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THE UNIVERSITY OF TEXAS AT AUSTIN ✦ COCKRELL SCHOOL OF ENGINEERING

TxDOT

TEXAS PAVEMENT PRESERVATION CENTER

TEXAS PAVEMENT PRESERVATION CENTER TWO-YEAR SUMMARY REPORT

Dr. Yetkin Yildirim, P.E., TPPC Director

CENTER FOR TRANSPORTATION RESEARCH
BUREAU OF ENGINEERING RESEARCH
THE UNIVERSITY OF TEXAS AT AUSTIN

AUGUST 2011
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Dr. Yetkin Yildirim, P.E., TPPC Director
E-mail: yetkin@mail.utexas.edu

Mailing address:
Texas Pavement Preservation Center
Center for Transportation Research
The University of Texas at Austin
1616 Guadalupe St.
Austin, TX 78701

Tel: (512) 232-3084
Fax: (512) 232-3070

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Texas Pavement Preservation Center

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Delia Atmaca (Web design)
Umid U. Azimov, Graduate Research Assistant
Juan Du, Graduate Research Assistant
Mustafa B. Erten, Graduate Research Assistant

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Gerald D. Peterson, Director of the Asphalt and Chemical Branch of the Materials and Pavements Section of TxDOT's Construction Division
Joe S. Graff, P.E., Vice President of Regional Operations at Halcrow, Inc. in Austin
Barry Dunn, President at Viking Construction, Inc

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TEXAS PAVEMENT PRESERVATION CENTER (TPPC)

About the Center

The Texas Pavement Preservation Center (TPPC), in joint collaboration with the Center for Transportation Research (CTR) of the University of Texas at Austin and the Texas Transportation Institute (TTI) of Texas A&M University, promotes the use of pavement preservation maintenance strategies in order to allow highway agencies to adopt cost-effective and efficient programs to sustain roadways and extend pavement service life. The concept of pavement preservation focuses on dealing proactively with pavements still in good to fair condition rather than reacting to pavements in poor condition. Historically, federal highway funding focused primarily on new construction and states were held responsible for all subsequent maintenance. Since 1976, there has been a trend allowing states to use federal funds for highway maintenance that extends pavement life, thus raising the role of this activity in agency operations and subsequently the budget.

If correct treatment is applied at the right time, then pavement preservation offers a way to lengthen the service life of pavement, ultimately saving money because it delays costly rehabilitation or reconstruction activities. The many benefits of such a strategy include increased return on investment, extended service life, improved customer satisfaction, expedited treatment turn-around time, increased productivity, and enhanced pavement performance.

With pavement preservation, the service life of a roadway can exceed its initial design life and operate at a high level of user satisfaction. In fact, there can be up to a 10 to 1 return on money spent on preservation versus rehabilitation or reconstruction programs; or rather, every $1 spent in preservation eliminates or delays spending $10 on rehabilitation or reconstruction later.

Pavement preservation requires a customer-focused program to provide and maintain serviceable roadways, in a cost-effective and timely manner, encompassing preventive and corrective maintenance as well as minor rehabilitation. One of the challenges of pavement preservation is in determining the right maintenance or construction operations at the right time on appropriate roads. Choosing a road that is in fair condition without structural damage is important, and then choosing the best, most cost-effective technique among the many choices is essential for proper life enhancement. Consideration should be given to geographic and environmental conditions, existing pavement materials, and local traffic patterns.

The Maintenance and Design Divisions of the Texas Department of Transportation (TxDOT) created the first Preventive Maintenance Program. Preventive maintenance is a tool for pavement preservation. Non-structural treatments are applied early in the life of a pavement to delay deterioration. This program mandated the use of $115 million per year for seal coats, thin overlays, crack sealing, micro-surfacing, concrete pavement repairs and bridge preventive maintenance projects. The program has grown to about

$325 million per year. Because of the size of TxDOT's preventive maintenance program and the historical support for pavement preservation, Texas was a logical choice for the development of the Texas Pavement Preservation Center.

Our Mission

Established August 11, 2005, The TPPC serves the broad range of needs of the Texas Department of Transportation (TxDOT), and other agencies within the highway community by promoting awareness of pavement preservation as a feasible and practical maintenance strategy, providing training in preservation methods, operating as a source of knowledge for new techniques and procedures in this area, and supporting a long-term pavement performance approach. The TPPC has been actively involved in promoting awareness of pavement preservation methods at the state, national, and international levels for the past four years, which the following summary of TPPC projects and activities should serve to clearly demonstrate.

Personnel

Dr. Yetkin Yildirim is the Director of the TPPC, which is a collaboration between the Center for Transportation Research (CTR) and the Texas Transportation Institute (TTI). Yetkin Yildirim and Dr. Kenneth H. Stokoe represent the CTR, while Cindy Estakhri and Joe Button represent the TTI. The Center has been working closely with the Foundation for Pavement Preservation to attract industry attention to the center. The TPPC Board of Directors is made up of nine (9) members from TxDOT and five (5) members from the pavement industry.

TPPC TxDOT board members include Michael W. Alford, P.E., Ray L. Belk, SPHR, Gary D. Charlton, P.E., Tracy Cumby, Toribio Garza, Jr., P.E., Randy R. King, Paul Montgomery, P.E., Tammy B. Sims, P.E., J. Jeffrey Seiders, Jr., P.E. Industry leaders are also represented on the TPPC Board of Directors. TPPC industry board members include Joe S. Graff, P.E. of Halcrow Group, Bill O'Leary of Martin Asphalt Company, Jim King of Cutler Repaving, Inc, Nelson Wesenberg of Ballou Pavement Solutions, Inc., Barry Dunn of Viking Construction, Inc., and Myles McKemie of Ergon, Inc. TPPC instructors also include Gerald D. Peterson and Joe S. Graff, P.E.

Training Courses

One of the primary goals of the Texas Pavement Preservation Center is education. By raising awareness of pavement preservation practices, the TPPC hopes to inform both engineers and policy-makers of the most effective options for highway maintenance that are currently available. Courses on Seal Coat Application and Inspection, Seal Coat Planning and Design, and Microsurfacing were offered by the TPPC to meet the needs of TxDOT and other partner organizations. These district-level training courses, designed by the TPPC, provide valuable instruction on the latest pavement preservation techniques and offer hands-on experience to a wide audience of engineers and technicians.

The Texas Pavement Preservation Center also makes training materials available to the wider public, through a series of free online courses. These user-friendly instructional materials serve to promote the awareness of pavement preservation practices by making the latest highway maintenance research easily available to students, highway engineers, researchers, and policy makers alike.

In the past two years, the TPPC has posted 13 lectures online at http://www.utexas.edu/research/tppc/conf/index.html, with topics ranging from Transversely Varying Asphalt Rates (TVAR) to Hot In-Place Recycling. Lectures from various pavement preservation seminars and seal coat conferences are gathered in these online courses, making the TPPC website a valuable resource for the survey and evaluation of current pavement preservation practices.

Also, in partnership with the Center for Lifelong Engineering Education at the University of Texas, the TPPC offers an online seminar for professional certification:

http://lifelong.engr.utexas.edu/shortcourse.cfm?course_num=1047

This online pavement preservation seminar offers participants an arsenal of pavement preservation best practices that will allow them to assess each situation and determine the appropriate pavement maintenance treatment.

Publications and Research

The TPPC webpage not only offers these training materials, but serves as an outlet for the dissemination of pavement preservation research. Newsletters, research reports, and conference presentations are made available online, attracting many visitors to the TPPC website. Furthermore, the Pavement Preservation Journal attracts technical papers and research from around the world in the area of pavement preservation, and the technical papers are edited by the TPPC.

The TPPC has been conducting research on pavement preservation methods such as crack sealing, micro surfacing and slurry seal, seal coats, thin asphalt overlays, and fog seals for the past two years. The center has consistently published research reports through CTR at UT Austin and TTI at Texas A&M, and twenty technical papers have been selected by high quality national journals. Additionally, the TPPC has organized six presentations for national and international pavement preservation meetings in order to inform the broader highway community of its research results. The TPPC has been present at the annual meetings of the Transportation Research Board of the National Academies and the International Conference on Asphalt Pavement, attended various national pavement preservation task force groups, and actively participated in program developments. Since 2005, the TPPC has also hosted annual Pavement Preservation Seminars that provide attendees with an excellent overview of the concepts, techniques, and materials involved in pavement preservation.

Outreach and Education

TPPC has also been involved with various outreach and education projects to provide pavement preservation information to the traveling public. Through a partnership with the Engineering Education Research Center, the Texas Pavement Preservation Center has been able to collaborate with local high school students in the development of pavement-related science fair projects.

http://uts.cc.utexas.edu/~cosmos/index.html

Such a partnership provides local students with the opportunity to engage in challenging extra-curricular research at a nationally ranked university, while increasing public awareness of the essential practices of pavement preservation. Students sponsored by the Texas Pavement Preservation Center have continued to compete in the International Sustainable World (Environment, Energy, Engineering) Project Olympiad, an international science fair held in Houston, TX.

www.isweep.org

By supervising these students as they develop and complete their science fair projects, the TPPC continues to pursue its mission to promote awareness of pavement preservation as a feasible and practical maintenance strategy.

Newsletters

The following report compiles eight newsletters published by the Texas Pavement Preservation Center from the year 2009 to 2011 in addition to fifteen newsletters published in the 4-year report. These newsletters include summaries and reports from various pavement preservation seminars and conferences over the past two years, including IRF Pavement Preservation Workshop, Hot-In-Place Recycling, TRB Annual Meetings, Evaluation of Training Requirements in Pavement Preservation Methods in the State of Texas, Pavement Preservation Strategies with A-R Workshop, Peer State Review of TxDOT Maintenance Practices, and Evaluation of the Curing Time and Other Characteristics of Prime Coat.

Research Report

Following the newsletters is a compilation of research projects conducted by CTR at UT Austin and TTI at Texas A&M. The research reports cover a wide range of pavement preservation topics, including Investigation of SafeLane Delamination on Bridge Deck in Fort Worth District; Pavement Preservation Treatment Performance; Removing Excess Asphalt: Initial test of ultra high pressure water a success; and Evaluation of Rejuvaseal as a Pavement Preservation Treatment in the Laredo District of Texas. Some research projects serve to solve real-world pavement problems; others form a supplement to the pavement preservation theory. This collection of information prepared by the TPPC provides a comprehensive overview of the work of the Center and the present state of the pavement preservation industry.

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TEXAS PAVEMENT PRESERVATION CENTER

TxDOT Newsletter

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IRF Pavement Preservation Workshop

TPPC Board of Directors

Our Mission

The mission of the TPPC, in joint collaboration with the Center for Transportation Research (CTR) of the University of Texas at Austin and the Texas Transportation Institute (TTI) of Texas A&M University, is to promote the use of pavement preservation strategies to provide the highest level of service to the traveling public at the lowest cost. The executive sponsor for the TPPC is the Texas Department of Transportation (TxDOT).

Contact Us

Director: Dr. Yetkin Yildirim, P.E.
E-mail: yetkin@mail.utexas.edu
Website: www.utexas.edu/research/tppc

Past and Upcoming Events

Hot In-Place Recycling

The Hot In-Place Recycling (HIR) Open House and Workshop was held in Fort Worth on October 29. The workshop was jointly sponsored by Cutler Repaving, Inc., Martin Asphalt Company, the City of Fort Worth, FP2, and the Texas Pavement Preservation Center. The implementation methods and potential benefits of hot in-place recycling were presented by John Rathbun, and Bill O'Leary described the additives used in HIR. Yetkin Yildirim described HIR in relation to pavement preservation, and Najib Fares, infrastructure manager for the City of Fort Worth, described his first-hand experience with hot in-place recycling methods. Videos of this workshop and additional instructional materials regarding hot in-place recycling will be available for use online at:

http://www.utexas.edu/research/tppc/conf/HotInPlace/index.html

TPPC Seal Coat Training Courses

Seal Coat training courses will continue to be offered by the TPPC. The course designed for inspectors, entitled "Seal Coat Inspection and Applications," focused on proper inspection methods and the equipment used during chip seal construction. The other, "Seal Coat Planning and Design," instructed engineers on planning, designing, and constructing chip seals.

For more information on the Seal Coat courses, please contact Dr. Yetkin Yildirim, P.E. at yetkin@mail.utexas.edu or (512) 232-3084.

TPPC Interview with TxDOT's Gerald Peterson

Gerald Peterson, TxDOT and Yetkin Yildirim, TPPC

The Pavement Preservation Center recently interviewed Mr. Gerald Peterson, Asphalt and Chemical Branch Manager of TxDOT's Construction Division, about some of the recent asphalt technologies that have been implemented in Texas. According to Mr. Peterson, Performance Graded (PG) specifications have been instrumental in addressing rutting in Texas roads. First developed in 1997, PG specifications include more information about the properties of the binder than older specifications, allowing engineers to use much stiffer binders than could be typically used under the Asphalt Concrete (AC) system. These specifications were initially designed according to local climate conditions, while subsequent experience has found that a 64-22 binder could be used with 95% confidence rating for 80% of the state. Almost all of the other grades are essentially bumped up from the 64-22 specification, according to the needs of the local traffic conditions. Now, engineers typically select binder grades based on their own experience and familiarity with the PG specifications. The stiffening of the binders facilitated by the PG specifications has significantly reduced rutting problems in Texas, but this kind of "grade-bumping" would theoretically not significantly impact the cracking resistance of the asphalt.

The TxDOT central laboratory monitors the quality of the asphalt from all of the major binder sources in Texas, receiving samples of every grade twice a month from each producer. There is no requirement for regular field testing; it is up to the project engineer to decide how frequently field tests should be conducted. But it is recommended that engineers conduct sample testing in the field in order to corroborate the laboratory results and generate enough field data to be able to sufficiently analyze problematic regions. The specification book does not mention any steps to be taken in case of the failure of a binder. In such cases, districts generally negotiate with their contractors for a pay reduction, but still there is some uncertainty among engineers as to what the appropriate action is in this scenario.

The PG specifications were modified in 1999, and the polymers used for each grade were specified in the binder name. This was an attempt to keep engineers from bumping the grade of their binder simply to get a polymer in the mix, but the material codes became too confusing. In 2002, the PG system was modified again, allowing polymers to be specified in the plan notes rather than the binder specifications. Also, an intermediate temperature test was introduced, independent of the specification's higher temperature. This modification distinguished the PG specifications from AASHTO specifications, so that grade-bumping would not affect the intermediate temperature of the binder. Then in 2003, the elastic recovery test was added to the requirements in the PG specification book.

Rubber modified asphalt is another new technology that TxDOThas been using for a number of years now. There are two basic types of rubber modified asphalts: asphalt rubber and tire rubber. Asphalt rubber, which is generally blended on site, consists of a minimum of 15% tire rubber, and is cured at a low temperature for a short period of time. On the other hand, tire rubber is blended by the supplier, is highly cured, and can be used like any other modifier. Mr. Peterson observed that tire rubber has performed particularly well in seal coats and hot mixes.

In 2005, more scrap tires were used in Texas than were produced. Around 6% of all waste tires recycled in Texas were used in Crumb Rubber Modified (CRM) rubber projects: approximately 10,000 tons of tires per year. In Texas, the wet process is the preferred method for the production of rubberized asphalt concrete. Rubberized asphalt concrete can be manufactured by either a wet or dry process. The wet process is used in Texas, and involves the blending of crumb rubber with asphalt cement (18-25%) before the addition of aggregates.

The PG specification for such a recycled asphalt material is difficult to determine. Initially, binder from the recycled material was extracted and blended with the proposed binder in the proper proportions. The specifications of this blend would then closely approximate the PG specifications of the recycled material. However, this procedure was cumbersome and often inaccurate. Instead, a maximum limit has been set on the amount of recycled material that can be used in a binder. If the binder includes less than 20% recycled material, the PG specification of the binder does not need to be altered. TxDOT encourages the use of recycled materials (RAP or shingles) for binder hardening by allowing "grade dumping." In other words, TxDOT specifications allows a lower grade binder to be substituted for a higher grade if the mixture still passes the Hamburg Wheel Tracking test.

Warm-Mix Asphalt (WMA) has also been gaining popularity in Texas in the past few years. As the name suggests, this method reduces the temperature at which asphalt mixes are produced and placed. Warm-mix methods are now allowed for in the specifications: as long as mixture requirements are met, it is not a concern with TxDOT whether the mix is produced via hot or warm mix processes. Foaming and EVOTHERM are the two most popular warm-mix methods for lowering the viscosity of the asphalt mix without severely increasing the temperature. Even though there are questions about the long term performance of warm mix asphalt, this process has been generally well accepted because of its potential economic and environmental benefits.

Mr. Peterson also discussed the benefits of Open Graded Friction Courses (OGFC). These pavements help to reduce wet weather accidents, as they allow for water to drain off the road surface quickly. However, they are unsuitable for regions with heavy snowfall, since the clearing of snow and ice from open graded pavements is difficult, and these pavements often respond poorly to freeze and thaw.

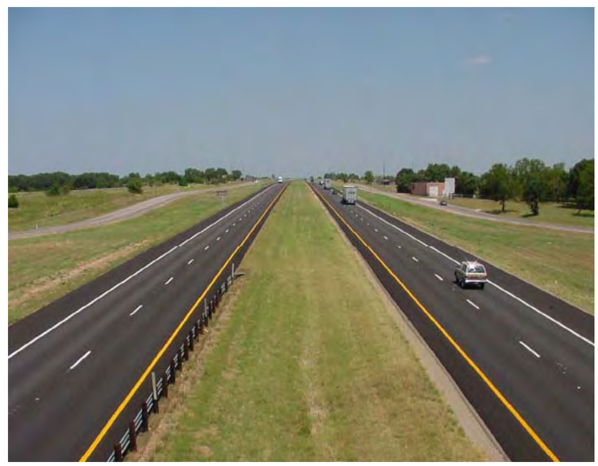
What is Successful Pavement?

Dr. Chang, representing the **University of Texas, El Paso**, gave a brief summary of a TxDOT sponsored project to create a database for flexible pavement sections in Texas. After reviewing the pavement performance characteristics, life cycle information and deterioration models, Chang proposed the definition of successful pavement as "a pavement structure that has met performance expectations over its service life with only normally expected levels of maintenance for its age, materials, traffic loads, and local conditions." This TxDOT project proposes to define successful flexible pavement performance and create a database of representative, particularly successful flexible pavements in Texas, which would serve as successful examples for future analysis and planning. For this database, the primary considerations for pavement selection included geological and climate parameters, pavement structure type, traffic levels, age and degree of success of pavement. Successful performance was attributed to a judicious combination of average annual maintenance expenditure and average condition, distress and ride scores. A Tier Two list of flexible pavements is currently in development. This has adequate representation of both thick and thin Asphalt Concrete Pavements (ACPs), pavements subjected to different traffic levels and a variety of ACP mixture layers. When completed, this database will be publicized statewide, and could be used to address future TxDOT design challenges, as well as provide a means for documenting innovative maintenance-placed experimental pavement sections.

Asset Management Lessons for Pavement and Bridge Preservation

Butch Wlaschin, Director of the **Federal Highway Administration**'s Office of Asset Management, highlighted the need for integration of Transportation Asset Management, based on business and engineering practices for resource allocation and utilization, in decision making. It is a systematic process that helps analyze tradeoffs between objectives and maximize returns in the upkeep of a transportation infrastructure. To accomplish this, quality information based on accurate data, sound engineering and economic analysis is a prerequisite. Effective and timely monitoring of systems supplement the data collected. Ageing infrastructure, growing congestion, funding shortfall and increased focus on system performance are challenges that make the use of Asset Management a necessity.

More than just a performance management system, asset management accounts for the entire network over the whole life-cycle. Wlaschin notes that the most successful asset management programs are renouncing the "worst first" investment strategy, in favor of investment principles that are based on life cycle costing. Furthermore, successful programs undertake scenario analysis showing the consequences of various investment decisions on performance measures. The challenges to the implementation of Asset Management System include the collection of right data for performance measure, linking it to decision making and bringing about an acceptance for the system among the top management. The benefits of asset management approach will ensure that public funding is invested wisely, and will assist government providers and operators of transportations systems in minimizing long term costs, without compromising the achievement of desired service level.



Environmentally Friendly Pavements

Masahiko Iwama of the **Nippo Corporation** gave a detailed summary of the implementation of environmentally friendly pavements. Warm-mix asphalt, enhanced by the additive agent ECOFINE, reduces the mixing temperature by 30 to 50°C. This results in reduction of CO_2 emission by about 14 to 23%. The ECOFINE additive also improves the workability of the asphalt, especially in winter, thereby causing lesser disruption of traffic. Use of ECOFINE also makes it possible to increase the Reclaimed Asphalt Pavement (RAP) ratio by 40% without RAP heating.

Masahiko also explained the invention of solar heat-blocking pavements. Pavement, like concrete structures, is a source of heat, with surface temperatures often reaching 60°C or higher in the summers. Hotter pavements have been linked with the urban heat island phenomenon and the high temperatures are likely to impact the health of the pedestrian. Solar heat-blocking pavements were developed in response to public demand in Japan to reduce the temperature of road pavements, and have been successful in reducing road temperatures by about 16°C. Use of a highly reflective pigment sensitive to the near infrared rays and hollow ceramic particles to reflect the infrared part and solar radiations respectively results in considerable reduction of pavement temperature. The visible part of light remains unaffected by the above reflectors hence visibility is not hampered in any way. Also, the surface coating did not adversely affect the performance of the pavement. Rather the use of this technology decreased the rate of rut depth by 50% as compared to conventional pavements. Masahiko indicated that in future NOx reducing pavements and Vibration reducing pavements are the subject of research at NIPPO.

Dense Cold Mixes: Preservation of Low Volume Roads

Eric Jorda of **Akema Inc,** describes a process used in Europe, especially France for pavement preservation: dense cold mix asphalt emulsion. Dense cold mix consists of emulsion mix asphalt comprising selected aggregates totally coated with binder and is used exclusively as wearing course. When compared to standard Hot Mix Asphalt (HMA) mixes, dense cold mixes demonstrate global energy savings of over 30%. Also cheap and easy to produce, dense cold mixes are particularly suitable for pavement preservation applications. This technology has been in use for more than 20 years in France. However, the mix should not be applied before a complete and accurate laboratory study is conducted to adapt emulsion to aggregate for this type of application. In this study, the engineer must define the aggregate gradation curve and properties, the minimum total water content, the total emulsifier content, the pH adjustment as a function of aggregate properties, and the minimum emulsion content. Then the final composition can be optimized considering the mechanical properties of the mix. The use of dense cold mixes does not require the road to be closed during application as the road can be reopened to traffic just after compaction.

