. They are damaged by snowplows, particularly if the skew is 20 degrees or greater and should be avoided if the skew angle and snowplow angle are the same.

Problem areas are at gutter lines and places where sharp breaks in the horizontal and vertical deck cross section occur. Tears of the membrane usually occur as the result of non-compressible materials lodged in membrane crevices when it is expanded. As the joint closes these materials become wedged in the crevice and can cause rupture with loss of water tightness. Breakdown can also occur as a result of traffic movement over debris filled joints. The seals also occasionally pull out of their groove in the metal facing.

NCHRP Synthesis 319, Bridge Deck Joint Performance published in 2003 reported that the strip seal was the most favored type joint seal system based on a questionnaire distributed to

every state. This system should be expected to last 15 years if installed and maintained properly and the strip membrane can be replaced if the metal facing is not damaged.

2.24 Plug Seal — The asphalt plug joint system (plug) is gaining popularity with some agencies. The plug seal is used for expansion joint openings with less than 50 mm (2 in) movement. While the system can be recessed into concrete decks it is often used when an overlay is being added. A popular application is on decks with a waterproof membrane, topped by bituminous (asphalt) concrete overlay.

The joint requires a block-out centered over the joint. Typical dimensions of the blockout are 570 mm wide by 60 mm (minimum) deep (20 in x 2 in). A backer rod is squeezed into the remaining joint below the block-out. A polymer modified asphalt binder material heated to 190° C (380° F) is used to coat the block out and fill the joint above the backer rod. A steel plate approximately 230 mm (8 in) wide is centered over the joint, bridging the opening, for its entire length.

The block-out is filled with an open graded aggregate coated with the asphalt binder. Just before mixing, the aggregate is heated to the same temperature of the binder. After placement, the material is consolidated with a vibrating plate compactor or roller used for consolidation of asphalt roadway pavements. Finally, binder material is poured over the top of the compacted material until all the voids are filled and a fine grit is used to coat the surface for skid resistance.

The big advantage of this system is ease of installation. Short sections can be repaired without replacing the total joint system. Other advantages include low installation and repair cost, low instance of snowplow damage, smooth/quiet riding surface and the fact that it can be cold milled.

The major disadvantage of this system is that it was developed almost exclusively for bridge deck joints without curbs, barriers, parapets etc. This system does not provide an effective method of sealing joint upturns, especially for longer decks and skewed deck joints where joint movement will degrade the system resulting in early system failure. The system seems to be preferred less in hotter climates where it more likely to soften or rut.

2.25 Inflatable Neoprene Seal — The inflatable neoprene seal is installed in the joint after it is coated with a bonding material on both sides. Elastomeric concrete is normally used to form the joint block-out. After it is in place, the seal is inflated, compressing the neoprene to the sides of the joint which helps achieve a watertight bond while the adhesive is setting. The manufacturer recommends waiting 24 hours before deflating the seal to ensure that the bonding material is set; however, traffic is permitted to cross the joint while the seal is inflated.

The advantages to the inflatable seal are that it can be placed rapidly with only minor inconvenience to the highway user. Unlike the compression seal, it can accommodate minor irregularities in the joint opening. Disadvantages include the fact that after it is deflated it totally relies on the bond with the joint edge to remain watertight. It will also fail if the joint edge is damaged after it is installed.

2.26 Cushion Seal — The cushion (also called "plank") seal consists of a steel reinforced neoprene pad recessed into the deck over the joint opening and rigidly attached on both sides. The attachment is accomplished with rods anchored in the deck and threaded on top with

nuts holding the pad down. If properly installed the neoprene stretches as the joint opens and shrinks as the joint closes. Internal reinforcement with thin steel plates embedded in the neoprene makes this seal more durable. Cushion seals are used to accommodate movement up to 100 mm (4 in).

These joints were popular a couple of decades ago but have diminished in favor today, particularly by agencies that use snowplows. Snowplows cut into the material and occasionally rip out complete sections. Since these seals normally require total replacement when damaged, cost is a consideration in this choice. Splice failure is another problem. Caps, covering the anchor nuts, dislodge due to adhesive failure and traffic. The joint edge spalls making the seal more vulnerable to leakage and traffic or snow plow damage. Another common problem is that the cushion seal must be set when the bridge deck is at the proper temperature. Only then it is capable of expanding and contracting for the full range of movement. If the ambient temperature is too cold when it is set, the pad will buckle-up in the middle and be damaged by traffic when the temperature gets hot. Excess stretching during cold weather will damage the seal material or the anchors if the weather is too warm when the joint is set.

2.27 Modular Joint Sealing Systems — Modular joints are fabricated to accommodate larger movements over 100 mm (4 in). The joint components are sized based on the magnitude of movement, which dictates the opening width. Modular joints have been designed for use on very long span bridges with the capability of over 2-m (7-ft) movement. The typical movement is between 150 mm (6 in) and 600 mm (24 in). They consist of three main components: sealers, separator beams and support bars. Sealers and separator beams form a watertight joint at the riding surface. Separator beams often are extruded or rolled metal shapes and allow joining of the seals in series. The separator beams are supported on support bars at frequent intervals.

Designing a modular expansion joint system is similar to designing another very short span on a long bridge. The difficulty is that the joint system must be capable of expanding and contracting 100 times more than the other parts of the deck, it must remain watertight and a movable framing system must support it. The most difficult issues to resolve are related to durability. The sealer material must be very tough and the framing system must be designed to resist very large fatigue stresses.

Modular joint systems have experienced their share of problems including fatigue cracking of welds, damage to equalizing springs, damage to the neoprene sealer material, damage to the supports, and snowplow damage. Some agencies object to their high initial costs and use finger joints where possible, placing more emphasis on drainage troughs.

Modular joint seals have improved and are continuing to improve. Designers understand more about the need to provide fatigue resistant details. Some agencies use them exclusively for large movements. Others use them just for the very large movements. An excellent resource for information about modular joint systems is "NCHRP Report 402 - Fatigue Design of Modular Expansion Joints."

3.0 Maximizing Joint Seal Service Life

While not all agencies achieve the same service life from watertight joint systems, there are some common factors that account for these differences. Some factors are not controllable such as climate (particularly temperature range), volume of truck traffic, use of snowplows and use of deicing materials. However, the difference between the satisfactory and unsatisfactory performance of an expansion joint seal is often controllable by the agency that operates the bridge. Following are examples of the things that agencies can do to ensure that the joint system performs properly and lasts a reasonable period of time--

3.1 Implement Proactive Preservation Program- In some agencies, bridge maintenance is "reactive." It is restricted to reacting to the failure of some part of the structure. To maintain is to preserve, which requires a "proactive" strategy. Unfortunately, the resources allocated to bridge maintenance are often inadequate for crews to respond to anything other than immediate problems. This strategy is justified because budgeted funds are inadequate. Neglecting maintenance is rarely cost-effective. The appropriate level of maintenance extends the service life of the bridge and saves money for the taxpayer.

A proactive bridge preservation program stresses preventive maintenance. Preventive maintenance involves using "maintenance friendly" products and designs, which may cost more up-front. Maintenance friendly joint systems are durable, accessible, repairable, and replaceable. Preventive maintenance activities include pressure washing decks (including the joints), cleaning drains, removing debris and fixing small problems before they grow and cause the failure of the system. Experience has shown that for preventive maintenance to occur, it must be agency policy and promoted by top management. Unfortunately, agencies do not keep the kind of records necessary to quantify the benefits of a proactive bridge preservation policy.

Preventive maintenance (or preservation) extends the life of joint seals. To say that a leaking joint seal may be better than no seal is like saying a leaking roof is better than no roof. The objective of preventive maintenance should be to maintain a watertight seal. The seal should be repaired if any part is leaking. Debris and gravel should be removed from the surface to prevent damage to the seal. Preventive maintenance includes improving the approach roadway pavement surface or drainage to keep debris off the deck. The joint service life and the condition of the bridge support system can be improved when an agency enforces a proactive preservation strategy.

3.2 Use Deck Joint Blockouts- A blockout is a rectangular section of bridge deck, adjacent to the joint, which is removed (or not cast). The blockout is used to facilitate proper sizing of the opening and positioning and anchorage of the seal assembly. It also permits the use of a more durable joint edging material. The blockout is often required if the joint system is replaced in an existing deck. Concrete is removed when a joint system is replaced and anchors are positioned before concrete is recast.

Blockouts are also used when certain types of joints are being placed in new decks and deck overlays. It is much easier to control the joint width and shape when the blockout is cast after the deck. This permits the joint to be cast after the dead load deflection and concrete shrinkage has occurred. It is easier to install the joint system at the proper elevation for optimum riding surface and minimum traffic damage when the blockout is cast after the deck, particularly for those systems that are cast into the deck.

The material placed in the blockout is very important. Many joint systems fail because of the failure of the deck material around the joint. Blockouts permit the use of stronger and durable material to support the joint system and provide more impact resistant joint edges to avoid or minimize damage from heavy truck traffic. Many agencies are pleased with the performance of elastomeric (polymer) concrete to cast joint blockouts.

3.3 Bond Joint System to Sound Concrete- A newly replaced joint system is no better than the adjacent bridge deck concrete. It is important that the adjacent existing concrete is sound. Many failed joint systems are the result of a thrifty maintenance crew attempting to bond the material in a newly cast joint blockout to existing salt contaminated or unsound concrete. This is similar to a good quality deck patch surrounded by poor quality existing deck concrete. The patch will fail because the interface between the old and new concrete weakens and fails. Corrosion engineers tell us that corrosion cells develop when salt contaminated and new concrete are cast at adjacent locations. This difference in the old and new concrete accelerates the corrosion of the reinforcing steel, which results in subsurface deck delamination.

While it is always important that new concrete be placed, and consolidated properly, it is particularly important to provide a good quality support and anchorage for the joint system. If metal plates and armor are not completely supported, due to voids in the concrete, they will flex under traffic. Such flexing accelerates metal fatigue and anchorage failure. Anchors should be recessed below the deck surface to protect against snowplow damage.

3.3 Position of Seal Should Match Ambient Temperature- Expansion joint seals must be capable of expanding, without damage, to accommodate the maximum opening that occurs in the winter when the bridge superstructure is cold. They have to contract or buckle, without damage, to accommodate the smallest opening that occurs on the hottest day in the summer. A properly designed seal should accommodate the full temperature range assuming the opening is the correct width and the seal is positioned properly at time of installation to reflect the ambient temperature.

To ensure the most efficient use of the seal material, it is important that quality control procedures are implemented to ensure that the seal is set, or anchored, in the proper position to reflect the ambient temperature. For example, if the seal is set in a midrange position on a very hot day it may not be capable of expanding to accommodate the opening on a very cold day without damaging the seal or anchors and compromising the waterproofing capability.

3.4 Construct Proper Size Joint Opening- The sizes of joint seals are determined based on the range of movement. The size of the opening is designed to keep the seal watertight at all times without damage from tearing or crushing. For the joint seal to function properly for its optimum service life, the opening must be constructed properly. It is critical to the seal performance that the opening be the correct size for the deck temperature at the time it is measured. The sides of the opening must be vertical and the opening must be straight, with parallel edges, for the total joint width. This is particularly important when compression seals are used.

If a compression seal is being replaced the actual opening should be measured and deck temperature recorded to ensure that the new seal is properly sized. If an existing deck is being saw cut to accommodate a new compression seal, a template should be securely attached to the deck surface to ensure that the saw cut is straight. A two-blade saw should be used in the sawing to ensure a uniform width.

3.5 Install Joint after Placing Overlay- Various methods are used to reinstall joint systems when an overlay is placed on a bridge deck. Some agencies have relocated the joint system first by casting a concrete dam around the joint and placing the overlay up to the face of the dam. On rare occasions, joint systems have been anchored in place and installed as part of the overlay by consolidating the overlay material around the joint system anchors. Both these methods tend to result in a rough riding surface over the joint. A smoother riding surface is achieved by placing the overlay across the joint opening: then installing the joint seal to match the overlay surface. Saw-cutting and removing the overlay material around the joint creates blockouts. The new joint system is cast into the blockout with concrete or polymer material. This is a better method of achieving a smooth riding surface.

4.0 Conclusions

Clearly, there are things that can be done by bridge owners to influence the effective service life of the different joint systems. They include:

- Implement proactive maintenance program
- Construct joint systems using deck joint blockout
- Support replacement joint system on sound existing concrete
- Install seal to match ambient temperature
- Construct proper size and shape joint opening
- When placing deck overlay, install joint after overlay is placed
- Protect against unusual joint movement
- Follow manufacturer's recommendations for selection and installation
- Avoid splices in premolded expansion material
- Protect against snow plow damage

While the current trend is to eliminate joints in bridge decks whenever possible, the vast majority of existing bridges have joints. This will be true for many years in the future. Damaged and leaking bridge deck joints are a significant problem for most transportation agencies. It is important to minimize the leakage to avoid serious damage to the bridge structural support system. The major reason that most agencies do not use open joints, such as the butt, sliding plate and finger joint, is they permit corrosive contaminants to drain through the deck. While drainage troughs may help, they introduce another group of problems on most bridges.