Asphalt Pavement Crack Sealing Field Performance: 25 Year Review

In this presentation, **Patricia Irrgang** of **Crafco Inc**, reviewed the evolution of crack sealing technology over the last 25 years, cataloguing the results of various significant research projects. Before 1970, crack sealing was rarely performed, although research conducted throughout the 1950's and 1960's led to the development of various materials for the sealing of cracks in bituminous pavements and the first categorization of crack types: reflective and random. In the late 1970's and 1980's, as crack sealing was adopted as a commonplace practice, lab and field evaluations of crack sealing materials became more frequent as well. The Utah DOT, the Ontario Ministry of Transportation, and the Sweden National Testing Institute conducted important early tests contributing to, among other things, the designing of the heat lance, the standardization of sealant material and methodology, and the determination of daily and seasonal crack movement rates. In the 1990's the SHRP H-106 Project, led by Smith and Romine, monitored crack movements and configurations for seven years in order to determine the service life and cost-effectiveness of various sealant materials. The study determined that rubberized asphalt provided the best performance, while emulsions and asphalt cement proved to be ineffective crack sealant material. Also, with appropriate project design, materials, installation geometry, installation procedures, and quality control, service lives of at least 7 years could be achieved with both crack filling and crack sealing processes. The most recent research on crack sealant materials has focused on refinement, implementation, and appropriate project design for existing conditions and has defined new criteria for successful crack sealing. For instance, the pavement conditions must be appropriate for crack treatment, and

the sealant properties must be matched to climate. Agencies that have studied and designed the crack sealing process for their climate and pavement conditions have demonstrated maximum success, sometimes extending pavement life up to four years.

New Asphalt Technologies for Pavement Preservation

Microsurfacing and slurry seal

Jack Van Kirk of the **Valley Slurry Seal Company** reviews the use of slurry seals, scrub seals, fog seals, cape seals and microsurfacing in pavement preservation. Slurry seals have been used successfully in a wide variety of environments, including interstates, city streets, and parking lots in coastal, desert, and mountain climates. Microsurfacing is a specialized form of slurry surfacing that can be placed anywhere that slurry surfacing is placed. However, microsurfacing sets faster than slurry seals, and can be placed in much thicker layers. Also, microsurfacing treatments are typically stronger than slurry seals due to the use of higher quality aggregates. Thus the advantages of using slurry seal and microsurfacing include rapid application, extended pavement life, excellent surface texture among various other things.

Van Kirk also discussed the use of cape seals with slurry seals and microsurfacing treatments. A cape seal is a chip seal plus a slurry seal or microsurfacing application, providing both micro and macro surface texture for maximum skid resistance. Cape seals improve the ride and extend the service life of typical chip seals, thereby providing an economic alternative to costly overlays. Fog seals and scrub seals are mainly used to rejuvenate older slurry or cape seals.

Considerations for Flexible vs. Rigid Pavements

Carlos Chang of **University of Texas, El Paso**, explains how the state Departments of Transportation have begun to implement the practice of including rigid versus flexible pavement structure alternatives in construction plans in order to provide flexibility in contractor competition. Ideally, the inclusion of alternate pavement designs early in the bidding process would allow DOT's to achieve a best-value bid price, but there is concern that alternative pavement designs might not be truly equivalent. Several Life-Cycle Cost Analysis (LCCA) studies have been conducted in order to determine whether the alternate designs included in contracts will display comparable performance lives. In California, pavement design alternatives are analyzed for design lives of 10, 20, and 40 years, in order to determine the most cost-effective alternate pavement design life. Furthermore, the Colorado Department of Transportation recommends a 40-year analysis period when comparing flexible and rigid pavements, and the Alternate Design – Alternate Bid (ADAB) procedure developed by the Louisiana DOT appears to have been adopted as standard industry practice. TxDOT project 0-6085 has been conducted to develop a protocol for designing pavement structure alternatives and to provide guidelines for the inclusion of alternate designs in pavement plans. This protocol includes an analysis of general project information, an LCCA comparison of flexible and rigid pavement designs, and a final engineering project evaluation. Equivalent pavement designs should be considered for major highway projects, and projects with a high volume of trucks.

Asphalt Modification Processes

Delmar Salomon, representing **Pavement Preservation Systems LLC**, provided a classification and overview of various asphalt modifiers, explaining their benefits in terms of performance, workability, and adhesion. Asphalt can be modified in order to improve rutting resistance, reduce mix/compaction temperatures, or improve water resistance, and to generally address traffic load and climate variations in order to extend the service lives of pavements. Asphalt modifiers can be broadly classified into chemical, polymer and hybrid formulations. Common asphalt modifiers include block polymers, latex SBR, plastomers, recycled tire rubber, polyphosphoric acid, and gilsonite. Modifiers increase the modulus of asphalt, which results in increase in softening point and reduction in penetration. This improves the workability of the mix. Polymers used as modifiers only alter the physical nature of asphalt and do not combine with it chemically. The polymer used should be ascertained to be compatible with asphalt for best results.

Additives in asphalt thus are used to modify binder performance in order to provide resistance to environmental stresses, improve asphalt-aggregate adhesion resulting in improved water resistance and to enhance the workability of mix by lowering the mixing and compaction temperature.

Sulphur Enhanced Asphalt for the 21st Century

Gary Fitts of **Shell Sulphur** Solutions made a case for the use of sulphur enhancement in asphalt mixes. The potentially negative environmental impact of sulphur usage requires strict management and regulation of this resource, and the proposed use of sulphur in enhanced asphalt hopes to remove sulphur from systems in to which it does not contribute value (e.g. fuels) and introduce it into new technologies that will provide a greater benefit to consumers at a lower environmental cost. In the 1970's and early 1980's, the energy crisis disrupted the traditional bitumen asphalt binder supplies, forcing engineers to incorporate sulfur as a practical means of extending a limited bitumen supply. Shell Thiopave functions in a similar way; the additive replaces up to 25% of the bitumen in the asphalt mix. Sulphur as an additive in asphalt increases stiffness at high service temperatures, reduces temperature sensitivity, improves resistance to rutting, and enhances the load-spreading capability of a pavement surface. Sulphur-enhanced asphalt can be applied in structural courses for thick pavement structures, for instance as an asphalt stabilized base. The limitations with using Thiopave is that strict temperature control is required during production and it cannot be used in thin-surfaced flexible pavements or with bitumen modified with polymers that can cross link with sulphur.

Warm Asphalt Mix Technologies

Eric Jorda of **Akema Inc**, reminded the group that, while relatively simple to produce, hot mix asphalts (HMA) have a severe impact on the environment besides the social and economical concerns it raises. High temperature (320°F) though necessary to remove the liquid water in aggregates and to reduce bitumen viscosity to a workable level, results in practical environmental and safety concerns. Continued efforts to reduce the asphalt mixture fabrication temperature without compromising quality and strength have identified that decreasing the temperature of aggregate could be a viable solution to the problem as aggregates comprise 95% of the mixture.

Three techniques currently exist for the fabricating warm mix asphalt (WMA): foam based processes, wax based chemicals addition, and surfactant addition. In foam based processes, water is added (directly or via zeolite, emulsion, etc.) to form foam that improves aggregate coverage at a lower temperature (195°F to 280°F). Another option involves wax based additives that reduce the viscosity of the asphalt binder at processing conditions. These results in better coverage of the mineral aggregates at lower temperature (70°F), but addition of waxes may change the bitumen characteristics. Finally, surfactant addition improves workability of the asphalt mixtures at lower temperatures (70°F), requires no process modification or addition of water or binder rheology modifier. Thus the shift from HMA to WMA would be accompanied by a reduction in fuel consumption, a reduction in pollutant emissions that results from fuel combustion and bitumen, extended pavement life due to the decrease of bitumen ageing during production.

New Construction Testing Equipment

Rammi Kauppi of **Troxler Electronic Laboratories** presented the latest Troxler gauges and compactors, designed to provide the proper compaction and mix design that are critical to the lasting pavement performance. Gauges measure the moisture content, density, and percent compaction of construction materials, and help engineers save time and avoid costly errors, re-compacting, or patching pavements. According to developers, if 20% of failed pavements are prevented through the use of improved soil-compaction measurement devices, the estimated industry savings would be $3.3 million per year. In addition, use of gyratory compactors lead to improved asphalt quality and Kauppi claims that Troxler compactors simulate wear better than the Marshall method. The Troxler New Technology Ovens (NTO) is expected to improve asphalt quality claims; to use lesser energy than conventional ovens and return results in as little as 25 minutes. All the equipments marketed by Troxler are fully automatic and software managed thereby almost eliminating human error.

An Overview of Rubberized Asphalt Technology

Douglas Carson, Executive Director of the **Rubber Pavements Association**, outlined the engineering benefits and opportunities made available by rubberized asphalt development. Since the development of rubberized asphalt equipment in the 1970's, rubberized asphalt technology has become a relatively familiar method for pavement preservation, although misperceptions persist. ASTM defines Asphalt-rubber as "a blend of asphalt cement, reclaimed tire rubber, and other additives, in which the rubber component is at least 15% by weight of the total blend and has reacted in the hot asphalt cement, causing the rubber particles to swell". Poor quality control and absence of standard specifications obstruct the widespread adoption of this method. Asphalt rubber can be used anywhere that asphalt is used, but particulate rubber is not recommended for dense graded mixes. Asphalt rubber can provide open and pervious mixes that reduce splash and spray on roadways, reduce tire noise, and can last 5-7 years without modifiers. High asphalt prices make rubber a cost-efficient alternative, and pavement maintenance costs will be lowered due to the reduced cracking in rubberized asphalt. These pavements may last up to twice as long as conventional materials before requiring maintenance or replacement.

Using Crumb Rubber Modifier to Meet Demand in High Performance Asphalt

Cecelia Mancero of **Ecopath**, described the benefits of crumb rubber modified (CRM) binder in pavement construction. Asphalt rubber composed of 20% crumb rubber and 80% asphalt binder provides longer lasting road surfaces, reduced road maintenance, shorter breaking distances, and lower road noise.

Chip seal job with tire rubber

Addition of CRM to modern mixes such as Open Graded Friction Course (OGFC), Stone Matrix Asphalt (SMA) or Superpave results in considerable improvement in crack resistance, resistance to permanent deformation and resistance to ageing. By raising the upper failure temperature, decreasing the lower failure temperature, and increasing the viscosities, addition of crumb rubber to binder greatly improves binder performance. The extent of modification achieved would be a factor of base binder and crumb rubber properties. An Accelerated Loading Facility (ALF) study performed by the FHWA recently compared the performance of different Polymer Modified Asphalts (PMA) including SBS, terminal blend, and asphalt rubber. The results of this study demonstrated that over a wide range of load passes, asphalt rubber resisted cracking better than any other tested PMA.

Increasing the Awareness of Pavement Preservation

Yetkin Yildirim, Director, **Texas Pavement Preservation Center (TPPC)**, gave a brief overview of the various pavement preservation awareness projects that the organization has led. Established August 11, 2005, as a collaboration between Center for Transportation Research (CTR) of The University of Texas at Austin and Texas Transportation Institute of Texas A&M University, the TPPC has been actively involved in promoting awareness of pavement preservation methods at the state, national, and international levels. TPPC offers training in pavement preservation methods and practices to TxDOT personnel, contractors and material producers, engineering students, and even elected officials. Online courses in pavement preservation are available at the TPPC website, free and open to the public. Additionally, the TPPC offers classroom courses in seal coats and microsurfacing to engineers and inspectors for CEU credit. Other endeavors for creating awareness for pavement preservation among members of the highway community include the quarterly Pavement Preservation Journal (PPJ) and TPPC Newsletter. The PPJ is published in collaboration with the Foundation for Pavement Preservation and it attracts research from around the world in the area of pavement preservation. Yildirim also presented the most recent research work conducted by the TPPC in the area of seal coats and crack sealing. Out of this research, the TPPC has developed the possibility of stress absorbing layers designed for seal coat application. This method would enhance the performance life of seal coats by preventing the reoccurrence of existing cracks on the newly applied seal coat surface.

Pavement Management Overview

Carlos Chang of **University of Texas, El Paso**, described pavement management as a coordinated, systematic process for carrying out all activities related to providing a healthy pavement network. Pavement management primarily addresses maintenance, rehabilitation, and reconstruction projects by using decision making method to deal with the variety of project options. The standardized decision making process of a pavement management system allows state or national agencies to find cost-effective treatments and apply these treatments at the appropriate times to achieve desired levels of service. A typical pavement management system comprises of an asset inventory, a central database, and analysis and report modules. The system allows for road condition assessments to be analyzed effectively, and the determination of needed work and funds thereby leading to the identification of candidate projects. Data collected from the roadway is calculated into the Pavement Condition Index (PCI), an indicator of pavement health that serves as a ranking and communication tool among pavement engineers. PCI can be used to project the future condition of the pavement, establish a rate of deterioration, and determine maintenance and rehabilitation needs. The trigger points in the pavement management system establish specific levels at which treatments should be applied. Higher trigger value indicates a need for Maintenance and Rehabilitation. Multiple trigger values can be used to allow for a more flexible approach to backlogged pavement needs or to complex pavement challenges. Performance models or optimization methods can be used as alternative trigger based approach in pavement management system.

Asset Management for the 21st Century: Accountable Performance

Puneet Singh of **Poly-Carb** articulated the challenges faced by the US infrastructure and the need for asset management. In the United States, there are nearly 4 million miles of public roads that are rapidly ageing and under increased stress. Additionally, AASHTO estimates that 1 out of 4 bridges in the US need updates or repairs that would cost an estimated $140 billion. Under the current infrastructure model, repairs are conducted reactively. Puneet argued for a shift from this repair-oriented mindset to a truly preventative approach that seeks to proactively extend life cycles and consider the long term rather than the short term costs of pavement maintenance. A proactive infrastructure model would ensure future quality and preservation and provide increased safety and performance. This key to achieving this is increased accountability in order to maximize the limited resources of road agencies. The model is ideal for high value assets that are sizeable and cause great inconvenience to close. If performance is assured for every dollar invested, the unforeseen costs of rehabilitation or reconstruction will no longer inflate construction costs and put financial pressure on state DOTs. The allocated funds will be used efficiently to deliver the maximum value from limited resources.

Asset Management at the Regional Level

Theresea Rommel of **Metropolitan Transportation Commission**, presented the results of a case study evaluating the San Francisco Bay area pavement management system. In this area, a population of 7.1 million uses 42,000 lane miles of roadway. Local streets and roads, which support all modes of transportation, compose the biggest and most expensive piece of transportation infrastructure with an estimated $40-$50 billion replacement value. The Metropolitan Transportation Commision (MTC) developed the Regional Streets and Roads program to proactively manage this seminal portion of the pavement infrastructure. The program costs over $1.5 million annually, as opposed to the $1 million cost of reconstructing a single lane mile of roadway. The MTC uses StreetSaver software as its network level system in order to document needs and conditions and determine which projects should be given priority. Furthermore, the Pavement Management Technical Assistance Program (PTAP) is a federal grant program that provides $800,000 annually for the collection of quality road data that can assist in pavement management decision making. Rommel concludes that spending money on new construction is wasteful without having in place the appropriate infrastructure to ensure the preservation and maintenance of the new roadway. Asset management programs also provide the means for regulatory and financing agencies to ensure accountability and track progress.

Road Maintenance in Developing Countries: The World Bank Perspective

Ben Gericke of **The World Bank,** discussed the World Bank's Project Cycle for road improvement in developing nations, and the possible ways that this cycle could be better coordinated to the client country's internal project cycle. The World Bank typically merges its process of identification, preparation, appraisal, approval, supervision and completion with the client's project cycle of planning, design, construction, and maintenance. Through this cooperation, the Bank hopes to ensure efficient utilization of resources. Also, the middle income and International Development Association (IDA) require best practices to be included, such as institutional improvements, improved transparency, road safety and output and performance-based contracting. Case studies in the Philippines, Zambia, and Liberia demonstrate the value of partnering with local road agencies for development projects.

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TEXAS PAVEMENT PRESERVATION CENTER

TxDOT Newsletter ISSUE 17 / WINTER 2010

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HIR Open House and Workshop

Our Mission

The mission of the TPPC, in joint collaboration with the Center for Transportation Research (CTR) of the University of Texas at Austin and the Texas Transportation Institute (TTI) of Texas A&M University, is to promote the use of pavement preservation strategies to provide the highest level of service to the traveling public at the lowest cost. The executive sponsor for the TPPC is the Texas Department of Transportation (TxDOT).

Contact Us

Director: Dr. Yetkin Yildirim, P.E.
E-mail: yetkin@mail.utexas.edu
Website: www.utexas.edu/research/tppc

Past and Upcoming Events

Hot In-Place Recycling

The Hot In-Place Recycling (HIR) Open House and Workshop was held in Fort Worth on October 29, 2009. The workshop was jointly sponsored by Cutler Repaving, Inc., Martin Asphalt Company, the City of Fort Worth, FP2, and the Texas Pavement Preservation Center. The implementation methods and potential benefits of hot in-place recycling were presented by John Rathbun, and Bill O'Leary described the additives used in HIR. Yetkin Yildirim described HIR in relation to pavement preservation, and Najib Fares, infrastructure manager for the City of Fort Worth, described his first-hand experience with hot in-place recycling methods. Videos of this workshop and additional instructional materials regarding hot in-place recycling are available for use online at:
http://www.utexas.edu/research/tppc/conf/HotInPlace

TPPC Seal Coat Training Courses

Seal Coat training courses will continue to be offered by the TPPC. The course designed for inspectors, entitled "Seal Coat Inspection and Applications," focuses on proper inspection methods and the equipment used during chip seal construction. The other course, "Seal Coat Planning and Design," instructs engineers on planning, designing, and constructing chip seals.

For more information on the Seal Coat courses, please contact Dr. Yetkin Yildirim, P.E. at yetkin@mail.utexas.edu or (512) 232-3084.

Hot In-Place Recycling

"Additives Used in HIR and the Benefits" presented by Bill O'Leary, VP of Martin Asphalt Company

The Rising Cost of Asphalt

The Hot In-Place Recycling Open House and Workshop began with a brief overview on what asphalt cement is and where it comes from. Most asphalt is the byproduct of crude oil refining. However, only some crudes produce asphalt and finding crudes that are available for asphalt production is becoming more and more difficult. This stems from the fact that innovations in fuel refinement have made previously unusable forms of asphalt viable for fuel productions. This coupled with the rising price of crude oil has resulted in a steady increase in the cost of asphalt production.

Ever-rising costs present a problem due to the natural aging process of asphalt pavement and its inevitable need for maintenance. Asphalt pavement slowly oxidizes when exposed to air and water, causing the material to become stiffer, thicker, and brittle with age. These factors combined with the constant stress caused by vehicular loading results in the inevitable raveling, cracking, and eventual base failure that will occur with all asphalt pavements. Because of this aging process and asphalt pavement's inevitable need for repair, new ways of maintaining or recycling the asphalt material are necessary.

Pavement engineers are attempting to solve these problems through a process of preventive measures. It is far more cost effective to catch defects in the asphalt pavement early on because the cost of preventive measures are far less than the cost it would take to rehabilitate dilapidated asphalt material. Rehabilitation can cost up to ten times the amount that equally effective preventive measures would cost.

Components of Asphalt

In order for this to be a successful procedure, an acute knowledge of the properties and components of asphalt is required. Asphalt contains three key ingredients, and finding the appropriate balance between these components in the mixture is the key to successfully recycling asphalt. Newer asphalts known as "super binders" contain roughly 15% asphaltenes. These asphaltenes act as the skeleton that the rest of the asphalt builds upon. Secondly, it is important to keep the amount of saturates as low as possible in the mix. These saturates are wax-like hydrocarbon molecules that contribute to weaker bonds between the materials in the asphalt. Lastly, the asphalt mixture must have a healthy amount of polar and naphthalene aromatics. These glue-like components are composed of open bonds and are the most important component when trying to polymer-modify the asphalt material. Other authorities in the field will argue that all that is needed in recycling asphalt is to mix recycling agents into uprooted asphalt.

Separated Asphalt Components

"Implementing HIR in Both a City and Highway Agency" presented by John Rathbun, VP – Sales, Cutler Repaving, Inc**.**

Growing in popularity as a pavement rehabilitation measure is the hot in-place recycling (HIR) method. This process involves heating, loosening and rejuvenating the top one to two inches of an existing asphalt pavement while simultaneously applying a hot-mix-asphalt (HMA) overlay while the temperature of the recycled layer is still above 200º F.

Proper Pavement Preservation Candidates

Before any pavement preservation measures should be taken, it must be determined whether or not the road in question is a good candidate for hot in-place recycling. Proper pavement preservation applies the *right* treatment on the *right* road at the *right* time. Good candidates for hot in-place recycling are roads that show rutting, wearing, cracking, aging, or poor frictional characteristics. A poor candidate would be a road that shows unstable subgrade, wide transverse thermal cracks, asphalt stripping from aggregates, structural defects or lack of structural capacity, or a presence of geotextile fabric within the top two inches of the existing pavement. According to Ruthbun, HIR is the one of best preservation treatment to address the surface distresses within the top two inches of existing pavement.

Surface Recycling

Once it is determined that a road is a suitable candidate for the HIR process, one of three HIR methods must be used to improve the road. The first, surface recycling, consists of heating, loosening, rejuvenating and relaying an asphalt pavement in place. This method uses a preheater to loosen the surface asphalt, then applies recycling agents to the loosened asphalt, then the asphalt is laid back down. In the second method, remixing, the asphalt is heated, loosened, and then sent into a pug mill where it is mixed with new material, then laid as either the surface or binder course. In repaving, the top surface is heated, loosened and rejuvenated, then laid down in place as a leveling course. While the leveling course remains above 200º F, an HMA overlay is laid on top.

These HIR methods have varying degrees of appropriateness depending on the condition of the road in question. HIR is most appropriate when the road shows raveling, potholes, skid resistance, fatigue cracking, or edge, slippage, block, longitudinal, transverse, and reflective cracking. HIR is less appropriate, but still viable when the road shows bleeding, rutting, corrugation, marginal existing pavement strength, swells, bumps, sags, or depressions.

While all three HIR methods are currently in use, Cutler Repaving only uses the repaving method. Repaving is argued by many as better to remixing and surface recycling because repaving is the only HIR process that interlocks the aggregates of the recycled layer with that of the overlay. Additionally, repaving uses 50% less materials than other conventional methods. If that's not enough, while repaving expends approximately 52,000 BTUs per square yard, the "mill and fill" method expends 83,000 BTUs per square yard, and "cold in-place recycling" expends 91,000 BTUs per square yard. Greater efficiency translates into lower greenhouse gas emissions as well. Repaving expend 7 pounds per square yard of greenhouse gasses, while "mill and fill" expends 12 pounds, and "cold in-place" expends 13 pounds.

Cutler Once-Over Repaving Process

Six Steps of Repaving

As a result of the specialization of only using one kind of HIR method, Cutler Repaving has devoted their resources to streamlining the process by developing and manufacturing a 65 foot long machine that is capable of completing all of the repaving process' six steps in one pass. First, heating hoods fueled by propane are lowered over the damaged road. The pavement is slowly heated to 375º F – a high enough temperature for the pavement to loosen.

Underneath Heating Hood

Second, loosened pavement is scarified with carbide tipped teeth. By doing this rather than milling the asphalt, the risk of aggregate degradation, or damaging of the pavement's skeleton, is greatly reduced. Third, the uprooted pavement is mixed with polymer-modified recycling agents. Fourth, the new mixture is laid back on the road with a recycling screed. The mixture is still above 200º F because no more than 30 seconds has passed since the surface was uprooted at the temperature of 375º F. Fifth, a virgin hot mix is spread over the recycled material. What is left is one inch of recycled material on bottom and one inch of new material on top.

Applications of 1" Virgin Hot Mix

In contrast, the remixing method takes the recycled material and the new material and mixes them together. Such a method results in a weaker surface when compared to a surface composed of a recycled material leveling course covered by a fresh wearing course. The sixth and final step is the compaction of these two layers using double-drum laboratory rollers.

With this machine, these six repaving steps are completed in one pass. Such efficiency translates into a more cost effective project, as well as limits the time of inconvenience to commuters. On a highway without restricted hours, the machine can repave up to two miles a day. Such efficiency has directly translated into more projects.

"Pavement Preservation and Hot In-Place Recycling"
presented by Dr. Yetkin Yildirim, Director of TPPC

For years, the traditional approach to road maintenance has been used on our nation's roads and highways. This approach concentrates all of our resources on corrective maintenance, or maintenance that must be done in response to events that cannot be planned, or as reactive repairs. Several research studies that were conducted in an effort to improve the maintenance methods and life of roads have revealed that pavement preservation is a far more effective and cost efficient method of maintaining roads. Preemptive efforts to preserve the structural integrity and functional condition of our roadways have been on the table for the past three decades, but have not been strongly promoted until the past ten years.

Pavement Preservation

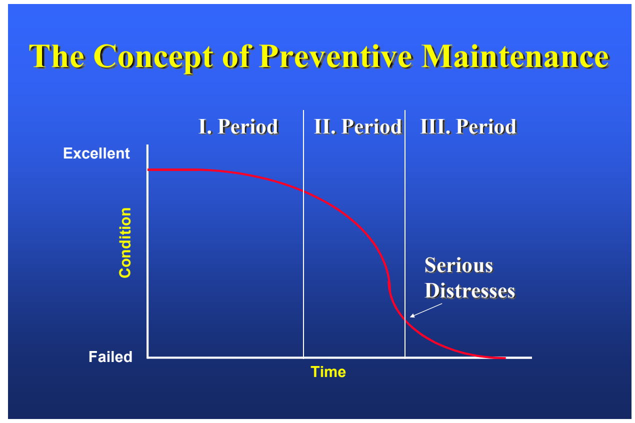

Figure I

Characteristics of a good pavement include fine drainage, a strong foundation, and acceptable thickness. These properties all get exponentially worse with time. Minor cracks allow water to seep through the pavement, resulting in more extensive damage as the cost to repair the pavement rises exponentially. Pavement preservation attempts to never let pavement fall below "Period I" in its three period aging process as illustrated in Figure 1. However, retroactive maintenance will never bring the pavement back to its original quality.

A proper pavement preservation strategy addresses the pavement while it remains in a good condition. If the onset of serious damage is allowed to occur, cost effective treatment would no longer be an option. However, if pavement preservation methods are applied at the right time early in the life of the pavement, the service life of the pavement can be increased significantly. To gain full benefit from adoption of pavement preservation tactics, it is essential to understand what causes the physical wear and tear on the pavement. Knowing the source of the problem will result in a better ability to stave off the effects.

Pavement After Crack Sealing

When considering whether a road needs work, certain things must be taken into account. The existing pavement condition, the climate and weather conditions surrounding the road, the properties of the materials available, the traffic load expected on the road, and local restriction are all important factors to consider when determining the appropriate time for application of pavement preservation methods. In short, it must be determined that it is the *right* treatment for the *right* road at the *right* time.

The Importance of Education

The only way to ensure that these decisions are being properly made will come from education and training. Texas Pavement Preservation Center (TPPC) provides training in the area of pavement preservation. Additionally, the center studies proper research implementation and does strategic planning for research.

Several research efforts spearheaded by TPPC have made helpful innovations on seal coats, crack sealing, thin asphalt overlays, and warm mixes**.** A new patent by TPPC, a stress absorbing layer for seal coats, has offered a method for enhancing the performance and providing longer service life to existing roadways. In three tests, seal coat was tested against a control group on different roads around the state of Texas and were monitored for three years. First, stress absorbing layers for seal coat was applied on the existing cracks on the test sections. After application of stress absorbing layers, seal coats were applied on the test sections and control sections were constructed without the application of stress absorbing layers. These tests found that test sections with stress absorbing layers showed superior performance in comparison with the test sections without stress absorbing layers – cracks did not show up on the surface of seal coats where stress absorbing layers were used.

Test sections: Control section in background and section with Stress Absorbing Layer in the foreground

In summary, pavement preservation programs extend pavement life, preserve structural integrity, enhance pavement performance, slow progressive failures, improve safety, improve ride quality, ensure cost-effectiveness, and improve mobility. Despite the obvious benefits of pavement preservation programs over traditional methods, these benefits will not be realized without proper training and education of the transportation service industry and the local, state, and nationwide policy makers.

"HIR in the City of Ft. Worth" presentation and Q&A with Najib Fares

Last year, the city of Fort Worth appropriated more than 17 million dollars toward street repairs. Through the employment of hot in-place recycling methods, the city has been proactive in their spending and has been able to repair and maintain far more square footage of roads than would have otherwise been possible.

In the early 1980s, Ft. Worth used HIR. However, the people of Ft. Worth were opposed to the large amount of equipment required, the pollution created by this equipment, and the burning damage to grass, trees, and bushes that this equipment caused. Because of this, Ft. Worth stopped using HIR methods and began using micro-surfacing in 1992.

In 2007, Jim King put on a presentation at University Park for the transportation officials of Ft. Worth in an attempt to showcase innovations on the HIR method. Fares and his colleagues observed the use of HIR being employed on small arterial roads lined on either side by lush landscaping. Fares witnessed a smooth operation with minimal inconvenience to commuters, few signs of pollution from the machines, and absolutely no burn damage caused by the machines to the near-by grass, trees and bushes.

Mountain Pass Repaving Job

As a result of this demonstration, the city of Ft. Worth decided to give HIR a second chance 15 years after abandoning the process. They were satisfied with the results. The first HIR project produced quick results, a smooth ride, and seams that were joined together perfectly. Additionally, after a year, reflective cracking was not present. All of this was done for cheaper than it would have cost the city using their previous methods. With these better than expected results, the city has since gone back to using HIR methods on most of their pavement preservation and road repair needs.

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TEXAS PAVEMENT PRESERVATION CENTER

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Contact Us

Director: Dr. Yetkin Yildirim, P.E.
E-mail: yetkin@mail.utexas.edu
Website: www.utexas.edu/research/tppc

Past and Upcoming Events

TRB 89th Annual Meeting

The Transportation Research Board is a division of the National Research Council, which serves as an independent adviser to the federal government and others on scientific and technical questions of national importance. TRB's mission is to promote innovation and progress in transportation through research. The Transportation Research Board's 89th Annual Meeting attracted more than 10,000 transportation professionals from around the world to Washington, DC January 10-14, 2010. The TRB Annual Meeting program consisted of over 3,000 presentations in 600 sessions. Summaries of selected seminar papers related to pavement preservation are included in this issue. For more information on these papers please contact CTR library at 512-232-3126.

TPPC Board of Directors

Our Mission

The mission of the TPPC, in joint collaboration with the Center for Transportation Research (CTR) of the University of Texas at Austin and the Texas Transportation Institute (TTI) of Texas A&M University, is to promote the use of pavement preservation strategies to provide the highest level of service to the traveling public at the lowest cost. The executive sponsor for the TPPC is the Texas Department of Transportation (TxDOT).

TRB 89th Annual Meeting
Selected Pavement Preservation Papers

Performance Evaluation of Asphalt Pavement Preservation Activities by Elie Y. Hajj, Luis Loria, and Peter E. Sebaaly

FHWA guidance issued in 2005 explains that pavement preservation includes all those proactive measures that promise to extend pavement's service life without influencing its structural condition. Minor rehabilitation, preventive maintenance, and routine activities fall under this category. Previous research has shown that preventive maintenance methods cost only 15-20% of the ultimate failure repair cost that will occur in the absence of maintenance activities.

The paper cites examples of several previous studies that were conducted to determine the long term performance and appropriate time of application for various preventive maintenance methods. A study by Peshkin et al. in 2004 evaluated the expected life of several pavement preservation techniques such as crack filling and sealing (2 to 6 years), fog seals (1 to 2 years), slurry seals (3 to 5 years), scrub seals (1 to 3 years), micro-surfacing (4 to 7 years), chip seals (4 to 7 years), and thin HMA overlays (7 to 10 years). Other studies reviewed provided an estimate of the expected lives of common preservation methods in various states.

The paper emphasizes that it is essential for each highway agency to develop its own model for predicting the performance of preservation methods. Generic models developed for the purpose do not provide a good estimate, as they neglect the environmental, traffic, and material properties that are specific to the state.

This study details the development of an effective pavement preservation program to maintain Nevada's flexible pavements. The methodology included an evaluation and review of long-term performance and cost effectiveness of various strategies adopted over the last 15 years by Nevada DOT (NDOT) to preserve its asphalt pavements.

Several preservation methods commonly used by NDOT were identified for study, after consultation with NDOT maintenance personnel. Their performance evaluation and analysis were then conducted by reviewing NDOT's maintenance records over 15 years (1990-2005), conducting field studies of representative sections identified, and analyzing NDOT's pavement management system data. This methodology ensured that all factors which impact performance, namely construction technique, material characteristics, traffic, and environment conditions are considered in evaluation.

Recommendations for the pavement preservation programs on state roads and US and Interstate routes are made based on the analysis. The suggestions are based on the value of the Pavement Serviceability Index (PSI), Roughness Index (IRI), and pavement condition. The recommended treatment methods are listed preferentially based on performance, expected improvements by its application, and benefit-cost ratio.

Improving Pavement Preservation Treatment Strategy Selection Using Expert System Approach by DingXin Cheng, R. Gary Hicks, and Alfonso Ochoa

Generally, states make use of decision trees or decision tables to assist with the pavement treatment selection technique. However, decision trees can be difficult to manage when they include a large number of alternatives and complex conditions. Also, they do not always consider all the important factors or the ways to handle multiple distress types and/or they limit the use of various innovative treatments. In this paper Chen et al. propose to incorporate the expert system concept into pavement treatment selection process. An expert system was developed at the California Pavement Preservation Center based on the guidelines given by the Maintenance Technical Advisory Guide to assist pavement engineers in ranking appropriate pavement treatments.

The conventional method applies specific procedures to the input data and displays the calculated results without any logical reasoning for the final decision. The expert system, based on logical facts and expert knowledge, helps us in reaching the conclusions that a human expert would reach if faced with the same problem. Thus it projects the fact that it can handle complex real world problems with ease and accuracy.

An expert system consists of three main components: a user interface, an interface engine, and a knowledge base which stores knowledge from experts or experienced engineers. The working of the expert system is briefly described in this paper, and the advantage of using such a system is discussed. Some of the advantages are listed below:

- An expert system can support inexperienced engineers in strategic decision making, and can also help seasoned engineers streamline and explicitly present their decision making process.
- The system allows experienced engineers to modify default values to local practical values which provide the system with considerable flexibility.
- The system is also expandable, which means that a knowledgeable engineer can update default values and add new treatments.

Performance of Recycled Hot Mix Asphalt Overlays in Rehabilitation of Flexible Pavements by Regis L. Carvalho, Hamid Shirazi, Manuel Ayres Jr., and Olga Selezneva

Increased environmental awareness and appreciation of the limited availability of virgin materials have prompted the increased use of reclaimed asphalt pavements (RAP) in Hot Mix Asphalt (HMA) production. Focused research sponsored by federal, state, and other agencies has resulted in tremendous improvements in pavement recycling technologies over the years. Survey reports indicate a 33% reuse of RAP in HMA production.

Despite concerted efforts for promoting the use of RAP and several technological advancements, its use in pavement engineering is still limited. Conventional beliefs and traditional practices still stand in the way of RAP use becoming a common practice. Research and investigation of long-term performance of pavement overlaid with RAP HMA is necessary to challenge the belief that recycled materials are inferior in quality to virgin materials.

As a part of FHWA's Long Term Pavement Performance (LTTP) Program, Strategic Highway Research Program (SHRP) initiated a study to evaluate HMA performance, including RAP and virgin mixes. Referred to as Rehabilitation of Flexible Pavements, Specific Pavement Studies-5 (SPS-5), this study evaluated performance at early stages of SPS-5 pavements. Only limited full term performance data was available.

This study provides a comparative analysis of the performance of RAP and virgin HMA pavements which have been in service for a long period. Statistical techniques are employed to compare performance data of pavements overlaid with RAP and virgin HMA. Comparisons were made only among those mixes for which pavement was overlaid under similar conditions and subjected to similar environmental and traffic conditions. The evaluation was based on performance indicators including roughness, rutting and fatigue cracking, and deflection as structural parameter. The data collection and monitoring period ranged from 8-17 years after rehabilitation.

Statistical analysis showed RAP performance to be equivalent to that of virgin HMA mixes at most locations. All 18 sites monitored had statistically equivalent deflections, thereby indicating that RAP and HMA overlays provide similar structural improvement. The data showed that the statistical variance between results was significantly lower for thicker overlays than for the thinner ones. Thus a thicker RAP overlay can be expected to perform as well as a thick virgin HMA overlay. Pavement condition prior to rehabilitation and site environmental conditions are important for evaluation, but their impact did not alter the final result of the analysis which statistically shows that RAP overlays are as good as HMA overlays.

An Apparent Healing Mechanism in Asphalt-Based Crack Sealants by Scott Shuler, Colorado State University

Dr. Scott Shuler, representing Colorado State University, gave a brief summary about a method that can be used for the determination of short term and long term performances of crack sealing depending on the type of crack sealant used, method used for installation and location of the pavement. In this method the measurements of the amount and severity of cracking as a function of the original filled crack length were taken, from which the performance was evaluated.

In order to assess the performance, three crack sealants were installed in three environments using three different installation procedures and two crack filling methods. It was seen from the results that most of the failures increased with time during the first year and then decreased. This is conclusive of the fact that there occurs a 'healing' mechanism in the crack sealants which does not depend on the application methods, materials or location and that this behavior cannot be explained as an aftereffect of expansion and contraction of pavement slabs between transverse cracks. This 'healing' action is caused due to the kneading action of traffic and may occur during hot weather. Thus the sealants will continue to perform efficiently for longer periods of time than what was believed until now.

Bonded Whitetopping Overlay Design Considerations with Regards to Joint Sealing and the Preservation of Reflection Cracking by Julie M. Vandenbossche and Manik Barman, University of Pittsburgh

Dr. Julie Vandenbossche et al. of the University of Pittsburgh gave an overview of the evaluation of pavement performance to establish criteria on when reflection cracks might develop essentially on thin PCC overlays of HMA pavements. The process of planning this thin concrete overlay on top of the distressed HMA pavement is called whitetopping. For the purpose of this study nine test sections were constructed on I-94 at the Minnesota Road Research facility. For long term good performance thin Portland cement concrete overlays were constructed so as to ensure perfect bonding between the concrete layer and the underlying asphalt layer. Also, the effects of joint sealing and usage of dowel bars on the performance of bonded whitetopping was evaluated.

It was concluded that reflection cracking would depend on the thickness of PCC overlay and HMA layer, panel size, climatic conditions, and accumulated vehicle loads. The rate at which reflection cracking occurs is a function of temperature, load related stress and stiffness of the concrete relative to that of the HMA layer. It was also noticed that the driving lane was susceptible to more reflection cracking than the passing lane and that reflection cracking will develop in bonded whitetopping if the relative stiffness of the layers falls below 1. From the study it was deduced that the sealing of joints helps in prolonging pavement life by preventing infiltration of water into the pavement, ensuring a good bond between PCC and HMA, and maintaining the quality of HMA. It was also seen that the usage of small diameter dowel bars would help in improving the performance of the overlay.

An Investigation into a Generalised Framework for Pavement Data Asset Management by Dr. Matthew Byrne, Dr. Tony Parry, Nottingham Transportation Engineering Centre

Dr. Matthew Byrne et al of the Nottingham Transportation Engineering Centre explain the significance and importance of acquiring quality data for a pavement assessment management system (PAM). PAM is used for long term analysis and decision making, and thus the data that is entered in PAM should be of high quality so as to ensure quality decision making. The management of this data is required to guarantee the highest level of performance for a fixed expenditure. This paper provides a blueprint for the various engineering methodologies which will ensure quality management of data, and identifies models which can incorporate pavement data asset management (PDAM) with PAM or wider infrastructure asset management (IAM). In this paper the authors attempt to answers questions that determine the successful implementation of PDAM, such as what the current information quality is, whether this information quality will be acceptable to make meaningful decisions, and how to improve the quality of information in the most cost effective way. A new data mining algorithm is introduced by the authors for the successful implementation of PDAM.

There is a need to move toward a more holistic approach instead of an individualistic approach for the assessment of data through an infrastructure asset management system. Since there is always a set budget for data collection which is unable to meet the true requirements of asset management decision making, it was concluded from this paper that better management through PDAM of the type described here using the new data mining algorithm should yield significant savings. Through this paper, a new and effective work plan was proposed to meet the requirements of PDAM.

Bituminous Overlay Strategies for Preventive Maintenance on Pennsylvania Interstate Roadways by Shreya Gopal, David Peshkin, and Amir Koubaa, University of Pittsburg

Shreya Gopal et al. discuss a two-stage process to identify appropriate bituminous overlay strategies for interstate pavements, initiated by PennDOT in 2008. Here, "bituminous overlay strategy" refers to the types of treatments that could be used to preserve high traffic volume bituminous surfaces. The first stage consisted of an extensive literature review of the preventive maintenance practices and best practices at a national level. The literature review was supplemented by a survey of selected states and PennDOT districts to determine the best practices with respect to different performance evaluation criteria such as climatic conditions, traffic conditions and volumes, geography, pavement age, pavement distress condition prior to application, pre-overlay repair, performance evaluation factors of pavement, and service life of maintenance strategy.

Some of the methods used for preservation of bituminous pavements include crack sealing, single course surface treatment / chip seal application, quick set slurry / slurry seal, cape seal application, fog seal, thin HMA overlay, micro-surfacing application, polymer-modified HMA overlay, and ultra-thin wearing course. Treatment type, traffic considerations, and treatment life are the main factors which influence the preventive maintenance treatments. The applicability of a treatment depends on a number of factors, such as the condition of the pavement, service life, geographical conditions, and the overall effectiveness of the applied technique. The post-treatment service life extension of the pavement is significant in determining the effectiveness of a practice. It was observed from the first phase of the study that the most common techniques used are thin hot mix asphalt overlays, micro-surfacing, chip sealing, and polymer modified hot mix asphalt overlay. It was also noticed that the treatment service life for micro-surfacing, thin HMA overlay and polymer-modified HMA were considerably higher than the other methods.

The second stage of the study focused on the maintenance practices used by state highway agencies with conditions similar to those in Pennsylvania or neighboring areas and within the districts of Pennsylvania. A survey was conducted with questions regarding preservation techniques, current and best practices for HMA overlays, techniques and guidelines for preventive maintenance, and effective methods of pavement preservation based on current practices. Five states – Michigan, Minnesota, Ohio, New York, and Virginia – participated in the survey. From this survey it was concluded that while most of the DOTs use similar treatments, some of them use measures and guidelines specific to the state. In addition to the survey of state DOT practices, a PennDOT district-level survey was conducted to study the practices and maintenance techniques in Pennsylvania. Chip sealing was found to be most effective in low traffic conditions, and cape sealing for higher traffic volume pavements. A list of available treatments for Pennsylvania interstate pavements was identified. Also, most of the districts reported the use of milling and overlay of 1.5 to 2 inches thick for high severity distress.

An Assessment of Procedures to Determine Intervention Levels for Pavement Preservation by Ghim Ping Ong, Tommy E. Nantung, and Kumares C. Sinha

For the selection of pavement preservation treatment, state highway agencies generally develop a set of intervention levels. Intervention levels for a specific project mainly depend on the measurements of pavement roughness, rutting on asphalt pavements, faulting on jointed or jointed reinforced concrete pavements, and pavement surface distresses. In this paper, Ong et al. discuss two different procedures to develop distress specific intervention levels for system wide pavement treatments: historical practices and decision matrices obtained from expert opinions. This is important because composite ratings representing the overall condition of pavement surfaces may not be suitable for triggering preservation treatments which tend to be distress-specific. Using information on in-house and contract maintenance/rehabilitation works, network-level pavement condition data, and highway pavement inventory data collected between 1998 and 2008, the mean historical intervention levels and their standard deviation were developed. Data used here are all relating to the state of Indiana. From expert opinion surveys conducted in 2008 decision matrices were developed.