Historically, state transportation agencies have never budgeted adequate funds for routine bridge maintenance considering the magnitude of the investment. Over recent years maintenance crews have been downsized and budgets cut. The remaining crew members spend all their time reacting to urgent needs such as deck patching and rail repair. The justification is that contractors will be used to do most of the work. Unfortunately, contractors are rarely used for routine preservation type activities. Consequently, most bridge deck joints leak and cause damage to the critical structural components below the joint. And billions of dollars are spent annually on contracts repairing, rehabilitating or replacing these damaged bridges.

The cause of leaking joints is not that there are no systems on the market that are capable of providing a watertight joint. While joints systems are continually being improved, the available systems are capable of doing the job if they are installed and maintained properly. In most states the maintenance staff has the knowledge to provide watertight joints. Unfortunately, they lack the resources. They lack the resources because they do not have documentation that quantifies the value of preservation activities such as watertight joints on all concrete deck bridges.

5.0 Suggestions for Research -

The most valuable research to improve the preservation of US highway is a comprehensive study that compares the cost of applying appropriate preservation procedures for each bridge component compared to the cost of the deterioration/damage over time when these procedures are not applied. The researcher will need to look in detail at the billions of dollars that are spent annually repairing, rehabilitating and replacing damaged bridges: then determine what would have prevented this damage and what it would have cost. For example most beam end, bearing and bridge cap damage is caused by leaking deck joints. A very large amount is spent every year repairing this damage. Most of these repairs are performed by contract. The total cost of keeping the joints watertight would be only a small fraction of the cost of repairing this damage.

This type of research is an important function of organizations like FHWA and AASHTO. The private sector does a fair job of developing products to preserve bridges components, but most go unused or are applied much too late. Bridge Management Systems have the capability of comparing repair and preservation alternatives. Unfortunately, most states do not have the data entered into the system to achieve useful results. The most difficult part of the analysis is to quantify the cost of doing nothing or delaying the work. If this cost could be quantified properly it would rarely be the best option. There has been very little unbiased research performed on this topic. The small amount that has been done is old and outdated. Selection of Preservation Strategies and Preservation Actions

The fundamental premise of bridge preservation is taking the right preservation action on the right bridges and the right time. This short statement implies a whole lot of knowledge that we currently do not possess, do not completely understand or cannot effectively apply:

- > The right preservation action
 - What preservation actions are effective?
 - What preservation actions are feasible and economical?
 - How long are preservation actions effective?
 - How much extended service life results from preservation actions?
 - How does the preservation action affect life-cycle costs of the bridge?
 - How does one action compare to other feasible actions?
 - How does each action compare to the "do-nothing action"?
- > The right bridges
 - What bridges are candidates for preservation actions?
 - o What specific conditions indicate that preservation would be effective?
 - How do you measure the specific condition?

\succ The right time

- At what age is preservation most effective
- At what age is preservation most cost-effective?
- At what stage in the deterioration of the specific condition is the preservation action most effective?
- What other factors impact decisions on timing e.g., agency resources, funding streams, established programs, conjunction with other maintenance and preservation activities?
- How do you determine an appropriate performance standard for the preservation action?

These questions apply to any number of situations where preservation actions might be used: Sound concrete decks Steel girders ,etc.

I-4 PERFORMANCE OF BRIDGE PRESERVATION STRATEGIES AND BRIDGE PRESERVATION ACTIONS

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1.0 Introduction

Understanding, measuring, and documenting the performance of bridge preservation strategies and actions is absolutely critical to the issues of if, how and when transportation agencies will implement vigorous, well planned, and adequately funded bridge preservation programs. These preservation programs would preserve bridges at a high level of condition and functional capacity rather than let the slide down the curve that leads from maintenance need to rehabilitation need to replacement need. Key questions include: what type of preservation action is appropriate; at what stage in the life of the bridge should the action be taken; how effective will the preservation action be in extending bridge service life; and ultimately, will a program of preservative treatments on bridge performance needs to be understood to increase the effectiveness of bridge preservation programs.

At this time, performance and bridge preservation are rather broad terms. For the purposes of this paper and the related workshop, definitions will be presented below. It will be seen that the relationship between any given preservation action and measured performance is not well understood. Performance measures have not been established, relevant and reliable data is not available and no rigorous studies have been done. This paper will discuss the concept of performance as related to bridge preservation, will address the need for specific performance measures, will discuss data that must be collected to evaluate performance, and will present key issues for developing bridge preservation strategies and applying performance measures in a bridge preservation program. In the conclusion, the paper makes suggestions for future suggested projects related to performance of bridge preservation strategies and actions.

2.0 The Concept of Preservation

What does bridge preservation mean? Where on the continuum of bridge life does it lie? The commonly discussed stages of a bridge life are planning, design, construction, maintenance, rehabilitation and replacement. There is no commonly accepted definition of bridge preservation or general agreement on what constitutes preservation versus what actions are maintenance, etc. The FHWA and AASHTO are attempting to develop a suitable definition, but have not yet succeeded. Arriving at an unambiguous definition is made more difficult by the multitude of elements in a typical bridge and the interrelationship between them. An example would be bridge joints, beams (especially the ends), bearings and substructure elements. If the joints on a bridge are properly preserved in a manner that maintains their intended function – controlling drainage on the bridge deck – preservation of the other elements is much easier. If joint function

is not maintained, the condition of the other elements is more problematic. The failure to control drainage – especially in regions where deicing salts are frequently and heavily used – is a much more severe regime for the other elements. The degradation of these elements progresses much more rapidly and more severely.

3.0 The Concept of Performance of Bridge Preservation

The term performance as related to a bridge preservation strategy or action requires the definition of some objective measure or measures. Among the most important factors to be used to measure performance would be:

- Cost (of the preservation action)
- Disruption to traffic and increased potential for accidents during the preservation activity
- Impact temporary or permanent on the local environment
- Duration of the desired effectiveness of the preservation treatment
- The relative degree of protection provided
- Extension of the service life of the element or the bridge due to the preservation treatment
- Change (decrease) in the life cycle costs of the bridge

Performance of a bridge preservation action is dependent upon a combination of many things, including type of treatment, materials, construction practices, QA/QC, traffic loads, climate, and the timing of the treatment as reflected in the condition of the element being treated and the interrelationship between these factors.

To be effective, performance measures should be based upon technically sound and reliable data, which is understandable at all levels of the agency, and reflects the needs and interests of the agency managers and the users.

The choice of treatments and treatment strategies, including timing are the most important factors effecting performance. Bridge preservation actions can be evaluated by themselves over time to determine their absolute performance or in comparison with other types and timings of treatment to evaluate relative performance. The method of measurement, as well as whether one evaluates potential (e.g., decrease in condition of coating or deck overlay) or actual failure modes (e.g., spalling, delamination, loss of steel section) can significantly effect the evaluation of performance. The performance of a specific treatment can be difficult to measure, since the same treatment under different bridge conditions, different levels of QA/QC, etc., will perform differently.

The most common performance measure of PP treatments reported in the literature—life of the treatment—is not the most reliable, since the performance of a particular treatment may not be a good indicator of how the bridge element or the overall bridge system performed. The cost of the treatment together with the extension of bridge life provided by the treatment, on the other hand, may possibly be the most important and the most useful measurement for planning and for bridge management systems. Such a technique must take into account both the life of the treatment and the effects of the bridge condition prior to applying the treatment.

Appropriate timing for the application of a treatment has significant influence on the performance of the treatment and the bridge. It is crucial to identify the optimal time to apply a treatment. Placing a bridge preservation treatment on a deck after structural damage has appeared may not prove cost effective and, in fact, may cause additional problems, such as, disguising continuing deterioration while too early of an application will result in an unnecessary expenditure.

To determine the most cost-effective time to apply a PP treatment, performance standards and indices need to be established through research, including collection of performance data. These indices should be descriptive of the environment in which the treatments are to be used and should include, not only bridge conditions, climatic data, material properties, and traffic loading, but also agency resources and funding limitations.

However, new testing techniques and a better understanding of the relationship between fundamental engineering properties and subsequent performance of the constructed product are required

I-5 PRESERVATION OF REINFORCED CONCRETE BRIDGE SUPERSTRUCTURES AND SUBSTRUCTURES – ELECTROCHEMICAL TECHNIQUES

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1.0 Introduction

The primary cause of concrete bridge deterioration is chloride induced corrosion of reinforcing steel. Left unaddressed, this leads to cracking and spalling of the concrete cover and eventually to structural failure. Application of de-icing salts to roadways in northern states and sea water exposure in coastal locations (or both) serve as the source for chlorides. During the past four decades, design and construction standards and materials have evolved to provide more durable new structures; and intervention technologies for repair and rehabilitation have been developed to address the inventory of older, corrosion damaged bridges. However, presently available methods for concrete bridge repair and rehabilitation are 1) often only partially effective, 2) of limited service life, and 3) expensive. These technologies are classified according to one of two general categories as:

- 1. Physical options such as overlays and membranes and
- 2. Electrochemical options.

The purpose of this paper is to provide a critical review of electrochemical rehabilitation options, describe advantages and limitations of each of such option, and identify gaps in existing electrochemical technologies as a precursor for prioritizing further research and development.

2.0 Electrochemical Treatment Alternatives for Corrosion Damaged Reinforced Concrete

There are four general categories of electrochemical treatment for controlling corrosion of reinforcing steel in concrete structures, as listed below:

- 1. Realkalization,
- 2. Cathodic Prevention,
- 3. Cathodic Protection (CP), and
- 4. Electrochemical Chloride Removal (ECE).

The first, realkalization, pertains primarily to older, poor quality, carbonated mortars and concretes with shallow reinforcement cover and has little or no applicability to bridges.ⁱ Consequently, it is mentioned only for completeness and is not discussed further. Technologies 2-4 are similar in that the principle for each is to provide a voltage between a supplemental electrode (anode) that is not part of the structural system such that a positive direct current flows from that electrode to the reinforcement. The fundamental difference between the three is the level of voltage and resultant current. This distinction can, however, result in major differences in techniques by which each is affected. All three have applicability to reinforced concrete bridge structures.

Cathodic Prevention

The principle of cathodic prevention involves application of a low level electric field in concrete between the reinforcing steel and an impressed current anode (normally embedded) via an external power source to null inward diffusional chloride migration that would otherwise occur in response to a concentration gradient.ⁱⁱ The design and operation of cathodic prevention systems are similar to that of impressed current CP (described below) but involve lower operating voltages and currents. This technology has been used sparingly but has been employed on a monumental bridge structure in the Italian Alps and for buildings in the Middle East.ⁱⁱⁱ While the technology of cathodic prevention is sound and first principles based, as are CP and ECE, it requires an initial capital outlay and subsequent monitoring to prevent corrosion that otherwise would not initiate for perhaps several decades or more.

Cathodic Protection

General: Cathodic protection is undoubtedly the most developed of the four electrochemical technologies and has been routinely employed to control corrosion of marine vessels and structures, buried pipelines, and holding tanks for many years.^{iv} Its application to reinforced concrete structures, however, is more recent. This delayed advent resulted, at least in part, because of, first, complexities afforded by the relatively high resistivity of concrete, which requires that anodes normally be spatially distributed, and, second, anode performance issues that stem from acidic corrosion products being confined to near the electrode-concrete interface. The design and operation of CP systems is similar to that for cathodic prevention; however, electromigration of chlorides away from the reinforcement is a side benefit while the primary objective is to polarize the embedded steel from a potential regime indicative of relatively high corrosion rate to one where it is low or nil. As such, CP operating voltage and current are greater than for cathodic prevention. Nonetheless, the fact that chlorides do migrate from the reinforcement and hydroxides are generated there as a consequence of the cathodic reaction can result in repassivation. Consequently, unlike CP in soils and waters, protection may be interrupted for as long as several months without significant corrosion reactivation. Application of CP does not, however, restore cross section of corroded reinforcement or lost load bearing capacity. Unlike cathodic prevention, CP is normally applied to bridge components subsequent to corrosion initiation, which may be several decades or longer after construction.

There are two basic types of CP systems: galvanic anode (GA) and impressed current (IC). For GACP, the driving force for current flow is provided by the native potential difference between

anode and cathode, whereas ICCP employs a rectifier to achieve this. Each of these is described and discussed below.