It is seen that both historical and expert opinion based procedures suggest similar pavement treatment, except for some small differences in the levels of severity at which treatment is triggered. It was observed from the study that decision matrices using expert opinions were better suited for implementation within a statewide pavement management system compared to intervention levels based on historical practices, especially for new and innovative treatments where sufficient data for analysis may not be available. Some of the treatment preferences obtained from the study are listed below:

- Crack seals are preferred on pavements with low rut severity, excellent or fair international roughness index and medium crack severity.
- Micro-surfacing is preferred when IRI is fair and rut severity is low or moderate.
- Chip seals are only used on non-interstate pavements with poor friction and low or fair IRI.
- Thin overlays are used on pavements with fair IRI or on Interstate and non-Interstate pavements with poor friction (provided there is no significant structural deterioration).
- Crack seals are preferred on jointed concrete pavements with excellent or fair IRI, low fault severity, and low or medium crack severity.
- Joint-bump repair, load transfer retrofitting, and diamond grinding are preferred when faulting is of moderate severity at most.
- Partial and full depth-repairs are applied on jointed concrete pavements with moderate fault and crack severities.

Exploring Sustainable Pavement Rehabilitation: Cold In-Place Recycling with Expanded Asphalt Mix by Peter Chan, Susan Tighe, and Susanne Chan

Sustainable pavement rehabilitations are inevitable requirements for maximizing pavement performance with the available funds. Chan et al. explore the planning, design, construction, quality assurance, and environmental aspect of Cold In-Place Recycling with Expanded Asphalt Mix (CIREAM) in a qualitative manner. CIREAM is a sustainable pavement rehabilitation method currently used in the industry. It is an in-place recycling technique which makes use of expanded asphalt (foamed asphalt) without pulverizing the existing pavement. The CIREAM process is very similar to cold in-place recycling (CIR) in terms of milling existing asphalt pavement at partial depth, except for the fact that CIR rehabilitation makes use of emulsified asphalt to provide additional adhesion to the recycled aggregates, whereas CIREAM rehabilitation uses foamed asphalt during the rehabilitation process. Here water is used as an additive to cause asphalt cement to foam.

A successful CIREAM rehabilitation involves good planning, design, construction and quality assurance. The planning component for CIREAM rehabilitation requires a pavement distress survey to identify the distresses present. The design components to be considered for CIREAM rehabilitation are milling and processing depth, overlay thickness, and foamed asphalt mix design. To avoid breaking through into the granular, the mill depth should avoid the bottom 25 mm of existing pavement. Overlay design determines the thickness of the pavement depending on the traffic load. Various overlay design models and computer software are available to help in the overlay design, though these were not further discussed in this paper. The foamed asphalt mix design involves the determination of cold water injection rate and percent asphalt added during CIREAM rehabilitation so as to provide adequate thickness for the required traffic load.

The CIREAM rehabilitation process consists of the following 6 steps:

- Setup road closure and traffic protection
- Cold milling of pavement and process into CIREAM binder with the addition of expanded asphalt
- Cure CIREAM binder for three days
- Sweep and clean the cured surface
- Provide tack coat to CIREAM binder course to enhance adhesion of final overlay
- Provide new asphalt overlay and compaction

Some of the quality assurance tests that are performed were also discussed. Dry tensile strength, wet tensile strength, and tensile strength ratio are used to determine moisture susceptibility, rutting potential, and cracking potential of the binder. Bulk specific gravity tests are used to provide an indication of how well the CIREAM binder is mixed during the recycling process. Last, the environmental impact of CIREAM construction was evaluated using PaLATE software, from which it was seen that it provides emission and energy savings when compared to conventional mill and overlay.

The potential benefit of CIREAM includes savings in asphalt cement, savings in aggregates, significant money and time savings incurred by reducing transportation cost and disposal cost, and short curing time after rehabilitation for traffic. It is expected that CIREAM will become more popular in the future because of its immense potential benefits.

An Exploration of Matter-Element Analysis for Pavement Preventive Maintenance, Optimal Timing Determination and Treatment Selection by Qiang Li, Xiaohong She, Kevin C. P. Wang, and Kevin D. Hall

Qiang Li et.al. explore a new methodology for treatment selection and its optimal timing based on Matter-Element Analysis (MEA). MEA methodology is used to solve problems with contradictions and incompatibilities. Pavement preventive maintenance decision-making accurately fits into this category.

Definition of matter elements, extension mathematics, and matter element transformation theory form the three main pillars of any MEA. A matter element is a representation of the characteristics of the object under study, which can be defined using an ordered triad such as ME = (N, C, V), where N denotes the name of the matter, C is its characteristic (or representative parameter), and V is called the “Field” session (which can be a number, an interval, or a verbal description). Once the matter elements are defined, matter element based transformation processes can be executed to determine quantitative relationships among the various elements, from which decisions can be made.

Data set consist of SPS-3 pavement sections from the Long Term Pavement Performance database. Using this data, statistical performance deterioration models are developed for do-nothing and post-treatment scenarios for four typical preventive treatments (chip seal, slurry seal, crack seal, and thin overlay). These models capture the variations in environment, traffic level, structural condition and pavement age; the performance indicators employed are International Roughness Index, Rutting, and Friction Number.

Calculation of post treatment benefits is done by calculating the area under the curve for indicators that decrease over time (e.g., Friction Number) and area above the curve for condition indicators (e.g., IRI, Rutting). Based on NCHRP 14-14 recommendations, Equivalent Uniform Annual Cost (EUAC) was used to compare the different cost streams associated with each preventive maintenance method. A discount rate of 4.0 percent is used in the analysis.

The optimal timing for each treatment is calculated following the matter element transformation by evaluating the correlation coefficients among the matter elements. The timing corresponding to the largest overall correlation coefficient is taken as the optimal timing of the treatment application. When more than one preventive method is suitable for a pavement under consideration, the optimal timing corresponding to each is determined separately, and then the corresponding benefits and cost for each treatment type at the optimal timing scenario are integrated to generate another matter element. Then by following the same method the overall correlation coefficient is determined, forming the basis for the selection of the most appropriate method.

This method is theoretically simple, easy to understand and implement, but it is important for each agency to develop its own models and review the selected factors regularly, as performance models for preventive treatments are critical to obtaining accurate analysis results. Also, the complex relationships among treatment, cost, timing, weighting factors, time value of money and performance deterioration require future exploration.

Assessment of Surface Treatment with Textiles for Pavement Rehabilitation and Maintenance by Lita Davis and John Miner

Surface treatments such as chip sealing or thin asphalt overlays are generally used to preserve and extend the life of a pavement. Placement of paving fabric during asphalt concrete resurfacing operations has been practiced for decades. Davis et al. discuss the climatic regions where chip sealing can be done successfully over paving fabric, as well as the cost effectiveness of this method. The use of paving fabric in conjunction with chip seal combines the benefits realized from chip sealing and those realized with a paving fabric interlayer when used hot mix asphalt concrete resurfacing. This method has been used in warm climates of California and Texas for over 25 years, and it was observed that the paving fabrics can extend the life of a chip seal by an additional 50 to 75 percent. Since chip seals have temperature requirements that are more restrictive than those for placing a paving fabric with asphalt concrete resurfacing, there is a need to develop a reasonable approach for placing chip seals over paving fabrics in various climatic conditions of the US, in addition to those experienced in California and Texas.

33 chip seal over fabric projects were installed in varying climatic regions across the United States including Colorado, Illinois, Michigan, Minnesota and Washington DC, as well as other parts of California and Texas. Field experiments were conducted, from which it was concluded that year-round climatic conditions were found to be as important as the day of construction, and also that identifying a roadway as a proper candidate is important to guarantee success. It was also observed from the experiments that many of the regions were able to obtain the same success rate as California and Texas.

The climatic regions where there was a high success rate of using chip sealing over paving fabric were quantified, and the climatic regions or environmental conditions that prevent successful performance were determined. The method of using chip seal over paving fabric was found to be highly beneficial for preserving flexible pavements and reducing future road maintenance. All in all, Davis et. al. explain the treatment's economic and environmental benefits, quantify the climatic areas where chip sealing over paving fabric can be done successfully, and discuss the application of construction material depending on climatic condition.

Network-Level Multi Objective Optimal Maintenance and Rehabilitation Scheduling by Lu Gao, Chi Xie, and Zhanmin Zhang

Pavement Maintenance and Rehabilitation (M&R) is a major cost for all transportation agencies. The process involves making several complicated decisions with regard to which pavement to select for treatment, when it should be treated, and which treatment should be used within cost constraints.

Pavement Maintenance is the more routine procedure that ensures pavement is in a good condition. It may be preventive or reactive, and includes activities like crack filling, patching potholes, chip seal coating, or use of slurry seal among others. Pavement rehabilitation, on the other hand, is a more expensive procedure which is performed to improve the pavement's structural capacity. Resurfacing (overlay), resurfacing with partial construction (localized reconstruction), and complete reconstruction fall into this category.

All agencies today use the Pavement Management System (PMS) to help make relevant decisions to meet the objective of providing the best performance while minimizing the cost incurred.

In this study, Gao et al. formulated a multi-objective pavement maintenance and rehabilitation scheduling model that would simultaneously optimize the two parameters involved in the decision – pavement condition and budget utilization – for a pavement network.

Generally, the solution for a multi-objective optimization problem is a set of non-dominated solutions rather than a single superior solution. This set of solutions is called the Pareto-optimal solution set. The general practice in any multi-objective situation is to identify the Pareto-optimal solution set and then select the alternative that provides the best trade off for the system with regard to objectives and preferences.

Earlier models that were developed with similar objectives used integer programming (IP) or linear programming (LP) formulation, but these approaches work well only for a small and homogeneous network. Genetic algorithm (GA) was then considered, but it proved to be very complex and time consuming. This paper used the Markov-based multi-objective linear programming approach for scheduling and parametric method for obtaining the Pareto-optimal (non-dominated) solution sets. This proved efficient at providing optimal solutions for network-level problems.

The model proposed in the paper was applied to a road network in Dallas, Texas. Through this case study it was verified that parametric method is more efficient for solving multi-objective pavement M&R scheduling problems. Furthermore, it ensures a full set of Pareto-optimal solutions. Sensitivity analysis for budget constraints and condition requirement was also performed. It showed that altering the condition requirement would not significantly change the outcome. The study thus successfully provides an efficient decision making tool for M&R activities that would enable decision makers to make more informed and optimal decisions.

Network-Level Pavement Roughness Prediction Model for Rehabilitation Recommendations by Nima Kargah-Ostadi, Shelley M. Stoffels, and Nader Tabatabaee

Transportation agencies today rely heavily on Pavement Management Systems (PMS), an indispensable tool that helps in decision making with respect to Maintenance and Rehabilitation (M&R) activities. A typical network-level PMS consists of a repository of information that includes performance data, condition assessment, and pavement performance models that identify need, prioritize M&R alternatives, and predict future performance. Moreover, it includes a feedback mechanism that is essential for Life Cycle Cost Analysis (LCCA).

Pavement performance models utilize performance indicators to accomplish the task of future performance prediction. Pavement surface roughness is a critical indicator of pavement performance. It is characterized by the irregularities on the pavement surface, and is determined by mapping the longitudinal pavement profile. It is directly correlated to ride quality, and previous research has shown it to be a good indicator of pavement structural condition as well.

This paper details the development of a performance model that is based on changes in International Roughness Index (IRI) over time. IRI was modeled as a dependent variable, while the parameters that impact pavement roughness were input as independent variables in the model. Traffic, climate, subgrade properties, pavement structure and material, construction quality, M&R, and drainage all affect pavement roughness. The large number of factors that impact pavement roughness and their interdependency complicated the model. Furthermore, collecting data on all these factors is not economically feasible.

Artificial Neural Network (ANN) pattern recognition technique was thus used to deal with the complex relationships among variables. The modeling used data from SPS-5 asphalt concrete rehabilitation experiment available in FHWA's Long-Term Pavement Performance (LTPP) database. The model developed is used to predict possible pavement performance after the application of any rehabilitation alternative, based on IRI variation trends. The output from the model, along with LCCA, is used to make M&R recommendations.

The model was tested using real data, and the predicted IRI and roughness trends were found to be close to actual performance. Thus the ANN model developed using SPS-5 database can be applied for M&R decisions for pavement sections in conditions similar to those of SPS-5 experiment, i.e. in Wet-Freeze climate. For other databases, specific ANN model would need to be trained before implementation in the decision making process. For the example data set, the life cycle cost of thick overlay without milling was found to be the least among the available rehabilitation alternatives. Furthermore, the predicted IRI trends of thick overlay were far better than those of thin overlays. Milling did not result in any significant difference in the treatment performance. These findings were concurrent with previous research.

A New Tool for Minimizing Total Asphalt Pavement Life Cycle Costs by Goran Mladenovic and Cesar A. V. Queiroz

Life Cycle Cost Analysis (LCCA) is an essential part of decision making when selecting between alternatives for pavement maintenance. Budget constraints make it necessary to choose the alternative that would minimize the total transport cost, including both the road agency and user cost. Mladenovic *et al.* present a graphical tool in this paper which can provide a fast and reliable Life Cycle Cost Analysis. This, in turn, would help in identifying the alternative for asphalt pavement rehabilitation which would cost the least. Life Cycle Cost Analysis Graph Tool (LCCAGT) thus compares the *Base* and *Project* alternatives and presents the comparisons graphically for visual and easy interpretation. Key project indicators are calculated for a pre-determined analysis period which may be as long as 40 years. The *Base* here refers to the option when only routine maintenance is performed during the analysis period and pavement is reconstructed in its last year. The *Project* alternative, on the other hand, would include a maximum of three overlay treatments along with routine maintenance during the analysis period.

LCCAGT has been developed using MS Excel® 23 using Visual Basic for Applications. It uses the following four models for analysis:

- Road deterioration model
- Road work effect (RWE) model
- Routine maintenance cost model
- Road users' cost model

All models are well defined in the tool, and an option is available to change pre-determined parameters if required. The tool has a user-friendly interface and all models used in it can be altered as per specific conditions, thus enabling it to be used for analysis of different roads under different conditions. It can also be used for Sensitivity Analysis to determine how Life Cycle Cost would vary with change in input parameters such as number of overlay treatments during analysis period, time of application, cost, etc.

The tool was tested on a project level basis, and further research would be required to develop a model on similar lines that could be used for a road network. Future development of the tool, it is suggested, should include a procedure that would automate the optimization process. Modeling of preventive maintenance treatments is also recommended.

Pavement Maintenance Methods Effect Reducing Cost and Prolonging the Service Life of Roadway Pavement – A Discussion and Case Studies by Lorena Gutierrez, Fazil T. Najafi, and Harold Boudreau III

This paper emphasizes the importance of "Preventive Maintenance," also known as "Pavement Preservation," to ensure serviceable pavement conditions under the constraints of shrinking budget. Preventive maintenance includes timely application of relatively economical treatments to prevent pavement from deteriorating further, thereby prolonging its service life and improving its condition. State transportation agencies have begun to appreciate the need for preventive maintenance to ensure pavement functionality and delay costly rehabilitation needs.

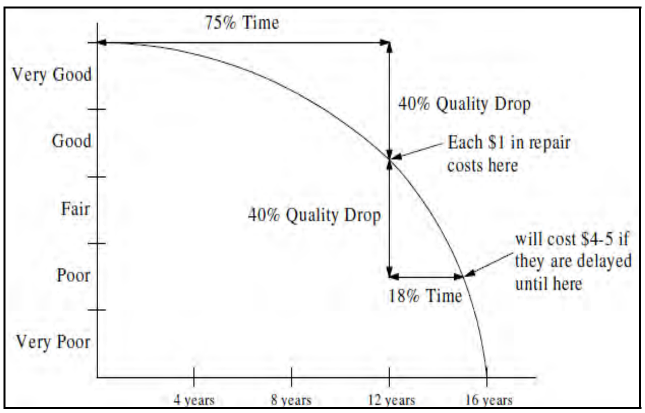

Figure 1. Pavement Life

Though Pavement Maintenance Methods (PMMs) vary from state to state, the paper outlines the general steps involved in the process:

1. Distress Data Collection - Type of pavement, flexible or rigid, governs the type and method of distress data collection. Distress data includes cracking, raveling, spalling and settlement, among others. The data collection methods have also evolved from mere visual inspection to the use of imaging and laser/sensor based technologies that scan the road surface to determine condition.

2. Data Evaluation and Roadway Network Inventorying - Distress data collected is quantified to give either the Pavement Condition Index (PCI) or the Pavement Condition Rating (PCR). Based on the Index, the pavement is characterized from very good to very poor. The index is also used to determine alternative treatments available that would restore the pavement condition to very good level.

3. Creation of a Maintenance Cost Plan - Pavement management systems are used to determine the impact of several combinations of fund allocations for reconstruction, rehabilitation, and preventive maintenance on long-term pavement conditions. This enables decision makers to make more informed decisions.

4. Project Improvement Ranking - A Project Improvement Ranking table is developed to ranks the improvement projects based on several factors. This helps identify where funding is essential and would provide the most long-term benefits.

5. Fund Allocation Using Project Improvement Ranking - For an effective pavement management program, it is essential for an agency to implement "The Right Treatment at the Right Place and the Right Time." Legislators and customers need to be educated on the benefits of preventive maintenance to ensure that a dedicated funding is available for the program.

The paper further describes the above approach being implemented by the City of Gainesville, Florida, and the Minnesota Department of Transportation.

Quantifying Pavement Sustainability in Economic and Environmental Perspective by Peter Chan and Susan Tighe

Infrastructure sustainability is a key concern today that aims to maximize performance in the present without compromising the ability to meet future needs, thus minimizing environmental impact. Sustainability of highway infrastructure is thus important and has gained recognition with the development of LEED™, Greenroads, and GreenLITES evaluation systems.

This paper is based on a research project conducted at the Center for Pavement and Transportation Technology (CPATT) at the University of Waterloo. The study was initiated by the Ministry of Transportation Ontario (MTO) to improve the sustainability of highway infrastructure in Ontario. The goal was to develop a decision support tool that would enable MTO to incorporate sustainable practices in its daily practices. This paper details the initial step in the process that includes quantification of pavement sustainability.

Chan and Tighe indicate that pavement sustainability depends on maintaining a judicious balance between economical, societal, and environmental factors during design, construction, and rehabilitation phases. The environmental and economic saving quantification is done using the PaLATE (Pavement Life-Cycle Assessment Tool for Environmental and Economic Effects) software. It is Excel based software developed by Dr. Arpad Horvath from the University of California at Berkeley. "*The tool takes user input for the design, initial construction, maintenance, equipment use, and costs for a roadway, and provides outputs for the 1 life-cycle environmental effects and costs.*"

The MTO Green Pavement Rating System (GPRS) and LCC were both used for evaluation of sustainability of project alternatives. The PaLATE analysis showed Cold-in-Place Recycling (CIR) and Cold In-Place Recycling with

Expanded Asphalt Mix (CIREAM) to be the most environmentally friendly rehabilitation alternatives, while CIR and Full Depth Reclamation (FDR) were found to be the most economical options. An interesting indication from this analysis was that flexible pavement is more environmentally friendly, while rigid pavements result in more saving of construction material.

- The 2-in HMA overlay appeared to be more beneficial in terms of both performance and cost-effectiveness for a thinner pavement subjected to a higher traffic volume.
- The crack sealing is expected to last longer at lower costs for a thicker pavement in a better condition.

Preservation of Flexible Pavements in Connecticut – Case Study by Iliya Yut, Derek Nener-Plante, and Adam Zofka

The concept of perpetual pavements came into existence in 1960s. Because of the increasing maintenance and rehabilitation budget and a need to improve the effectiveness of roadway paving, the State Highway Agencies (SHA) adopted longer service lives of 50 years or more for pavement design. Pavement structures are classified as perpetual if they are one of the following:

- Full-depth pavement with a thick asphalt course placed directly on subgrade
- Deep strength pavement consisting of an asphalt surface and asphalt base layers supported by a minimal aggregate base layer.

The Asphalt Pavement Alliance (APA) selected a 2.75 mile segment of Route 82 in Connecticut for the 2007 Perpetual Pavement Award. This study reviews the construction, maintenance, and operations history of this pavement with particular focus on pavement preservation techniques and their timing of application. The pavement data is compared to that of another similar pavement section (Route 9) in Connecticut to identify factors that might have resulted in better performance and longer life of Route 82.

The paper includes a review of pavement preservation techniques used for this particular pavement segment, namely crack filling and HMA overlays. A detailed analysis of the effectiveness of these strategies is presented based on historical performance data collected by the Automatic Road Analyzer (ARAN).

The data review indicated that this segment of Route 82 had exemplary performance for over 38 years, despite being overlaid only once 25 years after construction. Its deep strength pavement structure and low truck volume are cited as major reasons for its improved service life. Moreover, the availability of good quality aggregates from cutting rocks further added to its strength.

The performance data and deterioration trends of Route 82 were compared with those of Route 9. The Route 9 segment selected was similar in structure and age to Route 82, but had four times higher traffic volume. It survived without major rehabilitation for the same period as did Route 82, but required crack filling on several occasions and overlay at 20 years of age owing to high rate surface deterioration.

Comparisons of the two pavements revealed that

Selective Flexible Pavement Rehabilitation Based on Forensic Investigation and Deflection Analysis: Seventeen Years Case Study in Virginia by Mohamed Elfino and Hari Nair

This paper details a comprehensive forensic investigation conducted for a flexible pavement that showed signs of premature failure. The subject pavement is a 3 mile long, four lane, divided primary road on Route 3 in Lancaster County, Fredericksburg, Virginia. Constructed in 1992, this pavement was comprised of 6 inches of soil cement treated layer that rested on natural subgrade. A 6 inch dense graded aggregate layer followed the soil-cement layer, and finally a 4.5 inch asphalt concrete top layer.