<u>Galvanic Anode CP</u>: As noted above, systems in this category rely upon the native potential difference between anode and reinforcement to provide the driving voltage for current flow. Consequently, such systems are generally limited to applications where current demand of the reinforcement is relatively low. Because anodes of this type corrode in proportion to current output, system life is determined by this wastage rate. The Florida Department of Transportation (FDOT) has developed and now routinely employs GACP systems for marine bridge substructures based upon thermally sprayed zinc (TSZ) on above waterline, cast-in-place components and zinc mesh lined fiberglass jackets with mortar fill for precast members.^v In both cases, the systems are supplemented by a submerged bulk zinc anode to reduce current drain from the lower elevation TSZ or mesh and thereby extend anode life. As of 2006, some 46 Florida bridges utilized GACP for substructure corrosion control.

A thermally sprayed Al-Zn-In alloy, modeled after the bulk Galvalum III anode that has been used extensively offshore for protection of bare steel but with higher Zn and In contents, has also been employed but only limited long-term experience is presently available.^{vi}

Galvanic anode CP systems have been reported to perform satisfactorily in several instances where they have been employed on bridge decks. One such application involved perforated Zn sheets in a mortar bed and covered with a concrete overlay and a second Zn strips embedded in grooves cut into the concrete. Current output for such applications is expected to be relatively low because concrete resistivity is higher than for marine bridge substructures. Application of humectants to anodes has been reported to enhance current output in such situations.

Some recent attention has focused upon relatively small discrete or point galvanic anodes (zinc embedded in mortar discs with exterior dimensions about 65mm diameter by 25 mm high) for installation in concrete patches of corrosion induced spalls.^{vii} The objective in this case is to minimize the "halo" effect whereby reinforcement corrosion otherwise is accelerated in the chloride contaminated concrete just beyond the patch due to galvanic interaction between it and steel in the patch area. If effective, such anodes could provide a low cost intervention alternative; however, to-date mixed results regarding the extent of corrosion protection have been reported.^{viii,ix} Also, even if corrosion rate reduction is affected immediate to the patch, attack may continue in the original concrete further away.

Impressed Current Cathodic Protection: Due to relatively high concrete resistivity, most CP systems on bridges have been of this type, particularly for decks. Earlier installations were based upon systems with inadequately performing anodes which failed at locations where current density was relatively high or generated acid corrosion products which attacked both the anode and concrete. These have been largely overcome with development of the catalyzed mixed metal oxide coated titanium mesh anode which exhibits nil wastage rates at relatively high current densities and does not generate acidic reaction products. Life of CP systems with this anode type is normally determined by factors other than the anode per se. Advantages of ICCP compared to GACP are that, for the former, voltage and current density can be varied and structures with relatively high current demand can be protected. Disadvantages include the requirement for

rectifier monitoring and maintenance, failure of electrical connections, and the fact that any electrical short between anode and reinforcement compromises protection.

The Missouri and Florida Departments of Transportation (DOT) have been at the principle states to utilize CP on bridges. Bridge decks are the primary issue in the former case, although leakage at expansion joints and roadway splash of deicing runoff contribute to substructure deterioration. Since 1975, Missouri DOT has installed ICCP systems on over 140 bridges. Florida DOT has employed ICCP on some 20 bridge substructures in cases where current demand was judged too high for GACP. These typically involve titanium mesh encapsulated in gunite or reinforced concrete where structural repairs are necessary.

In addition, Oregon DOT has employed ICCP via thermally sprayed Zn and activated titanium^x on elevated arch substructure components of historical coastal bridges for which replacement was not an option.

Electrochemical Chloride Extraction

In this technology, a relatively high voltage is applied between a temporary surface-mounted anode and the reinforcement, the purpose being to electromigrate chlorides away from and repassivate the reinforcement.^{xi} Only a fraction of the chlorides are actually extracted; however, this in combination with, first, their being displaced from the steel-concrete interface and, second, generation of hydroxides at the steel surface is sufficient to reduce corrosion. It has been estimated that an ECE treatment can extend bridge life by up to 20 years.^{xii} To avoid damage to the concrete, current density is maintained below 5 A/m². Preliminary studies have indicated that a total charge transfer of 600-1,500 A·h/m² is generally sufficient, which corresponds to a treatment time of 10-50 days. This option may have particular utility for extending life of substructures that have become chloride contaminated.

3.0 Prestressed Concrete

Prestressed concrete can be of either the pre- or post-tensioned type. In addition, segmental construction utilized tendons that consist of multiple post-tensioned strands. Each of these utilizes cables comprised of multiple high strength steel wires (minimum tensile strength 1,860 MPa (270 ksi) in many cases). Despite the fact that the steel is of a pearlitic rather than tempered martensitic microstructure, the former being relatively resistant to hydrogen embrittlement compared to the latter, concerns regarding brittle fracture have resulted in -0.90 V_{SCE} (-0.97 V_{CSE}) being identified as a maximum polarization limit. This precludes corrosion control via ECE and, in many cases, ICCP unless failsafe design, installation, and monitoring measures are taken and leaves GACP as the preferred option. Because strands in post-tensioned systems are encased in ducts, they are shielded from any CP except for end anchorage areas.

4.0 Commentary on Electrochemical Options for Corrosion Control of Bridges

Given that CP and ECE are first principles based options that are proven to control corrosion, the question arises as to why these technologies have not been more widely adapted by highway agencies and, instead, remain underutilized. A contributing factor is that current systems are not always cost effective on a cost basis. However, cost aside, CP was oversold initially by the private sector before materials and designs were adequately studied and understood; and many early installations either failed or did not perform adequately. At the same time, there was a lack of commitment by many highway agencies to understand the technology and provide necessary monitoring and maintenance. This is in spite of the fact that a multi-year FHWA project committed approximately \$5M to funding CP demonstrations and workshops for state DOTs throughout the country. The previously mentioned agencies (Missouri, Oregon, and Florida as well as several others) are exceptions.

5.0 Knowledge Gaps and Research Needs

Based upon the above summary of electrochemical corrosion control options (namely CP and ECE) for bridge decks and substructures, knowledge gaps and research thrusts related thereto have been identified without prioritization, as listed below.

- 1. Limited current output of GA compared to IC anodes. With the exception of the experience provided by GACP of marine bridge substructures in Florida, it is unclear that present galvanic anodes can provide adequate protection in high current demand or relatively dry applications. Research to develop higher current output galvanic anodes would be high risk but with high payoff if successful. An analogy as to what could result is provided by the development of mixed metal oxide ICCP anodes, which leapfrogged this technology from precursors such as conductive paints and polymers.
- 2. Lack of knowledge regarding long-term performance of the thermally sprayed Al-Zn-In GACP anode. A research effort that provides long-term monitoring of the limited systems that are in place and installs and monitors new systems is warranted.
- 3. Lack of long-term data, in other than sub-tropical marine applications, regarding performance of present technology GACP systems. A research effort that provides long-term monitoring of the limited bridge deck and non-marine substructure systems that are in place and installs and monitors new systems is warranted.
- 4. Lack of understanding as to how CP and ECE can be installed with reduced effort or traffic disruption (or both). One possibility involves development of an efficient method for anode placement on the deck underside.
- 5. Lack of understanding of rehabilitation options for the 500-1000 bridge decks comprised of ECR in the top mat and black bar on the bottom, where the latter is corroding and spalling concrete sections onto traffic passing underneath.

6. Lack of a central reference or resource and clearing house that documents past experience and state-of-the-art technology for electrochemical options. This is in spite of the fact that approximately \$100M has been spent by states on CP and ECE of bridges.

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Bibliography

I-6 RESERVATION of STEEL SUPERSTRUCTURES & SUBSTRUCTURES

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1.0 Introduction

As the nation's inventory of steel bridges ages, the advancement and application of durable, costeffective service life extension technologies becomes increasingly critical. An increasing level of effort and cost has been expended over the past 15 years toward emergent or backlogged maintenance of older, deteriorated steel bridges. This effort has paid dividends in many cases, but as the age of the overall inventory advances, traditional condition-based maintenance actions will not be able to keep pace with the level of need. In addition, funding sources for such activities will become increasingly stressed. There is no doubt that a more holistic, systemsbased, rational approach to steel bridge preservation is called for at this time.

In large part, preservation of in-service steel bridges is achieved through the use of protective coatings. As such, the primary questions involved in preservation decision making for steel bridges regard the timing of painting activities, the associated costs, impact of painting operations on traffic and the surrounding environment, and the tradeoff between coating quality and performance and level of effort and cost of the operations.

Why is this area important?

The national inventory of steel bridges is mature. According to the NBI database, the majority of steel bridges on the NHS are over 40 years old. Most of these structures were designed to a standard performance life of 50 years, and although it is apparent that the robust nature of steel structures coupled with design conservatism has provided much longer inherent lives for these structures than this original design goal, it is clear that significant and increasing effort and funding will be needed to extend the system-wide service life of bridges. Also, it is clear that the recent common past approach of deterioration, posting, and rehabilitation/reconstruction is a management cycle doomed to failure. There simply will not be enough money, time, workforce and residual highway capacity to allow for major rehabilitation efforts while also allowing the system to concurrently function and move traffic. A more rational approach to bridge service life extension is required. We must begin to recognize, prioritize, and minimize the common, system-wide maintenance problems before they become impacting issues. To accomplish this, we need to aggressively investigate the development and application of new technology and operational strategies.

2.0 Background

To place this issue in proper perspective, it is important to briefly examine the technology timeline associated with bridge maintenance painting. For decades, bridge steel was preserved with multiple thin coats of lead-containing paints. These paints were inexpensive, easy to apply, and required little surface preparation. In addition, in-service, these paints could be applied over themselves multiple times. This approach prevailed on major bridges and bridges in high visibility areas for many years. Most other typical structures built for the interstate system during the 1950's and 60's received this type of treatment upon construction, but then received little to no maintenance painting on a regular basis.



During the 1970's, steel fabrication shops installed high productivity blast machines, and initial cleaning and removal of mill scale became commonplace. These cleaner surfaces opened the door for widespread use of higher durability zinc-rich primer coating systems. The zinc-rich primer, multi-coat paint systems are still dominant to this day, although the specific paint chemistries have developed significantly through efforts to improve environmental compliance of the paint materials and enhance coating system performance at the same time.

The 1980's and 90's were dominated by technology development in two areas: first, paint formulations were mandated to contain far less solvent (VOC's) to reduce their environmental impact. In addition, mandates for the removal of lead and other toxic heavy metals impacted paint formulation. These mandates required reformulation of all traditional industrial paints. Research and technology application funding, effort and talent were dedicated to solving this problem for the better part of two decades.

The second dominant issue during the 80's and 90's was the lead paint removal issue. Specifically, methods for removal of existing, deteriorated lead-containing paint on bridges in a manner that minimized impact to the environment and health impact to workers were developed, validated and institutionalized. These changes had the overall effect of making steel bridge maintenance painting a much more expensive undertaking than in the past. It also caused bridge painting operations to be much more complex and of longer duration. This created a corresponding impact of these operations on traffic in and around work zones.

Although technology innovations continue to arise in the area of environmentally compliant, high performance coating materials, research results show that this issue has been largely addressed, and the current state of the issue is likely approaching diminishing returns for future materials-centric research. In addition, this issue has largely been transitioned to the stewardship of the AASHTO-NTPEP qualification test program.

This leaves the major work to be accomplished in the areas *of maintenance painting operations* and *coating system quality* as-applied under real world conditions. In addition, the issue of timing of maintenance coating activities remains essentially unstudied. The concept of *risk minimization* – followed in maintenance coating activities in many other industries – has, for the most part, not been explored for bridge systems.

What sorts of issues are known to be hindrances to preservation?

The concept of life cycle cost minimization is well understood by the majority of engineers on a theoretical basis. The problem lies in the fact that the system under which we prioritize and budget maintenance work pays little to no reward to the consideration of life cycle cost. Also, by nature, there is little definitive data available upon which to make life cycle cost decisions. Because of the fuzzy nature of long term system performance assumptions, the life cycle cost argument loses its punch when faced with the daunting realities of overstretched annual budgets. Capitalization of major maintenance efforts could be a future consideration that provides some relief.

Also, traditional one-off contracting for maintenance activities can be a hindrance to achieving quality and operational efficiencies. For the most part, the private sector uses longer term, alliance contracts with painting contractors for their various facilities (power plants, refineries, paper mills, etc.) this contracting mechanism allows them extended flexibility and rescues them from the constant pressure on end result quality that arises from the low bidder culture of highway jobs. The reality of the industrial painting contracting world is that the very best contractors *do not* participate in public sector (and particularly not highway) work because their mandated level of quality would not allow them to be competitive. This is a fundamental issue in moving forward into a higher level of quality for the highway bridge maintenance initiatives and work in examining innovative contracting approaches and expansion of the contractor pool into the better contractors is essential.