By 1994, several white stains were observed on the pavement surface but no distress was reported. Fatigue and alligator cracking caused failure of truck lanes at many locations by 1998. In response, the top 4.5 inches of asphalt layer was milled and replaced. The treatment proved to be inadequate as similar distresses appeared again by 1999 and the pavement failed all the more severely. The second failure made it necessary to identify failure mechanism before selection of rehabilitation strategy to ensure a permanent and effective solution. Furthermore, cost effectiveness of rehabilitation strategy is also a pre-requisite. This requires analysis of adequate background information as well as field data.

Structural performance data for the pavement was determined using Falling Weight Deflectometer (FWD) analysis. Forensic investigation revealed further field and background information. The forensic study and FWD tests were conducted in 2000 to determine the cause of failure. Together, the above two methods were found to provide adequate and relevant information to determine an economical and effective rehabilitation strategy for the prematurely failing pavement.

Figure 2. Pavement Condition before Rehabilitation, 1999

Based on information collected, the pavement failure was attributed to the dense plain aggregate layer that had an unduly high percentage of fines. In the absence of pavement edgedrains, this caused moisture to get trapped between the stiff top and bottom layers. Moisture weakened the pavement structure and caused premature failure due to heavy axle loading in truck lanes.

This analysis led to a unique and selective rehabilitation strategy for truck lanes with heavy loading and passing lanes with light loading. In the truck lane, the asphalt layer was removed and the aggregate layer was cement stabilized to improve pavement strength. The pavement performance since then has been exceptional, with no distress having been reported. This study provides a well documented resource that may guide similar rehabilitation studies in future.

Figure 3. Pavement Condition after Rehabilitation, 2005

Study of Evaluation Method to the Transverse Crack for Freeway Asphalt Pavements by Lan Zhou, Fujian Ni, and Yanjing Zhao

Transverse cracking is an essential indicator of pavement condition. The transverse cracking is generally assessed based on either Transverse Crack Spacing (TCS) or Transverse Crack Width Ratio (TCWR). However, there is still need for a comprehensive indicator.

This paper proposes a scientific method for evaluation of transverse cracks. The model was developed based on the existing conditions of asphalt pavement freeways in China. The model establishes a Transverse crack Condition Index (TCCI) to provide an objective means for evaluation of pavement transverse cracking condition. TCCI is a numerical assessment that is based on factors such as longitudinal distribution of cracks and degree of crack severity.

Several existing transverse crack evaluation methods adopted worldwide were reviewed, but all the methods were found to be inadequate in determining the distribution of transverse cracks in pavements. Hence they did not clearly establish the influence that transverse cracking has on pavement condition.

Transverse Crack Condition Grade	Range of Transverse Crack Evaluation Index	Maintenance Classification	Treatment Method
Very Good	≥ 90	Routine Maintenance	No action
			Minor Crack Sealing
Good	80-90	Routine Maintenance	Crack Sealing
Fair	70-80	Preventive Maintenance	Fog Coat
			Extensive Crack Sealing
Poor	60-70	Corrective Maintenance	Thin overlay of 1.5cm ~ 3cm thickness with fiberglass-polyester paving mat
			Hot-mix patching
			Hot or cold recycling technology
Very Poor	<60	Rehabilitation	Traditional overlay of 4 cm thickness with fiberglass-polyester paving mat
			Partial depth removal & resurfacing
			Reconstruction

The TCCI model was developed with data available from Wu Xuan freeway in Anhui province. The reliability of the index was proven with data from two other freeways in Jiangsu province. The results corroborated the utility of TCCI in providing an accurate assessment of transverse crack condition of freeways.

In order to enable the use of TCCI as a tool in comprehensive pavement performance assessment, its compatibility with other pavement condition parameters was essential. Thus TCCI was normalized to a 1-100 scale using an "Expert Score Method." A questionnaire was prepared and a survey conducted, the results of which were used for the normalization. The normalized index is called Transverse Crack Evaluation Index (TCEI). The index ranges from 0 to 100 and is divided into five performance levels. Each level has an associated maintenance recommendation, derived from the survey analysis and practical maintenance experience. Thus TCCI is a useful aid in determining preventive pavement maintenance methods that would result in maximum benefit for pavement.

Removing Excess Asphalt: Intial test of ultra high pressure water a success by Cindy Estakhri– Texas Transportation Institute

Summertime in Texas means rising temperatures, long days, and the emergence of maintenance forces ready to take on over 186,000 lane miles of roadways. The Texas Department of Transportation (TxDOT) spends close to $180 million maintaining the state's roadways, and seal coats are a very part of TxDOT's preventative maintenance program. But what happens when the maintenance needs maintenance?

A recent test study lead by Darlene Goehl, a pavement and materials engineer in the TxDOT Bryan District, sought to find a cost-effective option for correcting "bleeding" or "flushing," which is a common problem with seal coats and surface treatments in Texas.

"Bleeding or flushing occurs when excess asphalt binder is pushed to the pavement surface, covering the aggregate," explains Texas Transportation Institute Research Engineer Cindy Estakhri. "What you will see is a black and frequently sticky surface, which can lead to a loss of skid resistance."
The demonstration project was conducted on March 3 on a half-mile stretch of farm-to-market roadway in Grimes County, Texas. The process involved using a truck called "The Blaster Vac" that shot super high-pressure water at 34,000 psi into the flushed roadway to remove the excess asphalt, where it was then vacuumed up. Rampart Hydro Services from Pennsylvania provided the truck, which is commonly used to remove rubber from airport runways.

"This is the first time this technology has been used in Texas," said Goehl. "We picked a test section that exhibited heavy flushing across the roadway, not just in the wheel paths. It truly is a worst-case scenario type of road that is able to give us a true measure of how this technology works."

The removal width of the truck's sprayer and vacuum is two-feet, and after one pass the observers were able to notice a significant amount of asphalt removed from the roadway.

"One of my concerns was that the water would blast not only the asphalt, but also the aggregate down to the base," said Goehl. "This test showed that not to be the case, and that the aggregate was restored."

Texas Tech Assistant Professor of Civil Engineering William Lawson agreed with the assessment, noting an unexpected benefit. "If you look at the results closely, not only did it nearly restore the seal coat to its original condition, but the high-pressured water also increased the angularity of the aggregate, which will improve friction."
Lawson was the research supervisor on a project (TxDOT RMC 0-5230) that studied short-term solutions to "bleeding" asphalt pavements. The use of ultra high-pressure water cutting to remove excess asphalt was one of the published recommendations from this research project.

"Certainly this test is encouraging," said Goehl. "This technology has the potential to save the state time and money by performing maintenance on a roadway instead of having to do a full rehabilitation project."

For more information, please contact Darlene Goehl at (979) dgoehl@dot.state.tx.us or William Lawson at William.D.Lawson@ttu.edu.
A PDF of a project summary report of TxDOT research project 0-5230 can be accessed at ftp://ftp.dot.state.tx.us/pub/txdot-info/rti/psr/5230.pdf.
The Blaster Vac specifications can be found at http://www.rampart-hydro.com/rubber-removal-equipment.htm

THE UNIVERSITY OF TEXAS AT AUSTIN ✦ COCKRELL SCHOOL OF ENGINEERING

TEXAS PAVEMENT PRESERVATION CENTER

TxDOT Newsletter

ISSUE 19 / SUMMER 2010

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Evaluation of Training Requirements in Pavement Preservation Methods in the State of Texas

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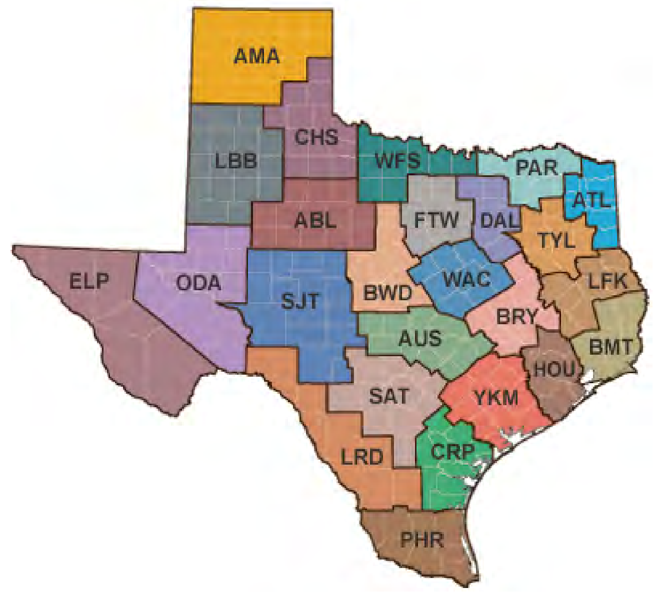
Contact Us

Director: Dr. Yetkin Yildirim, P.E.
E-mail: yetkin@mail.utexas.edu
Website: www.utexas.edu/research/tppc



Past and Upcoming Events

TPPC Microsurfacing Courses

Microsurfacing training courses will be offered by the TPPC. The course is designed for engineers and inspectors and is entitled "Guidelines on the use of Microsurfacing." The course recapitulates the pavement preservation concepts, specifically with reference to microsurfacing. It focuses on proper mix design selection and application of microsurfacing. TxDOT's experience with microsurfacing is also discussed. This course also includes discussion on the use and applications of cape seals.

Pavement Preservation Strategies with A-R

The Pavement Preservation Strategies with A-R Workshop was held on May 24th at the Center for Transportation Research at the University of Texas, Austin. The workshop included presentations by Dr. Yetkin Yildirim on pavement preservation strategies, Gerald Peterson on TxDOT materials and specification, Douglas Carlson on the advantages of using recycled tire rubber in asphalt, and Maghsoud Tahmoressi on case studies of AR seal coats and thin overlays.

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Seal Coat training courses will continue to be offered by the TPPC. The course designed for inspectors, entitled "Seal Coat Inspection and Applications," focuses on proper inspection methods and the equipment used during chip seal construction. The other course, "Seal Coat Planning and Design," instructs engineers on planning, designing, and constructing chip seals.

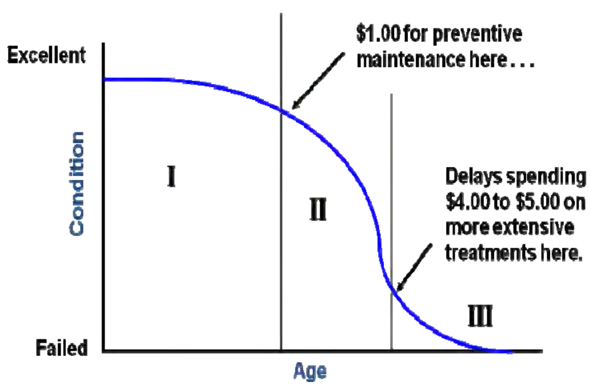
For more information on the Seal Coat courses, please contact Dr. Yetkin Yildirim, P.E. at yetkin@mail.utexas.edu

Evaluation of Training Requirements in Pavement Preservation Methods in the State of Texas

Introduction

Pavement preservation strategies have long been known to provide cost effective means to extend the life and performance of pavements. Most transportation agencies today are facing budget cuts and it is increasingly becoming a challenge to maintain high road service quality. Pavement preservation methods are thus gaining grounds and have been successfully accepted by the highway community as a means to maintain performance levels within available budget.

Pavement preservation methods include all those techniques which extend the life of the pavement by improving its surface condition without affecting its structural capacity. Therefore, it is useful only for those pavements that are structurally sound with good drainage and acceptable thickness. Selection of the right pavement is essential for achieving positive results. It is a proactive approach as opposed to the reactive maintenance approach and includes maintenance techniques like crack filling and sealing, fog seals, slurry seals, scrub seals, microsurfacing, chip seals and thin HMA overlays. Research suggests that every $1 spent on preventive maintenance techniques saves $5 on major rehabilitation. The critical factor for a successful pavement preservation program is the application of the right treatment at the right time.



The Texas Pavement Preservation Center (TPPC) has been providing exemplary assistance and training to promote pavement preservation strategies in the state of Texas (www.utexas.edu/research/tppc). Pavement preservation methods ensure that the traveling public gets the highest level of service at minimum cost. TPPC's mission is to make the practicing engineers and district officials aware of the available pavement preservation techniques. This would in turn result in better safety, quality and performance of state highways and also save large amount of taxpayer's money. The center identifies new research in the areas that could cater suitably to the state's requirements and needs. Thus, TPPC serves as an information center that provides the engineers, managers and district officials with the most relevant and the latest up to date information in the area. TPPC conducts training courses, workshops, conferences and also online courses through The University of Texas at Austin. The target audience for each of the above is TxDOT officials, industry personnel and agencies within the highway community.

Purpose & Objective

To be successful in fulfilling its mission, it is essential for TPPC to be aware of the requirements and training needs in the highway community – especially at TxDOT. Also, it is essential to assess if the pavement preservation practices currently being used in the state are performing adequately and serving the needs of the state effectively. For this purpose a survey was conducted for the TxDOT personnel.

The objectives of the survey were

1. To identify the pavement preservation strategies adopted by various districts in the state
2. To evaluate the benefits of these strategies adopted
3. To assess the requirement for training to improve the strategies
4. To evaluate the need for training in the pavement preservation techniques not used by the district till date

Study Methodology

For evaluating these requirements, an online survey was circulated among TxDOT employees. The survey can be found here: http://www.surveymonkey.com/s/tppc. The responses were collected over a two month period from February-March 2010.

The survey consisted of thirteen questions, three of which related to respondent's details and ten assessed the status and potential needs of the pavement preservation program in the district. The survey was sent out to approximately one-hundred TxDOT employees who serve in responsible positions and are related to pavement preservation programs in their respective districts. Fifty-six people responded to the survey in all.

Of the various pavement preservation techniques, the following were mainly focused on in the survey:

1. Crack Sealing

As the name suggests, crack sealing includes timely identification and sealing of top down cracks to prevent water from infiltrating into the pavement and causing severe distresses. Additional benefits include improvement in ride quality. Asphalt or specialized crack sealant materials are used for the purpose.

Figure 1: Crack Sealing

2. Seal Coating

Seal coat, also known as chip seal is application of single or multiple layers of aggregates covered in asphalt binder on existing paved surface. This technique is used to correct distresses like severe cracking, raveling, bleeding or to improve skid resistance.

Figure 2: Seal coat application in progress

3. Micro-surfacing

Micro-surfacing is the application of resurfacing material that is derived from polymer modified asphalt and aggregate mixture. It is quick setting and allows traffic to open within an hour of application. It requires specialized paving equipment for its application. It is a rehabilitative technique that restores surface texture, fills cracks, voids and ruts thus improving appearance, performance and life of the pavement.

Figure 3: Micro-surfacing in progress

4. Slurry Seals

Slurry seal is similar to micro-surfacing, the difference being that resurfacing material has lesser polymers and additives and thus longer setting time.

5. Thin Asphalt Overlays

A less than 1.5 inch thick HMA overlay that does not influence the pavement strength but is mainly applied to improve pavement appearance, ride quality and functional problems. Existing pavement surface is milled before application of new layer.

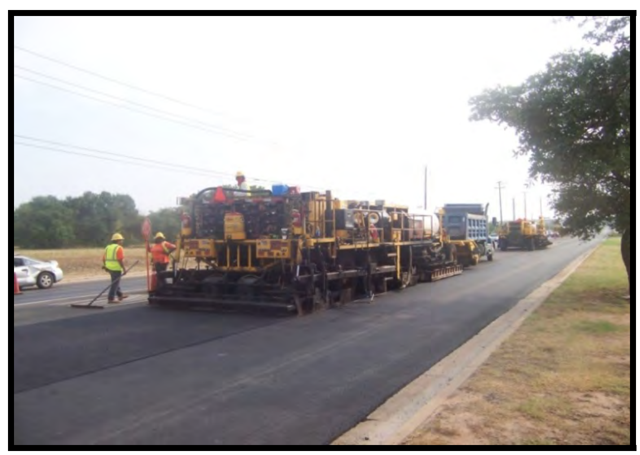


Figure 4: Hot-in-place Recycling

6. Hot-in-place Recycling

In the Hot-in-place Recycling technique, the top one to two inches of the existing pavement surface is heated, milled, mixed with recycling agents and replaced on pavement. The pavement temperature is maintained at 200°F during the entire process. It is a very useful and cost effective rehabilitative method that addresses several pavement distresses and lasts longer than other methods.

Figure 5: Thin asphalt overlay

Data Analysis and Results

Of the 56 responses received, two responses had to be eliminated because they were not employees of TxDOT. The remaining 54 responses included individuals from 21 of the 25 districts in Texas. The objective here is to identify the weaknesses in the existing pavement preservation strategies being adopted in the different districts in the state and to understand the specific training needs that might help overcome these weaknesses.

The first question in the survey identified the pavement preservation methods being used in the state currently and the frequency of their application. Crack sealing and seal coating are the two most common strategies used in all the districts. This can be attributed to their lower costs and easy application. Micro-surfacing and thin asphalt overlays are also used frequently in many districts while slurry seals and hot-in-place recycling are not preferred or hardly used.

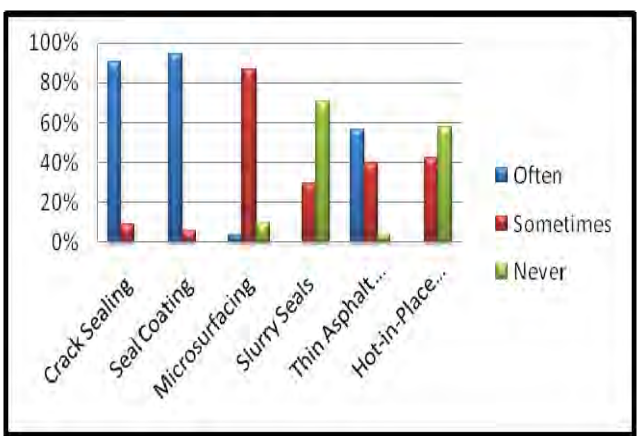


Figure 6: Frequency of use of Pavement Preservation Treatments

The reasons for not using particular pavement preservation strategies were then evaluated in the next question. The reason cited by most people was that the strategy did not address the needs of the district. Need of specialized equipments and lack of appropriate information about the treatment also emerged as significant reasons for the avoidance of certain strategies. Among other reasons mentioned, Hot-in-place recycling was considered to be cost ineffective as compared to using virgin overlay.

Most respondents expressed a desire for learning more on pavement preservation techniques, especially for asphalt pavement. The majority of pavements in Texas are flexible as opposed to rigid pavements. Thus districts have to deal with their maintenance more frequently.

The next question revealed that there is a general need for training for all pavement preservation strategies throughout the state. Though much has been written and spoken about pavement preservation, it is still yet to become a common practice and training district personnel is the key to ensure an effective and robust pavement preservation program for each district. As can be seen in Figure 11, the survey identified hot-in-place recycling, thin asphalt overlays and seal coats to be the ones that most districts would be interested to learn more about.

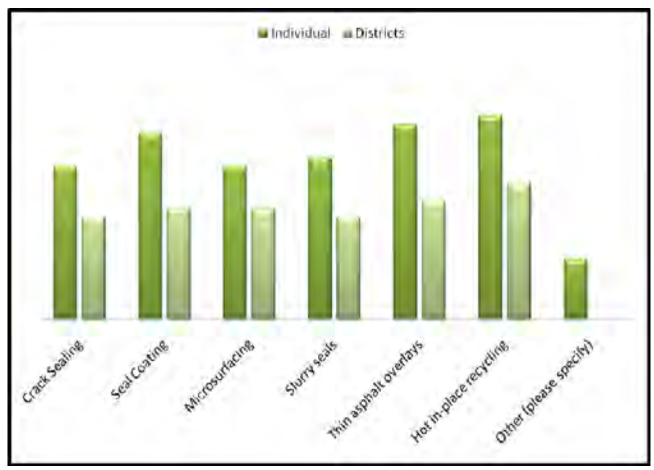


Figure 7: Treatments about which districts are interested in learning more about

Besides the specified pavement preservation strategies, certain personnel specified that their district, namely Houston and Wichita Falls, uses a lot of concrete pavement preservation techniques. The Dallas district indicated having used relatively newer techniques, Ultra Thin Bonded Wearing Course (UTBWC) and Bonded Permeable Friction Course (PFC), for preventive maintenance in addition to the mentioned strategies. UTBWC is an open-graded mix placed on polymer modified heavy asphalt emulsion layer using a specialty paver. It is especially useful in places where there are restrictions on overlay thickness due to clearance requirement. It improves ride quality and restores skid resistance of the pavement. PFC is known to improve safety and ride quality on high speed roadways.

Figure 12 illustrates which districts expressed a need training for which particular strategy. Atlanta, Beaumont, Lufkin and San Antonio indicated that training is required for all strategies in the district.

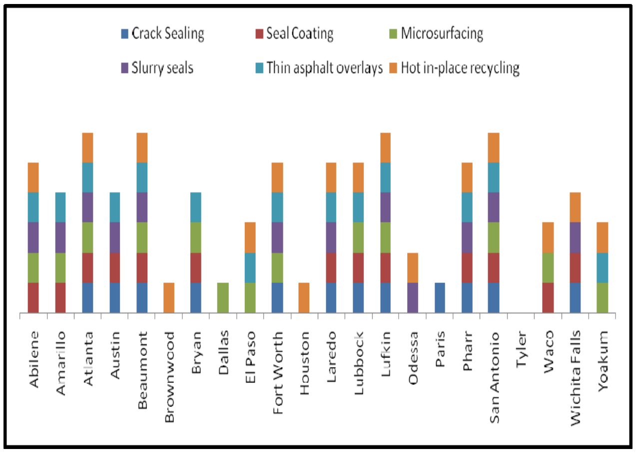


Figure 8: Training Needs in Districts

Furthermore, the responses indicated that more comprehensive and improved training techniques and methods would encourage more districts to use pavement preservation methods, especially hot-in-place recycling, slurry seals and micro-surfacing.

There is an urgent need to improve the training procedures and increase training programs frequency for pavement preservation techniques across all districts in the state. As mentioned by one of the respondents, most districts are familiar with most of the pavement preservation strategies discussed, but what is needed is better training in the use and application of each of these techniques to enable effective and viable preventive maintenance programs.

The decision for the need of maintenance on a particular pavement may be guided by several criteria. The decision has to be made keeping in mind the available maintenance budget and resources and the severity of pavement distress. Each district has its own criteria for making the judgment and based on the survey responses, engineering judgment is the most reliable factor followed by cost/benefit analysis and available in-house guidelines. This means that a lot depends on the engineering expertise, experience, knowledge and judgment. Thus it is essential that engineers be well acquainted with the pavement preservations methods to make the right maintenance treatment selection at the right time for the right pavement.

Most personnel considered their district to be well acquainted with pavement preservation efforts being practiced in other districts. Only 22% of the respondents felt that their knowledge was inadequate while 13% considered they were totally abreast with all developments in the field of pavement preservation in other districts.

The respondents were asked to rank the perceived benefits of a successful pavement preservation program. The benefits considered included cost savings, improved pavement performance, customer satisfaction, improved safety and more informed decision making.

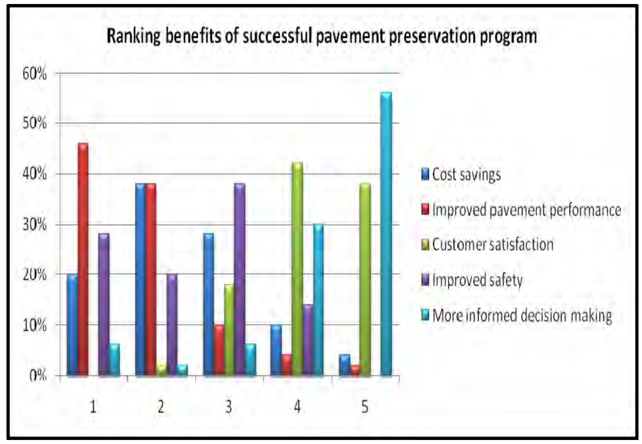


Figure 9: Ranking benefits of successful pavement preservation program

Most people picked improved pavement performance to be the obvious benefit of a successful pavement preservation program while more informed decision making was identified as the least useful benefit. This can be attributed to the fact that research in the area of preventive maintenance is yet to come up with a standardized guideline that would help in making the right decisions. Several methods/algorithms are available that help in making the decision, but none have proved to be a satisfactory standard. Much still depends on engineers' observation and judgment. There is no doubt in the fact that pavement performance is bound to improve with a successful pavement preservation program, as shown by the survey responses. Cost savings is considered to be the second most important benefit, which is obvious as pavement preservation methods are considered as a means to tackle maintenance issues in the face of shrinking budgets. This is followed by improved safety, then customer satisfaction. The ranking of benefits appear to be as expected based on the utility and performance of pavement preservation program.

The last question of the survey asked the respondents if any formal or informal quality assurance procedure for preventive maintenance application was in place in their district. No clear indication could be obtained as to the trend in the state since the responses were almost equally divided between formal procedures and informal ones. Some districts rely on PMIS scores as a quality assurance tools while others base their assurance on pavement management engineer's judgment. Standard specifications, material testing and equipment calibration before application are other means to ensure quality.

Conclusion

Pavement preservation methods have been acknowledged as cost effective techniques for improving pavement performance and extending their service life. Most districts in Texas use several pavement preservation methods but a significant need for improving the pavement preservation program in various districts of the state has been identified in this study. The survey responses covered most of the districts in Texas, thus the results can be considered as fairly representative for the whole state.

Of the common pavement preservation methods specifically examined in this study, crack sealing and seal coats emerged as the most frequently used techniques while most districts expressed their interest in learning more about Hot-in-place recycling, thin asphalt overlays and slurry seals so as to be able to use them more often and effectively. Almost all district personnel were unanimous in their observation on the need for better training for pavement preservation methods. Improved pavement performance and cost savings were identified as the primary benefits of a successful pavement preservation program. Most decisions for pavement maintenance rely on sound engineering judgment which makes it all the more critical for district personnel to be trained and experienced in effective and timely use of pavement preservation strategies.

Thus the survey clearly illustrates that the current pavement preservation program in most districts will remain inadequate if the district personnel are not trained to ensure its success. Also, the current training programs need to be modified to better serve the needs of the district. It is possible to achieve a high level of service for the traveling public within the existing budget constraints if the right pavement preservation methods are applied at the right time on the right pavement.

THE UNIVERSITY OF TEXAS AT AUSTIN + COCKRELL SCHOOL OF ENGINEERING
TEXAS PAVEMENT PRESERVATION CENTER
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Director: Dr. Yetkin Yildirim, P.E.
E-mail: yetkin@mail.utexas.edu
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Asphalt-Rubber and Thick AR Overlays Overview
A presentation by Douglas Carlson

Introduction

Asphalt-rubber has been around for over forty years now after first being developed in the 1960s by a City of Phoenix engineer who was trying to invent a pot-hole patch. The rubber patties that were used to fill potholes ended up outliving the rest of the road. This spurred the question, how can we utilize rubber for the whole roadway rather than merely in potholes? Forty years later that question has found its answer in the form of asphalt-rubber and tire-rubber asphalt.

Creating crumb rubber is the first step to making any A-R. Fiber and fabrics that exist in the tires are removed through a series of blowers at different stages of the rubber shredding process. As these fibers are lighter than the rubber, the blowers can sweep the access material away as the rubber moves through the crumb rubber process. Similarly, any steel that exists in the tires is removed with magnets. In its final form, the crumb rubber particles are smaller than one millimeter in diameter and are free of all non-rubber materials. This rubber is stored in large bulk bags, each weighing about a ton. The rubber remains in this form until it is taken to a hot-plant where it is turned into asphalt-rubber.

In the process, when mixing the crumb rubber with the binder, heat accelerates the absorption of the aromatic oils in the rubber. This heated mixture is constantly agitated to encourage even more release of oils from the rubber and to evenly distribute the rubber aggregate throughout the asphalt binder mixture.

Despite this being a very specialized process, Rubber Pavements Association does not have patents on any of the procedures or products because they want the product and processes to be in the public domain in order to promote competition between suppliers and contractors.

Hot-mix overlays with asphalt-rubber

With most pavement preservation projects, seal coats are used rather than hot-mix overlays because they are cheaper, easier, and often the road isn't in poor enough condition to necessitate an overlay. However, the warm, dry climate in most of Texas allows for a much thinner layer of hot-mix than in other states (approximately ¾ inch). Such a thin layer results in a cheaper cost due to the lowered amount of materials required, making a hot-mix overlay a good option for preventative maintenance on high volume traffic roads in Texas.

Hot-mix overlay projects have become an even more attractive option with the growing use of asphalt rubber (A-R) in gap-grade hot-mix material, where some of the fine aggregate is replaced with ground rubber particles. Such material has been used in the city of Phoenix for almost two decades now and has proved to be very effective. Many of their concrete roadways have received a 3/8 inch A-R hot-mix overlay that contains 20 +/- 3 % ground rubber particles. In this application process, the edges of the road at milled up to three feet on each side so that when the hot-mix is laid down it will fit flush to the edge or curb. A-R hot-mix application differs from the usual hot-mix procedure because the high viscosity of the A-R material results in a quick breaking of the emulsion. Because the pavement will stiffen so quickly, it is key to have the roller running as close as possible behind the paving machine.

Figure 1 Crumb Rubber

Recycling

There are many benefits of using A-R for maintenance projects. The most obvious is the huge amount of rubber waste that is recycled and put to use in the creation of an A-R mixture. In any given city in the country, approximately one scrap tire is created every year for each member of the population. So, for example, in Austin, TX where the population is approximately 760,000, about 760,000 tires will be moved to junk yards or scrap heaps every year. In certain cases, the entirety of the scrap rubber created by a community has been recycled into their road systems. One such example of this is the city of Thousand Oaks, where in the past 17 years, 1,695,000 tires have been recycled and used in the application of A-R hot-mix overlays. This accounts for all of the tires consumed by the population of this city in these past 17 years. So, not only does A-R hot-mix have a superior service life and track record, but it also sends a positive political message and is warmly accepted by the community because of the diversion of waste for recycling.

A-R vs. other kinds of asphalt

While A-R is clearly the more environmentally friendly choice, what is more important to most departments of transportation is performance life and safety. However, A-R hot-mix material out performed five other hot-mix materials in a test of simulated truck traffic. In trials of different asphalt material, the control hot-mix asphalt mixture cracked after 100,000 passes, a terminal blend HMA cracked after 175k passes, the SBS polymer HMA cracked after 275k passes, but A-R HMA did not crack after 300k passes and was estimated to be able to go 1 million passes before cracking.

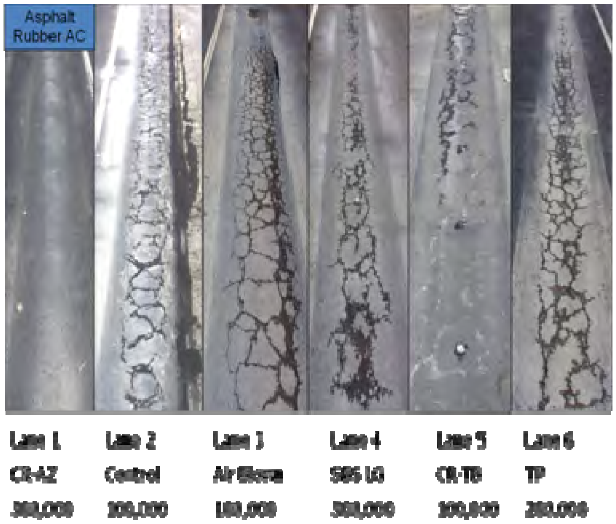

Figure 2 Six Test Sections - Asphalt-Rubber on Left

In all of the other hot-mix materials, cracks form between aggregates in the binder material. With A-R mixtures, the binder material is rubber which does not crack. This results in a far more durable pavement that will have a much greater service life than the other HMA mixtures used in the trial.

More benefits of A-R

A-R is not only an environmentally friendly recycled material with a long service life, but it out performs other HMA mixtures in other areas as well. A-R has the least pavement noise of all HMA alternatives. Pavement noise is greatly due to distress in the pavement, so having less raveling or cracking in the A-R results in less noise on the roadway. What's more, A-R overlays on concrete roads proved to have a higher friction coefficient than the high-friction concrete that was being covered. And if that's not enough, the softening of the road that occurs with the application of A-R material results in an improved, smoother ride and increased fuel efficiency for commuters.

Concrete vs. asphalt

In many hot climates concrete roads are preferred over asphalt because the black asphalt absorbs heat, raising the atmospheric temperature, while the white concrete reflects heat, keeping atmospheric temperatures lower. However, studies on concrete roads with think A-R HMA overlays proved that the thin layer of asphalt actually improved the temperature problems. First of all, concrete warps with temperature change which results in more frequent cracking. An A-R thermal blanket reduced the curling stresses on concrete by 8 to 25%. Additionally, because concrete roads are much thicker, denser and heavier than their asphalt counterpart, its greater mass results in longer temperature retention. So, even though the asphalt heats up more quickly than the concrete, because it is thin and porous, its heat is quickly released and doesn't greatly affect the atmospheric temperature. In contrast, the heavy concrete holds a great deal of heat and will slowly release that heat into the air during a cool night.

In conclusion, thin A-R overlays have many benefits to road systems. A road with A-R will have improved performance and durability, improved safety and ride quality, less highway noise, it retains less heat, it is cost effective, and as an added perk, its use results in a positive environmental impact because of recycling and improved fuel efficiency.

Tire Recycling in TxDOT
A presentation by Gerald Peterson

How recycling benefits TxDOT

TxDOT is committed to recycling and has always been innovative in environmental protection as they continue road system projects. Not only is it environmentally friendly, but using recycled material creates a better bottom line: there is relief on regional material shortage, native materials are conserved, environmental standards are met, construction costs are reduced, hauling and disposal costs are reduced, and markets for scrap materials receive support.

These saving are made clear by recent totals compiled by TxDOT of the economic benefits coming from the use of recycled materials. For example, use of RAP, recycled concrete and fly ash translated to a purchase cost savings of $40 million and a disposal cost savings of $19 million. Because the use of recycled materials results in savings such as these, TxDOT has used literally millions of tons of recycled material despite the fact that TxDOT does not mandate the use of recycled material. Rather, TxDOT allows recycled materials providers to compete equally with all other material providers.

2.8 million tons	Reclaimed Asphalt Pavement
948,000 tons	Recycled Concrete Aggregate
240,000 cu yd	Compost
200,000 tons	Fly Ash
3,600 tons	Glass Traffic Beads
7,800 tons	Crumb Rubber
2,300 tons	Cellulose Fiber Mulch

Rubber in Texas

Tire rubber in the state of Texas has mostly been used in tire derived fuels (at 61%). The next largest use comes from land reclamation projects using tires (at 25%). In land reclamation projects, tires are used to replace earth lost in strip mining operations or to create roadside embankments. Crumb rubber, such is used in asphalt rubber, stands at only 6% of the recycled rubber.

Despite being far from the leader in recycled rubber use, TxDOT still managed to use 8,000 tons of tires in 2009 for a variety of applications. Three-fourths of this rubber was put to use in the application of chip seals which is clearly the most common use of recycled rubber at TxDOT. The remainder of the rubber was put to use in A-R hot mix overlays and embankment projects.

While tires must be processed and transformed into crumb rubber before use in asphalt-rubber, scrap tires and tire bales can be used in embankments after minimal processing. Tire bales, such are used in the formation of roadside embankments, are merely discarded tires bound together in two-cubic-yard bales. These one ton bales are stacked up like bricks and covered with dirt to form embankments. Often tire shreds are used as added fill because they are durable and allow for free-draining.

Figure 3 Tire Rubber Roadside Embankment

TxDOT has found other miscellaneous uses for recycled tires as well. Examples of such applications include guardrail spacer blocks because the rubber is long lasting and easy to install, the inside of delineator posts because the rubber makes them more durable and resilient, and as vegetation control mats under highway signs. While these applications do not account for much of the recycled rubber use in the state of Texas, these innovations display TxDOT's commitment to finding creative ways to use recycled materials for projects that could be using non-recycled materials.

Figure 4 Tire Rubber Guardrail Spacer

While those are all examples of recycled rubber used with very little processing, the vast majority of rubber used at TxDOT must first be turned into crumb rubber before becoming one of the two kinds of rubber used at TxDOT. The first and most common, asphalt rubber (A-R), has tire rubber particles at approximately 15% of the mixture and has an oatmeal appearance. This form of rubber is used in applications such as TxDOT item 318, A-R seal coat. The second is called high-cure tire rubber (TR), which has been cured at high temperatures for several hours and has no visible rubber particles. It can be used like any other asphalt, but is mainly put to use as a premium seal coat binder (which stands at 40% of TR application). However, TR is also often used to modify PG binders in any hot mix.

Figure 5 A-R left / TR right

Seal coats with A-R

The most common use of A-R is in seal coats where asphalt is sprayed on to a surface followed by application of cover stone. It may also be applied as final base treatment between hot mix layers, or as a final riding surface or friction course.

Because Texas maintains more rural roads than any other state, there is always a need for a large quantity of contracted seal coats (about 16,000 lane miles per year contracted, and about 3000 lane miles of state force seal coats per year). These seal coats have an average service life of 6 to 8 years. Seal coats are good preventive maintenance due to their ability to keep water from penetrating the pavement surface to reach the base. Keeping moisture out of the base of a pavement is the best way to fend off irreparable structural damage. Frequent application of seal coats will reduce the possibility of a pavement falling into poor condition where expensive, reactive maintenance measures are required for repair.

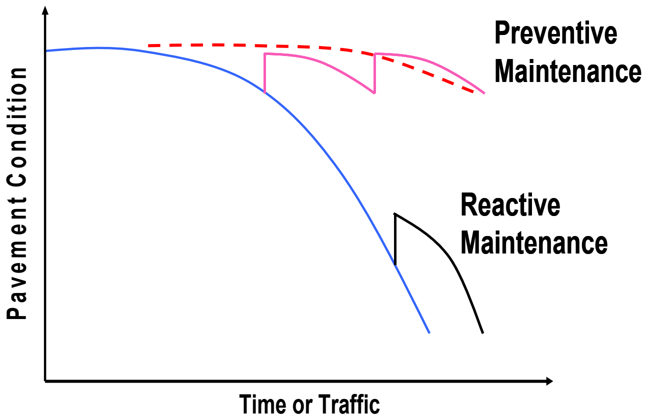

Figure 6 Pavement Preservation Timeline

These functions of seal coats are more effective the more asphalt that is in the seal coat mixture. This is because it is the asphalt, not the aggregate that creates the seal. However, too much asphalt will cause flushing and the aggregate is necessary to keep the car tires out of the asphalt and to provide a skid resistant surface.

Use of A-R and TR

TR and A-R offer similar benefits. Both allow for the use of more asphalt which creates a better seal, allows for deeper aggregate embedment and better chip retention, and the application is more forgiving. Additionally, the seal coat service life is extended with the use of rubber. The difference in TR is that dissolved rubber asphalt attempts to reuse the polymers that are in the tire rubber. But, using the rubber in the way, that is, melting the rubber down rather than using crumb rubber particles misses out on tire rubber particle properties.

When used in hot mix application, asphalt-rubber improves the properties of the mixture greatly. A-R effectively stiffens the mix, provides draindown resistance, and prevents reflective cracking – especially prevalent in PFC open grade mixes where the mix is generally very porous. Because of this, PFC mixes drain water off the road quickly so there is reduced spray, glare, and hydroplaning: all properties of a better friction surface.

The superior performance of A-R PFC mixes in wet weather conditions was made clear by a case study done on Interstate 35 in San Antonio. A PFC overlay was placed on existing concrete pavement. The pavement had relatively sound structure despite being 20 years old, but the ride quality was poor and skid numbers were in the single digits. A one and a half inch A-R overlay was placed on top of the road. This overlay improved ride quality by approximately 60%, reduced noise level by at least 8dbs, and wet weather accidents were cut nearly in half despite more wet weather days than the previous year.

Figure 7 Wet Weather Conditions Before and After A-R Overlay

Impact of Recycling

The Waste Tire Recycling Program in Texas from accumulated 75 million waste tires from 1993 to 1997. This enormous tire pile was reduced to 25 million by the end of 2006, and more tires were recycled than produced in both 2005 and 2006.

Picking the right road

Future of seal coat use hopes to promote competition in their material selection with help from a materials guidance table promoted by the TxDOT administration. This table will help in the selection of proper seal coat materials by showing which options are too expensive for many low traffic volume roads.

In this “materials guidance table,” roads are divided into tiers based on traffic levels. Each of the three traffic level tiers have different binders associated with them. Any binders from that tier, or any tier above it, would be appropriate for the maintenance operation in question.

Use of recycled materials in the future

The future of hot mix at TxDOT will be SP 341-024 for dense grade mixes. This new product with many new additives will bring down the cost of hot mix materials. The new binder promotes the use of recycled asphalt pavement and recycled asphalt shingles – further evidence of how TxDOT can make an industry out of recycling.

Over the past few years, TxDOT has been shifting their focus to maintenance. Previously, TxDOT received most of their money from the gas tax, but with fuel efficient vehicles on the rise, the income from the gas tax is becoming less and less. So, funding for expensive projects is no longer available as the transportation budget continues to drop, so cost efficient preventative maintenance projects are getting more attention. Research projects are also shifting towards the maintenance side of TxDOT activities.

While the benefits of using recycled rubber in asphalt mixes has become obvious to pavement engineers, wildcard factors exist in the use of tire rubber: oil prices (material haul costs, asphalt availability, tire usage), transportation budgets, new technologies, and shrinking tire piles may all contribute to recycled tires becoming a depleting resource.
In order to facilitate their use, transportation officials must treat the material like a product by protecting it from loss or damage, by keeping a proper inventory of availability, and keeping tires separated from other wastes. Additionally, it will remain important for TxDOT to continue to find ways to encourage recycling through research and product innovation.

Figure 8 Scrap Rubber Yet to be Put to Use

Pavement Preservation Strategies and Application of Asphalt-Rubber
A presentation by Dr. Yetkin Yildirim

For years, the traditional approach to road maintenance has been used on our nation's roads and highways. This approach concentrates all of our resources on corrective maintenance, or maintenance that must be done in response to events that cannot be planned, or as reactive repairs. Research that has been put into the aging of our road systems has revealed that pavement preservation is a far more effective and cost efficient method of maintaining roads. This preemptive effort to preserve the structural integrity and functional condition of our roadways has been on the table for the past three decades, but has been strongly promoted in the past ten years.

A healthy road

In order to understand why the traditional approach is no longer a viable method, a better understanding of our roads is required. First of all, the pavement must have good structure. This means that it requires fine drainage, a strong foundation, and acceptable thickness. These properties all get exponentially worse with time. Pavement preservation attempts to never let pavement fall below "period I" in its three period aging process. Because minor cracks allow water to seep through the pavement resulting in more extensive damage, the cost to repair the pavement rises exponentially as its age increases. Additionally, retroactive maintenance will never bring the pavement back to its original quality.

A proper pavement preservation strategy addresses the pavement while it remains in good condition. If the onset of serious damage is allowed to occur, cost effective treatment will no longer be an option. However, if maintenance begins early, the road will have a much better chance at remaining in its original condition. The key to effectively achieving this is to understand what causes the physical wear and tear on the pavement. Knowing the source of the problem will result in a better ability to stave off the effects.

When considering whether a road needs work, certain things must be taken into account. The existing pavement condition, the climate and weather conditions surrounding the road, the properties of the materials available, the traffic load expected on the road, and local restriction are all important factors to consider when deciding whether a road needs improving. In short, it must be determined that it is the *right* treatment for the *right* road at the *right* time.

Seal coats and asphalt-rubber

Once the right road is identified for maintenance operations, a seal coat will likely be applied (if the pavement has not fallen too deeply into a state of disrepair). Tire rubber asphalt has become a popular component of seal coats at TxDOT in the past few years. Its popularity has occurred for a reason as asphalt rubber has many benefits over other alternatives. Asphalt rubber reduces reflective cracking in asphalt overlays, it improves resistance to cracking, it improves resistance to rutting, it increases pavement life, it improves skid resistance, and it decreases noise levels. What's more, asphalt rubber is responsible for the beneficial use of 500 to 2,00 scrap tires per lane mile of maintenance operations.