Many material, equipment and operational innovations have been developed by the industrial painting community over the past two decades in response to regulatory pressure and the increasing cost basis of bridge painting work. These innovations have been applied on a

completely ad hoc basis, but with great success in selected cases. The impact on quality, cost, and environment of these innovations has only been studied very lightly. The reporting on the metrics associated with the various maintenance coating options now available to bridge owners has not been reported on to a degree where the data and recommendations are useable on a nationwide, routine basis.

In addition, some of the research findings from past efforts that may be quite useful have not been given significant horsepower and hence continue to languish without truly robust implementation and validation.

3.0 Preservation of Steel Bridges

The fundamental premise of bridge preservation is taking the right preservation action on the right bridges and at the right time. This short statement implies a whole lot of knowledge that we currently do not possess, do not completely understand or cannot effectively apply:

The right preservation action

- o What preservation actions are effective?
- o What preservation actions are feasible and economical?
- o How long are these preservation actions effective?
- o How much extended service life results from these preservation actions?
- o How does the preservation action affect life-cycle costs of the bridge?
- o How does one action compare to other feasible actions?
- o How does each action compare to the "do-nothing action"?

The right bridges

- o What bridges or bridge elements are candidates for preservation actions?
- What specific conditions could be measured and interpreted to reliably indicate that preservation would be effective and when it would be effective?
- o How do you measure and interpret the specific condition?

The right time

- o At what age is preservation most effective
- o At what age is preservation most cost-effective?
- At what stage in the changing value of the specific condition is the preservation action most effective?
- o What other factors impact decisions on timing e.g., agency resources, funding streams, established programs, conjunction with other maintenance and preservation activities?
- o How do you determine an appropriate performance standard for the preservation action?

These questions apply to any number of situations where preservation actions might be used and certainly apply to steel bridges. Regarding steel bridges, the following information would be useful:
- What steel bridge elements are most vulnerable to deterioration? Examples are ends of beams under joints, elements exposed to roadway spray, etc.
- How does the element progress from new, well protected condition to damaged condition as protective systems fail?
- What are the common methods and materials that provide protection?
- What are the most common types of coating systems on in-service bridges today? For which types would R&D pay the most dividends?
- How do you evaluate the effectiveness of these protective systems in different scenarios?
- What causes these protective systems to fail and how do these protective systems fail?
- What characteristics can you examine in order to evaluate the quality of the protective system as it ages and loses ability to protect?
- How can you detect and measure these characteristics in order to determine when best to intervene with a preservative action?
- How do you evaluate the service life of the preservation action and how do you measure its life-cycle cost based on what we know about the particular preservation action in short-term tests and/or limited in-service performance history?
- How do you determine how much extra service life will result from applying this preservation action?

Through the use of existing bridge condition databases and the development of additional cooperative knowledge-bases across state lines, there is great potential that a forward thinking risk minimization strategy can be developed and validated. Some evidence of the success of this type of approach exists within the bridge maintenance programs of many of the toll authorities. In general the toll authorities use their cash flow advantage to plan bridge maintenance on a more strategic basis and even capitalize maintenance activities.

4.0 Bridge Maintenance Issues Beyond Coating

The majority of the discussion in this area focuses on bridge maintenance coating materials and operations. However, there are other associated, non-paint topics that need to be considered for their potential to extend service lives and provide economical and rapid, effective maintenance benefits:

- *Caulking* a large portion of paint system deterioration occurs at the interfaces between built-up members. Caulking is performed on an ad hoc basis and anecdotal evidence indicates a large cost benefit. This area has not been studied to any reasonable degree, but a fairly modest study and resultant guidelines would pay significant benefits.
- *Joint repair/replacement* Joints have been studied extensively, and a recent NCHRP report covers the subject in detail; however, there is no doubt that failed expansion joints are a primary source of deterioration for the steel below. Any study of bridge maintenance must consider joint issues as part of the system.
- Supplemental steel in at-risk areas a comprehensive study of the cost/benefit of bridge coating operations may yield various answers depending on case specific conditions. Due to the high cost and traffic impact of coating in certain urban areas, there may be methods to rapidly build-up targeted areas of girders (e.g., under joints) that are deemed to be at risk. In certain cases, this approach may be competitive with coating in terms of cost,

environmental impact and impact to traffic. That is, it may be wise to "sister" certain structural elements rather than rehab the existing elements.

- Alternative Surface Preparation Methods significant innovation has occurred in the surface preparation equipment area over the past decade. There are many opportunities to examine high productivity equipment using innovative wet and dry blast gear that is now available and being used in other industries. Due to the high cost of this equipment, there is little motive for contractors that focus on the bridge painting market to invest without a specific owner driven demand.
- *Bridge Washing and Regular Cleaning Activities* A few states have attempted to regularly wash out and clean areas under expansion joints every Spring. Also, regular attempts to clear away salt and moisture-laden debris and vegetation have proven helpful in isolated cases.

5.0 Weathering Steel

Present guidance regarding the appropriate use of weathering steel resides in The Federal Highway Administration Technical Advisory, UNCOATED WEATHERING STEEL IN STRUCTURES, T 5140.22. This guidance was written based on consensus input from industry and bridge owner agencies in 1989. Significant efforts were made to update and refine this guidance based on modern data and information during the past several years, but a new document has yet to be published. These rewrite efforts identified many specific gaps in available data which could be used to maximize the beneficial design, maintenance and placement of weathering steel structures. These recommendations should be included in the scope of discussion during the subject workshop.

The guidance regarding weathering steel use is primarily targeted at design and new construction; however, there are specific maintenance recommendations. As the number of weathering grade steel structures increases, owners must be made aware that they are not "maintenance free" structures. Most of these actions are not arduous, but neglect can lead to cases of corrosion of the exposed weathering steel.

a. Maintenance Actions

- (1) Implement maintenance and inspection procedures designed to detect and minimize corrosion.
- (2) Control roadway drainage:
 - (a) Divert roadway drainage away from bridge structure.
 - (b) Clean troughs or reseal deck joints.
 - (c) Maintain deck drainage systems.
 - (d) Periodically clean and, when needed, repaint all steel within a minimum distance of 1 ¹/₂ times the depth of the girder from bridge joints.
- (3) Regularly remove all dirt, debris and other deposits that trap moisture.
- (4) Regularly remove all vegetation which can prevent the natural drying of wet steel surfaces.
- (5) Maintain covers and screens over access holes.

There is also the question regarding maintenance coating of weathering steel in instances where conditions have caused it to corrode beyond an acceptable rate. Guidance for maintenance painting of weathering steel was developed under a prior FHWA research study (FHWA-RD-92-055). This study has not been revisited in 15 years, since the implementation of HPS.

What existing literature/ research have already been applied?

FHWA and various state highway agencies conducted focused research programs in steel bridge coatings over the decades of the 1980's and 1990's. The majority of this work was dedicated toward determining the long term performance of modern, environmentally compliant coating systems and toward development and analysis of accelerated laboratory coatings testing regimes. This work paid great dividends as the responsibility for coatings testing and qualification has now been institutionalized at the AASHTO level through the NTPEP. A small sampling of these reports is given below:

- *Guidelines for Repair and Maintenance of Bridge Coatings: Overcoating*, Christopher Farschon, Robert Kogler and J.Peter Ault, FHWA Publication #FHWA-RD-97-092, August 1997.
- Environmentally Acceptable Materials for the Corrosion Protection of Steel Bridges, Robert Kogler, J. Peter Ault and Christopher Farschon, FHWA Publication #FHWA-RD-96-058, January 1997.
- The Federal Highway Administration Technical Advisory, UNCOATED WEATHERING STEEL IN STRUCTURES, T 5140.22.
- *Performance of Alternative Coatings in the Environment (PACE)*, Vol. I (Publication No. FHWA-RD-89-127), Vol. II (Publication No. FHWA-RD-89-235), and Vol. III (Publication No. FHWA-RD-89-236), Federal Highway Administration, Washington, D.C.
- *Environmentally Acceptable Materials for Corrosion Protection of Steel Bridges*, Publication No. FHWA-RD-91-060, Federal Highway Administration, Washington, D.C.
- *Lead-Containing Paint Removal, Containment, and Disposal, Publication No. FHWA-RD-91-100, Federal Highway Administration, Washington, D.C.*
- *Effect of Surface Contaminants on Coating Life*, Publication No. FHWA-RD-91-011, Federal Highway Administration, Washington, D.C.
- Evaluation of Volatile-Organic-Compound (VOC)-Compatible High Solids Coating Systems for Steel Bridges, Publication No. FHWA-RD-91-054, Federal Highway Administration, Washington, D.C.
- *Maintenance Painting of Weathering Steel*, Publication No. FHWA-RD-92-055, Federal Highway Administration, Washington, D.C.
- Corrosion Control of Highway Structural Components by the Application of Powder Coatings, Publication No. FHWA-RD-94-175, Federal Highway Administration, Washington, D.C.
- *Issues Impacting Bridge Painting*, Publication No. FHWA-RD-94-098, Federal Highway Administration, Washington, D.C.
- *Comparison of Laboratory Testing Methods for Bridge Coatings*, Publication No. FHWA-RD-94-112, Federal Highway Administration, Washington, D.C.
- AASHTO Guide for Painting Steel Structures, 1997.

• NSBA Steel Bridge Design Handbook, Chapter 23, Corrosion Protection of Steel Bridges, 2006.

In addition, the FHWA National High Priority Research Program for bridge coatings addressed the operational and environmental impact aspects of lead paint removal in the following studies:

- *Containment Efficiency: Environment and Worker Exposure*, Jeffrey Dawson, Mark Brown, and Robert Kogler. (FHWA report unpublished). Summary presented at the SSPC Spring Compliance Meeting, March 1997, Stamford, CT.
- *Cost Effective Alternative Methods for Steel Bridge Paint System Maintenance*, (FHWA report unpublished). Chris Farschon and Brad Shaw, December 2001.

These studies provided useful information to the states and the industrial coating industry at large in the area of abrasive blasting containment design and environmental and worker health and safety monitoring. However, the areas of operational efficiency and application quality have only been addressed in a cursory manner. There two areas have great potential for large payoffs if studied properly and cooperatively.

6.0 Specific Issues

- Most coating failures (70-80%) are known to be caused by improper application practices and techniques rather than coating materials themselves.
- Precursors to coating failures are not precisely known.
- There are no universal test methods that can sense early stage of coating degradation such as local adhesion loss, micro-cracks in the coating, excessive water uptake through thin coating, etc.
- There are no accelerated laboratory tests that can reproduce real life coating failures or allow reliable extrapolation for projecting long-term coating performance in specific service condition.
- No accurate in-situ test methods for assessing corrosion condition (quality of protective oxide film) of weathering steel other than visual and thickness measurement.
- No nationwide weathering steel bridge design and maintenance guidelines and manuals addressing all possible environmental and service conditions and where to use protective coatings over the weathering steel.
- Staining problems of weathering steel on adjacent concrete structures.
- Most of current blast cleaning methods cannot remove chloride residues on heavily corroded (pitted) steel surface. We need to develop chloride tolerant coating systems or inexpensive chloride removal chemical solutions

7.0 Summary

Proposed Research Topics

- In-situ performance evaluation methods of various protective coating systems
- Development of new metallized coating types for weathering steel with and without top coat.

- Advancement of existing nondestructive infra-thermal image technology to detect coating adhesion failure even before visual appearance.
- Other technology to detect coating failure even before visual appearance.
- Development of embeddable micro-sensors for monitoring state of coating degradation progress. For high build maintenance coating systems, this type of small and flat sensors can be installed without compromising coating integrity and data such as coating impedance and conductivity can be acquired at certain intervals in a non-invasive manner.
- Field evaluation (installation and monitoring) of overcoating systems selected from a recent FHWA overcoating study to determine effectiveness and limitations of the candidate coating products. Success of this work can be potentially big cost saving for old bridges coated with lead containing coatings.
- Refinement of existing accelerated laboratory test methods that will produce more realistic test results in good agreement with those of the long-term exposure ones. One key factor is how to introduce more "real life" like transition stresses (thermal, physical, and electrochemical) to the coating panels. A research program should be dedicated to address this challenge by changing four significant environmental conditions causing coating failures such as moisture, temperature, salts, and UV.
- Creation of a detailed national corrosion map for coated steel structures and uncoated weathering steel. The regional classification should be based on annual temperature variation, precipitation, UV data, deicing salt consumption, average daily traffic, type and concentration of pollutants including airborne chloride and sulfate ions. This type of data can be collected through the LTBP. Such data will provide bridge design and maintenance engineers with in-service information regarding level of environmental harshness of a particular bridge location.

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