Figure 9 Crack Seal

The only true way to make sure that these decisions are properly made comes from education and training. Both the Center for Transportation Research, and Texas Transportation Institute provide training in the area of pavement preservation. Many online courses are available at the center's website. These courses are free, will further understanding of pavement preservation, and are interactive, user friendly, and accessible from any computer with internet access.

Stress Absorbing Layers

Additionally, the CTR and TTI share pavement preservation technology, as well as study proper research implementation and strategic planning for research. Such research spearheaded by TPPC has made helpful innovations on seal coats, crack sealing, thin asphalt overlays, and warm mixes. A new patent by TPPC, a stress absorbing layer for seal coats, has offered a method for enhancing the performance and providing longer service life to existing roadways. In three tests, the seal coat was tested against a control group on different roads around the state of Texas and was monitored for three years. First, stress absorbing layers for seal coats were applied on the existing cracks on the test sections. After application of stress absorbing layers, seal coats were applied on the test sections and control sections were constructed without the application of stress absorbing layers. These tests found that test sections with stress absorbing layers showed superior performance in comparison with the test sections without stress absorbing layers – cracks did not show up on the surface of seal coats where stress absorbing layers were used. This new procedure keeps the cracks sealed and extends the life of the seal coat by three to five years. Inventors at UT, Austin at the CTR have developed a compound and documented its ability as a stress absorbing layer to enhance performance. One of the main components used to develop the stress absorbing layer is asphalt rubber.

Figure 10 Seal Coat with Stress Absorbing Layer in Foreground - without Layer in Background

In summary, pavement preservation programs extend pavement life, preserve structural integrity, enhance pavement performance, slow progressive failures, improve safety, improve ride quality, ensure cost-effectiveness, and improve mobility. Despite the obvious benefits of pavement preservation programs over traditional methods, these benefits will not be realized without proper training and education of our transportation service industry and the local, state, and nationwide policy makers.

Badly Deteriorated Pavements and Asphalt-Rubber

A presentation by Mahmoud Mahmoresi

Asphalt-rubber has been a viable product since the 1970s, but it has not always been as popular of an option as it is today. A couple decades ago, most asphalts were about half the price of asphalt-rubber. Today, asphalt prices have gone up considerably, but asphalt-rubber has gone up in price only very little due to recycling practices. With asphalt-rubber now standing as a cheaper alternative to many other options, its use has become more and more common.

More often than not, scheduled maintenance operations get postponed year after year because more important projects use up the entire maintenance budget. Because of this, pavements that should have preservation measures taken on them after seven or eight years will sometimes not have work done on them for twelve to fifteen years. As a result, previously planned maintenance procedures may no longer be viable and it is incredibly important to pick the options that will add the most years of service life to the pavement in question at the lowest possible cost.

Figure 11 A road that has missed its scheduled maintenance

An asphalt-rubber seal coat is likely the answer. However, because pavements are allowed to degrade beyond their planned level of disrepair, pre-maintenance measures must often be taken in order to get a pavement ready for a seal coat. Crack sealing and patching of the pavement prior to application of a seal coat is an effective strategy in rehabilitating pavements that have fallen below their planned level of disrepair. For example, active thermal cracks are too severe for a seal coat alone to take care of the problem. First, the crack must be filled before a seal coat can be placed on top.

Figure 12 Typical Thermal Crack

Additionally, before application of an asphalt-rubber seal coat, it is important to patch all large chunks missing from the roadway, to remove and replace all base failures, and it's always a good idea to use crack sealing around patches. It is not obvious how much patching is too much before seal coat application. In a road in poor condition, the very least that needs to be done is to patch all of the pot-holes that have developed. So, the pre-maintenance that is performed depends on the conditions of the existing pavement.

Once a pavement is ready for the seal coat, a mixture of approximately 20% crumb rubber and 80% AC-10 is commonly used as a seal coat material. The application rate for the A-R binder is approximately .55 to .75 gallons per square yard with 26 to 36 pounds per square yard of aggregate. If the road is not too badly cracked, the A-R binder rate could be as low as .45 per square yard. The worse the road, the greater the application rate must be for the A-R binder.

One of the unique things about asphalt-rubber is the need to have specialized equipment on site because crumb rubber does not stay in suspension for very long. Agitated spreader trucks must be used. The material must practically be made on site to be used while it is still fresh. It will take the mixture about one hour of interaction time before the crumb rubber has had a chance to absorb the asphalt and expand. When ready, the viscosity of the mixture must be at a minimum of 1,500 cP at 375 degrees F. During the application process, using pre-coated aggregate is a must when dealing with asphalt-rubber. If pre-coated aggregates are not used, dust particles will interfere with aggregate embedment because the viscosity of the A-R material is so high that it almost immediately turns into a gel after being released from the sprayer.

Figure 13 Agitating Spreader Truck

Though A-R seal coats are often a good choice for preventative maintenance, urban and suburban areas are less likely to use a seal-coat because of the risk of loose aggregate causing harm to vehicles and pedestrians. In these situations, a cape seal is a viable alternative. A cape seal is when a road has a seal coat applied to it, but then a slurry seal is placed over the surface of the seal coat in order to smooth out the riding surface. This procedure is a viable option for urban and suburban roads where a smooth road surface is desired.

Figure 14 Cape Seal on a Suburban Road

In conclusion, the use of A-R seal coats in pavement preservation measures has many benefits: a higher binder application rate is possible, there is improved resistance to reflective cracking, the road will have a longer service life, there will be a higher percentage of aggregate embedment and retention, it has better temperature susceptibility, it takes less construction time, it is an alternative to reconstruction, it may be used on in a variety of situations on many different types of roads, and it has a low initial cost when compared to alternatives.

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TEXAS PAVEMENT PRESERVATION CENTER
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Peer State Review of TxDOT Maintenance Practices

TPPC Board of Directors

TxDOT: Michael W. Alford, P.E., Ray L. Belk, SPHR, Gary D. Charlton, P.E., Tracy Cumby, Toribio Garza, Jr., P.E., Randy R. King, Paul Montgomery, P.E., Tammy B. Sims, P.E., J. Jeffrey Seiders, Jr., P.E., Industry: Joe Graff, Halcrow, Bill O'Leary, Martin Asphalt, Kevin King,TXI, Barry Dunn,Viking Construction, Myles McKemie, Ergon

Our Mission

The mission of the TPPC, in joint collaboration with the Center for Transportation Research (CTR) of the University of Texas at Austin and the Texas Transportation Institute (TTI) of Texas A&M University, is to promote the use of pavement preservation strategies to provide the highest level of service to the traveling public at the lowest cost. The executive sponsor for the TPPC is the Texas Department of Transportation (TxDOT).

Contact Us

Director: Dr. Yetkin Yildirim, P.E.
E-mail: yetkin@mail.utexas.edu
Website: www.utexas.edu/research/tppc

Past and Upcoming Events

TPPC Microsurfacing Courses

Microsurfacing training courses will be offered by the TPPC. The course is designed for engineers and inspectors and is entitled "Guidelines on the use of Microsurfacing." The course recapitulates the pavement preservation concepts, specifically with reference to microsurfacing. It focuses on proper mix design selection and application of microsurfacing. TxDOT's experience with microsurfacing is also discussed. This course also includes discussion on the use and applications of cape seals.

TPPC Seal Coat Training Courses

Seal Coat training courses will continue to be offered by the TPPC. The course designed for inspectors, entitled "Seal Coat Inspection and Applications," focused on proper inspection methods and the equipment used during chip seal construction. The other, "Seal Coat Planning and Design," instructed engineers on planning, designing, and constructing chip seals.

For more information on the Seal Coat and Microsurfacing courses, please contact Dr. Yetkin Yildirim, P.E. at yetkin@mail.utexas.edu or (512) 232-3084.

The PEER State Review Project

TxDOT's sponsored Peer State Review Project was an effort to get an unbiased opinion on the State's maintenance practices from knowledgeable experts in the field. The goals of this project were to provide TxDOT with an unbiased assessment of its maintenance practices, identify potential areas for improvement and understand best practices used in other states and evaluate their applicability to Texas. A workshop was conducted at the Center for Transportation Research (CTR) at the University of Texas, Austin and Austin District from the 5th to 7th of October 2010. It provided a forum for the Director of Maintenance (DOM) from selected peer states to study the TxDOT Maintenance Program and provide their recommendations on potential areas for improvement.
The five focus areas for this workshop included the following:

1. Maintenance Planning Process
2. Maintenance Practices at both the State and District levels
3. Four-Year Pavement Management Program Development
4. Maintenance Performance Measurement and Reporting
5. Funding Allocation at both the State and District levels

Six states' DOMs agreed to be a part of this project namely, California, Washington, North Carolina, Kansas, Missouri and Georgia. The primary purpose of the workshop was to capture the expert opinions of the peer state reviewers on TxDOT's maintenance program and practices. Several methods were used to enable this transfer of opinion including presentations and discussions, a road rally that included road condition evaluations, and a "Booklet of Questions" evaluation questionnaire.

The Booklet of Questions

The researchers at CTR carefully designed this questionnaire to allow the reviewers considerable freedom in providing their opinions and recommendations, while ensuring that their opinions were conveyed objectively. It consisted of 15 questions that addressed the five following areas of focus:

- Maintenance Planning Process
- 4-Year Pavement Management Program Development
- Maintenance Performance and Measurement Reporting
- Funding Allocation (Funding Levels and Allocation Formula)
- Overall Maintenance Operations

The answers to the questions in the booklet were provided at each reviewer's discretion during the course of the workshop. The presentations and activities in the workshop were designed to give the peer state reviewers a comprehensive understanding of TxDOT's maintenance program to help them evaluate and answer the questions. A Facilitated Consensus Meeting at the end of the workshop was organized to get a unanimous response on these questions. The figure below represents the consensus reached by the peer reviewers for each topic in the questionnaire:

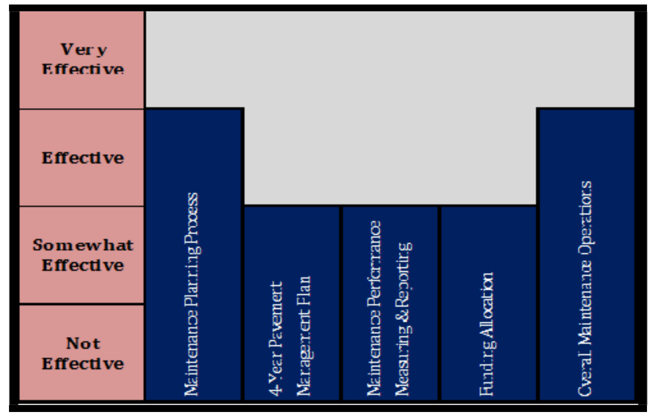

Figure 1: Group Consensus

Maintenance Planning Process

The general consensus reached during the Facilitated Consensus Meeting on Ratings was that the Maintenance Planning Process at TxDOT is "Effective". The Peers appreciated TxDOT's systematic approach to maintenance based on formulas and actual measured highway system needs. According to them the process seems to be working well overall.

The current process was considered effective because the four-year plan to integrate the construction budget and the maintenance operating budget has yielded a result of about 87% of roads in good condition. They supported TxDOT's decision to redirect resources from mowing and traffic activities to pavement repair, an initiative that is also part of MoDOT's five-year plan. The system was praised as "well-established" and the four-year plan was appreciated. However improvements suggested included using a more holistic statewide approach for funding rather than the current district-based approach. It was felt that pavement was TxDOT's only real maintenance priority and that many of the maintenance personnel were probably unsure about their other maintenance goals.

Figure 2: Maintenance Planning Process

The two most important strengths of the TxDOT maintenance planning process selected unanimously during the Peer review process were cited as:

1. Excellent communication with the personnel working in the field, and

2. The TxTAP (Texas Traffic Assessment Program) and TxMAP (Texas Maintenance Assessment Program) programs because they collect important data every year, build the system's history, and check the performance of the maintenance staff on a regular basis.

An additional third strength listed was the focus on pavement management, especially through the use of chip seals.

Several other strengths were identified by the Peers individually. Caltrans' Steve Takigawa thought that communication is TxDOT's biggest strength when it comes to maintenance planning; he felt that the most carefully-laid plans, data collection systems, and pavement management programs are all useless if there is a lack of clear communication between those in charge of planning and those on the field.

Roy Rissky from MoDOT responded that the two most important strengths of the TxDOT maintenance planning process were the PMIS, and the four-year planning process.

Eric Pitts from GDOT was of the opinion that the main strengths of TxDOT's approach to maintenance planning lay in the accountability of managers, and the managers' involvement in the planning process.

According to Jim Carney of KDOT the emphasis on pavement preservation, especially the use of a seal coat program, and the Central Office-led TxMAP and TxTAP inspection programs, which ensure statewide consistency were significant strengths of the TxDOT's maintenance planning program.

NCDOT's Jennifer Brandenburg considered the process' two main strengths to be the use of a 2030 Committee to evaluate the needs of the system, which she feels garners support from the industry, and the use of peer reviews, which she considers an optimal method of creating enthusiasm among the district-level personnel. These two activities bring those on the industry side and those working on the district level into the planning process and promote a team effort. She cited TxDOT's recognition of each road's unique condition during the planning process as a third strength.

David Bierschbach of WSDOT considered the main strength of TxDOT's maintenance planning process to be a focus on the future rather than just the current state of the system.

Among the weaknesses that were discussed, the peers agreed that the two main weaknesses of TxDOT's maintenance planning process were a lack of consideration for performance measures, and the focus on district-wide needs rather than statewide needs. The relatively low priority given to bridge maintenance in a state with over 50,000 bridges was listed as a third weakness. Other weaknesses cited include TxDOT's lack of recorded pavement histories, the relatively poor quality of the work-zone devices, and the difficulties in maintaining consistency between districts and areas posed by the current plan to change the mowing width and number of cycles.

The length of TxDOT planning process, the four-year plan was also considered as a weakness. The plan was considered to be appropriate for operations like seal coats but too short for bigger construction and rehabilitation projects.

The peers indicated that though TxDOT's maintenance planning process is working reasonably well, yet a few improvements would make the performance even better. It was suggested that TxDOT should tie performance measures to the planning process, maintenance operations should be planned according to the needs of the entire state, and bridge maintenance should be made a higher priority.

Additional improvement measures discussed were formulation of a plan that will prepare the organization in case that reduced funding and building up the experience of the in-house personnel in case funding for contracted operations is ever decreased. It was also suggested that TxDOT expand its repertoire of treatments beyond seal coats and overlays, as sometimes more expensive treatments yield better results. Finally it was proposed that Level of Service (LOS) information should be incorporated into the planning process, condition data should be used to allocate resources, and district engineers should be held accountable for LOS.

4-Year Pavement Management Program Development

During the Facilitated Consensus Meeting on Ratings, the peers rated the 4-year pavement management program development process as effective which was a compromise between their varied opinions. Some of the peers stated that involving the districts in the development of the plan was an excellent way to begin the process and believed that the program would be effective because it provided a direction for TxDOT as a whole, although third and fourth years of the plan were still uncertain entities. However, a few of them felt that although the 4-year plan seemed to be effective at the current time, the assessment could be premature.

Peers recognized the need for the Four-year Pavement Management Plan to be very effective in the future as it would enable TxDOT to plan out future maintenance operations while allowing flexibility in the event of changing pavement conditions or levels of funding. The synchronization with which TxDOT's district offices worked with the central office to develop the plan was appreciated. However, it was also felt by some that TxDOT should use deterioration curves developed from good cross-section measurements and consistent pavement condition measurements rather than just relying on assumptions. Overall, it was felt that consideration of long-term goals is a positive move for TxDOT. The plan effectively communicated roles and responsibilities to the field.

The individual ratings of the Four-year Pavement Management Plan are illustrated in the figure below:

Figure 3: 4-Year Pavement Management Plan

Several strengths of the 4-year pavement management program development process were identified by the Peers. The program's ability to provide the districts with a process to follow and manage and the flexibility it offers in the third and fourth years were recognized as obvious advantages. Additional strengths noted were the coordination between maintenance contracts with in-house maintenance efforts, the use of well-maintained cost records to support the budget, the peer exchange process between districts, the use of contract raters, which eliminated bias and the use of analysis tools like Mapzipper and ProviewLite, which provided district personnel with visual representations of their plans. Finally the ability of the system to communicate roles and responsibilities to the field, and the mapping process of the four-year plan itself were also noted as strengths.

Among the weaknesses identified, the top two weaknesses of TxDOT's Four-year Pavement Management Program were the use of visual condition ratings and opinions of expert staff members to make pavement decisions rather than the use of data and condition surveys or deterioration curves, and the current reporting system's inability to effectively communicate the financial needs of the DOT to legislatures. Additionally, some peers felt that the lack of deterioration curves and pavement substructure data was another weakness of the program. Thus, changes were suggested by the Peers to improve the efficiency of the program

The three most important changes suggested to improve the 4-year pavement management program development process selected unanimously during the Peer review process were cited as:

1. Shifting the plan to a statewide focus. The peers advocated planning according to the needs of the state as a whole rather than creating plans based on the amount of inventory in each district.

2. Increasing the amount of flexibility built into the program in the event of an unforeseen occurrence, such as an unusual amount of rain, freezing temperatures, or drought.

3. Breaking down the plans into specific goals for each person in TxDOT, and then holding that person accountable for meeting those goals.

Additional improvements suggested include limiting the amount of control the districts had over the funding they received and to continue making efforts to improve the data for years three and four of the program, as the four-year plan would not be sustainable unless this data was improved.

It was also recommended that the pavement rating method be changed from one utilizing contract raters to one using in-house staff or technology, as the two latter methods would increase consistency.

Maintenance Performance Measurement and Reporting

The Maintenance performance measurement and reporting of TxDOT were considered effective only to a certain extent by the Peers. It was stated that the measurements used in this process were very effective, but the communication of what those measurements were and what they meant to the legislature and the public needed improvement. The peers expressed concern over the lack of consistency between the information reported using three different systems (PMIS, TxMAP and TxTAP). The need to compile the information from each system into one consistent message was stressed upon. It was perceived that the current system is too focused on collecting and reporting data, rather than using the data collected to make decisions.

The ratings are reflected in the graph below:

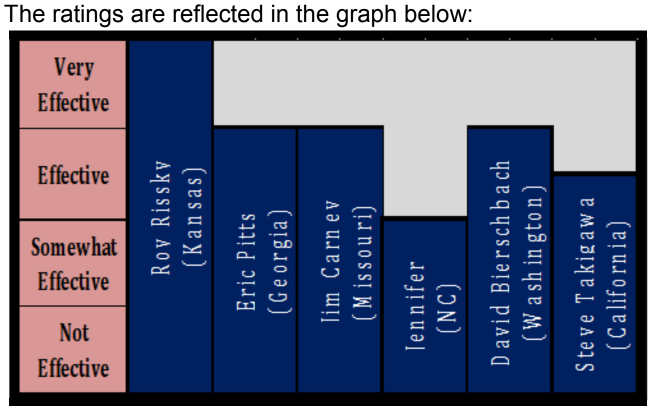

Figure 4: Maintenance Performance Measurement and Reporting

Roy Rissky appreciated the three different tools that are being used for performance measurement, namely PMIS, TxMAP and TxTAP. However, he reinforced the need to be consistent with the results of the three systems. Jim Carney wrote that TxMAP was using a process very similar to MoDOT's IMQA spring and fall reviews on interstates, which led him to the conclusion that TxDOT's measurement and reporting is effective. Jennifer Brandenburg clarified her rating by focusing on the problems with TxDOT's rating system. She pointed out that 4100 samples would not be sufficient to ensure statistically reliable condition ratings at the local level. She questioned the detail level in the TxTAP rating system, indicating that TxDOT could be rating an unnecessarily high number of traffic features and should scale down to reduce redundancy. David Bierschbach wrote that the current process was effective in that it is well understood by the staff. According to Steve Takigawa, the system was measuring an unnecessary number of activities which made it difficult for the field crews to meet all of their goals. He expressed concern over whether or not all of the activities included in the ratings could possibly be funded to a level that would allow the desired ratings to be achieved.

The two most important strengths of the TxDOT maintenance performance and reporting selected unanimously during the Peer review process were cited as:

1. The centrally-managed TxMAP and TxTAP systems, and

2. The year-round rating practices utilizing consistent raters.

Other advantages of TxDOT's maintenance performance and reporting system that were recognized include TxDOT's historical information, which allows system trends to be discovered that are supported by actual data, the statistical quality of TxDOT's historical data, limited number of people performing evaluations that allows increased control over the data, statewide quality control performed by central office staff and the high quality of the roadway and roadside condition assessments due to TxDOT's one mile drive-by samples. The practice of giving feedback to the districts immediately after the ratings were completed was highly appreciated.

The peers also identified certain weaknesses of the system. Roy Rissky identified the lack of data covering historical actions on the current pavement layers as the main weakness. This lack of data according to him would reduce TxDOT's ability to predict future actions using existing pavement performance records. According to Eric Pitts, the main strength of the system was also its primary weakness: a limited number of people performing the evaluations allowed for increased control over the data, but it also prevented the districts from becoming involved in the process. If the district staff were more involved, they would be more likely to accept the reports produced from the evaluations. Jim Carney reported that the system's main weakness was the drive-by sampling process, which could not provide a comprehensive review of features like pipe drainage, edge drop-off, or break-away signpost details. According to Jennifer Brandenburg, the weaknesses of TxDOT's maintenance performance and reporting were the statistical unreliability of the sample size used for TxTAP and the unnecessary level of detail in the TxTAP evaluations. Thus, changes were suggested by the peers to improve the efficiency of the system.

Eric Pitts suggested that the ratings would have been even stronger in Texas if the central office staff went out with the district staff to produce a collaborative rating, rather than the districts just handing in a report. Collaboration between the two would produce more consistent ratings. He also highlighted the need for district involvement in the review process, especially in one's own areas. He commented that when rating others' areas, raters tend to be more critical but when district personnel rate their own area, they then have an opportunity to objectively compare their performance with that of other districts.

Jim Carney suggested that the current weighting of traffic and roadside in TxDOT's PMIS be flipped. Currently, the weighting is 50% to pavement, 20% to traffic, and 30% to roadside. He recommended switching traffic to 30% and roadside to 20%. His rationale was that, excepting guardrails and guard cables, traffic features affect the safety of motorists more than roadside features, and safety should be the first priority.

Roy Rissky stressed the importance of collecting work history data in order to calculate service life for the treatments used. According to him, if TxDOT knew how long past actions have lasted, the maintenance performance would be much improved. He also stressed the importance of recording location-specific information about pavement actions through both district records and coring. This data would enable the system to predict the action that should be taken based on a current condition score and the historical performance of a suggested action.

Jennifer Brandenburg suggested that the data should be used to hold the districts accountable for the condition of the system.

David Bierschbach advocated the use of TxMAP to educate the legislature and communicate TxDOT's needs to them so that they will be able to justify increased spending on transportation.

Steve Takigawa advised TxDOT to consider how performance measures could be more closely tied to allocations and pavement decisions. He found TxDOT's system to be too detailed and suggested defining the top five to ten activities and creating corresponding performance rating goals. He recommended making the priorities of the maintenance program clear. Additionally, he recommended using the system to take specific actions based on the results obtained as any item that was rated and not implemented was a wasted resource and should be eliminated.

Funding Allocation Process (Funding Levels and Allocation Formula)

The general consensus was that TxDOT's funding allocation process was effective. These results are represented in the graph below:

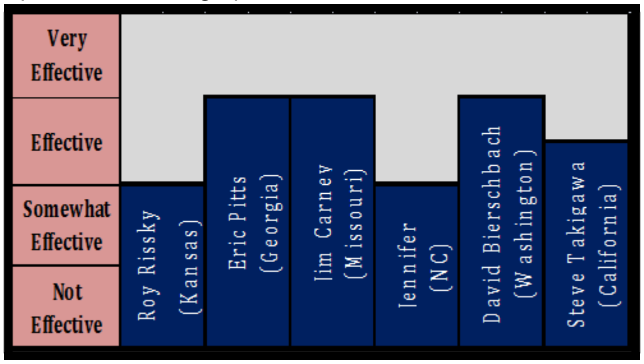

Figure 5: Funding Allocation

It was felt that the current system would be only somewhat effective in the future, although the system had been effective in the past. Pavement maintenance systems had a high dependency on the availability of funds. Given the recent downturn in the overall economy, the effectiveness of TxDOT's funding allocation system was doubtful.

The formulae for funding were perceived as being unnecessarily complex, as they used 56 specific functions in determining funds allocation. As a comparison, NCDOT's system was quoted that uses a more general formula in which funds were allocated throughout the state and the divisions are then accountable for achieving the desired Level of Service. Funds should only be used on the projects for which they were allocated.

The peers focused on the lack of improvements the current allocation process aimed to achieve in any activities or areas, suggesting that the current budget had not improved upon the previously derived budgets. However, the effectiveness of the current funding allocation approach with regards to the sustainability of the TxDOT maintenance program was noted.

The peers identified several strengths of the funding allocation. Eric Pitts responded that the primary strength of TxDOT's funding allocation process was that the formulae made the process easily repeatable and reportable. Steve Takigawa stated that the use of a reasonable check to ensure that the districts could actually use the funding they were allocated was an excellent component of the process. David Bierschbach commented that TxDOT has a well-defined process for funding allocation that would facilitate districts in planning for a consistent budget each year based on inventory. Roy Rissky considered the primary strength of the funding allocation program as its effectiveness for routine maintenance needs. According to Jim Carney, separation of preservation cycles by traffic volume and average rainfall and the high level of detail in the pavement selection criteria were the two main strengths of the process. Jennifer Brandenburg listed that separate funding allocation for pavement rehabilitation was the program's main strength.

However, the peers also identified the weaknesses of the funding allocation process. Eric Pitts responded that the main weakness of the funding allocation process was the lack of a state-wide approach. He also identified that the process relied on historical funding data to distribute funds rather than the current known needs of the system. Jennifer Brandenburg found the process' primary weakness to be the lack of connection between funding and pavement condition and David Bierschbach seconded this conclusion. She also reported that the complexity involved with funding to the function level and the lack of connection between the desired level of service (LOS) and the funding formulae were disadvantageous. Roy Rissky felt that the practice of allocating funds without considering the actual needs of the district was its major drawback. He suggested that some districts might be using funds simply because they have been allocated that money, rather than because they truly needed the funds they received more than other districts. He also considered the process' reliance on contracted maintenance as a weakness as he believed that the amount of funding TxDOT would receive in the future would not be sufficient to fund all of the maintenance needs as contract work. Jim Carney opined that the two main weaknesses of the process were the unnecessarily high number of roadside factors included in the formulae and the lack of emphasis on bridge maintenance. Steve Takigawa felt that the two most significant weaknesses of the process were the freedom districts had over how funds are utilized and the practice of inventory-based funds allocation. He stressed the importance of allotting funds where it was really needed and then ensuring the funds were used on those identified needs. Thus, changes were suggested by the peers to improve the efficiency of the process.

The peers agreed that the single most important change TxDOT could make to the funding and allocation process was moving from inventory-based funding to condition-based funding. They stressed the importance of tying funding allocation to the condition of the roadway and the system.

The peers recommended generalizing the formulae instead of tracking features in granular detail. It was also suggested that the language used to communicate funding requests to the legislature be changed. The general consensus from the peers was that asking for funding for either a "tolerable" or "desirable" LOS was not the most politically effective means of expressing the department's needs. Everyone's definition of "tolerable" was different, and therefore, the department should be more precise when asking for funding. It was also advised that the allocations should be moved from a historical data-based model to a predictive model derived from pavement condition surveys. Creating a performance-based funding allocation process that considered the priorities of the entire state rather than the current formula-based process was considered to be more useful. The maintenance priorities should be clearly defined to enable statewide monitoring.

The peers expressed concern over funding districts with the lowest condition ratings which according to them was essentially rewarding poor decision-making. They suggested that the districts should be held accountable for making the improvements for which they were given funding and the contract pavement funds should be distributed on a statewide needs basis rather than district-by-district. A few suggested factoring the roadway condition data into the funding allocation process to ensure that funds were supplied where they were most needed.

Overall Maintenance Operations

Overall the peers rated TxDOT's maintenance operations as effective.

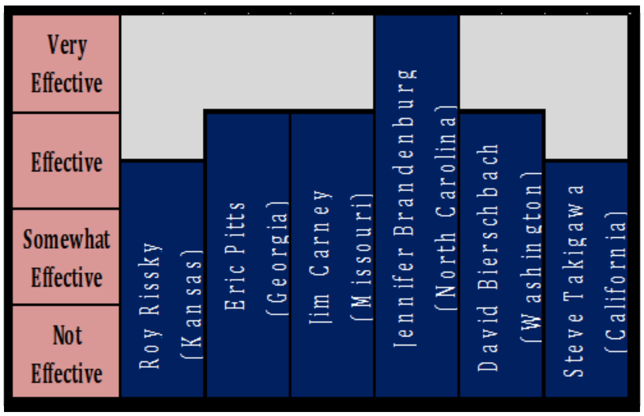

Figure 6: Overall Maintenance Operations

According to Mr. Rissky, the system has been very effective in the past but would require considerable changes and adaptability to sustain effectiveness in the face of restricted funding.

Jim Carney of Missouri explained that he found the overall maintenance operations to be effective partially because of TxDOT's efforts to regionalize the 25 districts, which he believed would improve the consistency of the maintenance activities in those regions. He reported that MoDOT has attempted to improve the consistency of their interstate maintenance activities by establishing six corridors in lieu of ten districts and considering regional concepts for bridge maintenance and striping operations.

North Carolina's Jennifer Brandenburg stated that TxDOT is a model for a lot of the contracting practices at NCDOT, such as the comprehensive contracts. She considered the peer review program as a very effective tool for communicating best practices across the organization. WSDOT's David Bierschbach appreciated the competency and dedication of the staff in particular and was impressed by the program overall.

Steve Takigawa of Caltrans was of the opinion that TxDOT's reporting is strong and very thorough and TxDOT's efforts to communicate with the field staff and develop mid-range plans for the system's pavement are excellent. However, he found a lack of flexibility in the program and felt that the funding allocation and decision processes currently in place may be difficult to convert into a performance-based allocation program. He also reported that the overall maintenance operations would be more effective if the department had specific goals for features other than pavement.

During the Facilitated Consensus Meeting on Ratings, the peers reached a consensus as to the three main strengths of TxDOT maintenance operations. The primary strength cited was TxDOT's knowledgeable staff, composed of people who take pride in their work. Next the peer review program was believed to be of considerable value and should be continued. Finally, TxDOT's willingness to evaluate and improve their program was considered a significant strength in itself.

Other notable strengths of TxDOT's maintenance program mentioned were the ability to supplement the workforce with contract work, the commitment to pavement preservation, the minimal amount of brush and undesirable vegetation on the roadsides, the contracting methods and the willingness of the department to seek new, more efficient and effective methods.

The peers also reached a consensus on the two main weaknesses of TxDOT's maintenance operations. The first weakness was the allocation of funding by district rather than condition. Second, the program should strive to be more reactive than it currently is, as many of the department's decisions are based on historical and cultural factors rather than the real needs of the system.

Additional weaknesses cited include the high number of activities contracted out, which could potentially result in lost expertise among the in-house staff, the mowing height, and an excessive number of crack seals. It was felt that the mowing height of 30 inches was possibly too high.

Some improvements that were suggested are working toward a statewide pavement preservation plan and collecting historical data on pavement treatments through district records or pavement analysis. Eric Pitts of GDOT recommended contracting out more activities, which would allow the in-house staff to focus on preservation. He also advised examining the amount of experience being logged in contracted areas. Jim Carney of MODOT encouraged the continuation of the district peer exchanges, which he feels promotes consistency and the sharing of best practices. Jennifer Brandenburg of NCDOT suggested giving the districts more flexibility in their contracting by increasing the small contract amount from $300,000. She felt that TxDOT should review which functions are performed in-house and which are contracted out. David Bierschbach of WSDOT advised seeking new, more effective ways of communicating performance measures and their meanings to the legislature and the public. Steve Takigawa of Caltrans recommended switching from a program based on "historical maintenance" to a more "action-oriented" maintenance program. He also suggested that TxDOT develop a means of holding the districts accountable for their maintenance allocation.

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TEXAS PAVEMENT PRESERVATION CENTER
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Contact Us

Director: Dr. Yetkin Yildirim, P.E.
E-mail: yetkin@mail.utexas.edu
Website: www.utexas.edu/research/tppc

Past and Upcoming Events

TxDOT Study on Prime Coats

Texas Pavement Preservation Center (TPPC) has conducted a study on most commonly used prime coats in Texas, their curing time and characteristics such as permeability and penetration.

TRB 90th Annual Meeting

The Transportation Research Board is a division of the National Research Council, which serves as an independent adviser to the federal government and others on scientific and technical questions of national importance. TRB's mission is to promote innovation and progress in transportation through research. The Transportation Research Board's 90th Annual Meeting attracted more than 10,900 transportation professionals from around the world to Washington, DC January 23-27, 2011. The TRB Annual Meeting program consisted of over 4,000 presentations in nearly 650 sessions. Summaries of selected seminar papers related to pavement preservation are included in this issue. For more information on these papers please contact CTR library at 512-232-3126.

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Our Mission

The mission of the TPPC, in joint collaboration with the Center for Transportation Research (CTR) of the University of Texas at Austin and the Texas Transportation Institute (TTI) of Texas A&M University, is to promote the use of pavement preservation strategies to provide the highest level of service to the traveling public at the lowest cost. The executive sponsor for the TPPC is the Texas Department of Transportation (TxDOT).

TxDOT Study on Prime Coats

TPPC conducted a study on Prime Coats to evaluate the curing time and other characteristics when applied to a granular base. The most commonly used prime coats in Texas were selected for the experiment. Specimens were subjected to real conditions such that prime coat applied base was left exposed to weather. Curing time was calculated in three different weather conditions to understand how the weather affects curing time. In addition to determining curing times, other important engineering properties that determine the performance of prime coats such as, strength (both dry and wet strength), permeability and penetration were also studied. Based on the curing times, strength tests, permeability and penetration tests, a unique ranking list was developed using dry and wet strength, penetration and permeability as the key factors to determine the prime coat which would serve all the intended functions effectively and efficiently.

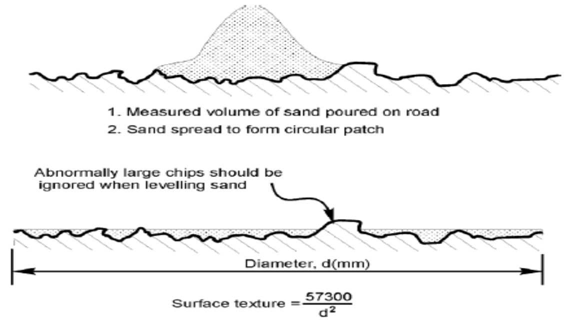
TRB 90th Annual Meeting Selected Pavement Preservation Papers

Comparative Analysis of Macrotexture Measurement Tests for Pavement Preservation Treatments by Bekir Aktaş, Douglas D. Gransberg, Caleb Riemer and Dominique Pittenger,

Determining macrotexture on pavement correctly and quickly is important for safety and economy in pavement preservation testing. This study investigated and compared two methods commonly used to determine macrotexture on pavement surfaces: the outflow meter ASTM STP 583 and the Transit New Zealand TNZ T/3 sand circle test. The research and analysis results have shown that there are functional limitations in each method's ability to accurately measure pavement macrotexture. The outflow meter provides users with results measured in seconds. It is portable, practical on wet surfaces, inexpensive, and fast, but the measured outflow time can be inaccurate for pavement preservation treatments with high macrotextures. The opposite is true for the sand circle method which should be avoided on surfaces with low macrotexture. This results in the following recommendations for appropriate use of each test method:

- If macrotexture < 0.79mm (0.03 in.), use the outflow meter only.
- If macrotexture > 0.79mm (0.03 in.) and < 1.26mm (0.05 in.), either test is appropriate
- If macrotexture > 1.26mm (0.05 in.), use the sand circle test only.

It is recommended that the macrotexture limitations for each test method should be contained in specifications for each test to ensure that the agencies that use these tests are made aware of each test's functional limitations.



Sand Circle Test for Texture Measurement (TRB 11-0346 pg. 5)

Outflow Meter Test Instrument (TRB 11-0346 pg. 6)

Innovation Process and Database for Pavement Preservation Treatments Used in California by DingXin Cheng, T. Joseph Holland, R. Gary Hicks and Larry Rouen

The California Department of Transportation (Caltrans) has developed a streamlined process and management system to support innovations by funding and documenting innovative projects, an effort made to promote the effective pavement preservation techniques in California. An innovation database has been developed to assist the implementation of innovation and new products in the area of pavement preservation and to encourage technology transfer through dissemination of information through websites. A number of new innovation projects, such as cold-in-place recycling, fog and rejuvenation seals, hot-in-place recycling, interlayers, polymer or rubber modified asphalt chip seals, open graded rubberized asphalt concrete with high binder contents (RAC-O-HB), and warm mixes have been stored into the database. The first version of Caltrans innovation online database has been created and published online. The Caltrans innovation procedure and database are valuable pavement preservation management tools. It has helped Caltrans identify and manage pavement preservation innovation projects. Other agencies can use it as a template to support their pavement preservation programs.

Finished RHMA-O warm mix overlay in Route 94, San Diego, CA (TRB 11-0445 pg. 14)

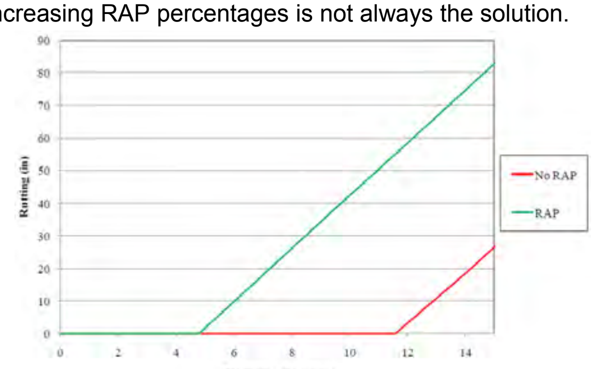
When to Safely Broom or Remove Traffic Control on Fresh Emulsified Asphalt Chip Seals by Scott Shuler

One of the most subjective decisions that must be made during chip seal construction is determining when the first brooming can be accomplished to remove excess chips or when to open a fresh chip seal to traffic. The author suggests that moisture content of the chip seal system is directly related to the strength of an asphalt emulsion residue. A new laboratory test that simulates the sweeping action of rotary brooms during chip seal construction was developed during this research. This test simulates the shear forces applied by brooms and uncontrolled traffic to fresh chip seals, and can be used to predict the time required before brooms or uncontrolled traffic can be allowed on the surface of the chip seal in terms of the moisture content of the chip seal. Also, three full-scale test pavements were constructed in differing climates and the results of moisture content testing in the field were compared with modified sweep test results in the laboratory. Results indicated that the three field tests were capable of resisting brooming and traffic damage when moisture content of the chip seal system ranged between 15 and 25 percent. This correlated well with results of laboratory testing using the modified sweep test on the materials from field tests as well as experimental laboratory materials. The test results also indicated that the moisture content at which 90 percent of the aggregate chips are retained during the sweep test is the "critical moisture content" corresponding to very high residue adhesive strength at which uncontrolled traffic could be allowed onto the chip seal field test sections. For equal residue strength, more moisture loss in the chip seal was required when dry aggregates were used than when saturated surface dry aggregates were used, confirming the belief that moist aggregates provide higher early strength than dry aggregates when building chip seals.

Modified Sweep Test Mixer (TRB 11-0562 pg. 10)

Reclaimed Asphalt Pavement: Save Today, Pay Later? by José P. Aguiar-Moya, Feng Hong and Jorge A. Prozzi

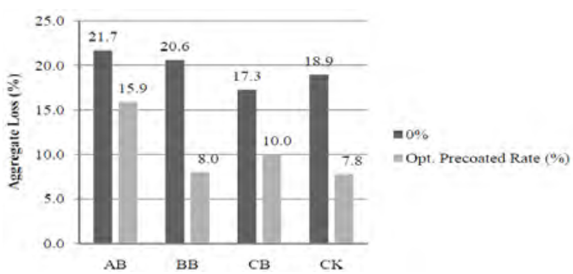
There are many advantages associated with the use of RAP, including economic benefits due to the reduction in virgin asphalt binder and new aggregates required, environmental benefits associated with the use of a recycled material, and short-term performance benefits due to increased rutting resistance. However, field observations have raised some concerns in terms of the long-term performance of mixtures containing RAP compared to those of virgin mixes. The long-term implication of using RAP and its effect on pavement cracking are yet to be better understood. The authors used data from FHWA's LTPP SPS-5 experiment in Texas to quantify and compare the field performance of pavement sections containing RAP with those that do not contain RAP. The results have indicated that milling prior to overlaying increases the life expectancy of the pavement structure when no RAP is used in the mix. In the case where RAP is used, the effect of milling is reversed. The authors thus emphasize that pavement designers need to be cautious with the use of RAP and to take into consideration that pavement structures with RAP might deteriorate faster in the long run, mainly in cases where RAP is used in thin overlays. Also, increasing RAP percentages is not always the solution.



Transverse Cracking Progression on a Pavement with a Thick Overlay (with Milling Prior to Overlaying) (TRB 11-1017 pg. 11)

Determining of Precoated Aggregate Performance on Chip Seals Using Vialit Test by Mustafa Karasahin, Bekir Aktas and Cahit Gurer

One of the methods that are commonly used for increasing performance of chip seals is precoating aggregate surfaces with bitumen on-site or in asphalt plants. Aggregates coated with bitumen help initial adhesion between binder and aggregate particles, particularly to overcome potential negative effects caused by dust and moisture, make surface markings clearer and reduce damages to vehicles on newly laid chip seals. In this paper, effect of precoated aggregates, which are used to increase performance of chip seal on aggregate-bitumen adhesion was investigated. Optimum precoated rates for four different aggregates, three different gradations of basalt and one gradation for limestone, were determined with Vialit Adhesion Test. Precoated aggregate with optimum rate ensured better adhesion than aggregates uncoated with bitumen. Results of experimental studies have shown that precoated aggregates contribute highly to performance of chip seal particularly in terms of aggregate-bitumen adhesion. However, authors suggest that precoated amount should be determined correctly and aggregates should be optimally coated with bitumen.



CB-Type-C Basalt; CK-Type-C Limestone; BB-Type-B Basalt; AB-Type-A Basalt;

Vialit Test Results of Pre-coated and Non-precoated Aggregates (TRB 11-1220 pg. 8)

Determination of the Performance of Chip Seal, Applied With HSKSC (Accelerated Chip Seal Simulation Device) on Unbound Base by Mustafa Karasahin, Cahit Gurer, Murat Vergi Taciroglu and Bekir Aktas

Chip seals applied on unbound granular bases are widely used in countries such as Turkey, Australia, New Zealand, and South Africa. Although several methods and techniques regarding measurement of the performance of chip seal on-site and under laboratory conditions have been developed in recent years, there is no evidence that a device, system or method in a laboratory setting could pre-measure the performance of chip seals. In this study, Accelerated Chip Simulation Device (HSKSC), which was developed and designed in Suleyman Demirel University (Turkey) was employed by the authors to assess the performance of chip seals applied on unbound granular bases under desired climate conditions. Two different chip seals (single-layer and double-layer) were designed with this device and the chip seal samples were subjected to performance test under mild and hot climatic conditions respectively. It was concluded that as the number of cycles increases, considerable decrease appears particularly on macro texture and a limited decrease in micro texture. The experimental research has shown that this device simulated the behavior of chip seal on unbound granular base realistically.

HSKSC Test Equipments (TRB 11-1225 pg. 5)

Automated Pavement Crack Sealing System Development by Wayne D. R. Daley, Sergio Grullón, Wiley D. Holcombe, David M. Jared, Steven D. Robertson, Colin T.Usher and Jonathan F. Holmes

Crack sealing is an accepted practice in many state Departments of Transportation (DOTs) as this operation is believed to add significant life to roadways. The research performed by the Georgia Tech Research Institute in conjunction with the Georgia Department of Transportation has proved that a commercial-scale automated crack sealing system is viable. Solutions related to the high-speed firing of nozzles, automated crack detection, and navigation in a real-time system have been demonstrated on a limited-scale system. A prototype of the automated crack sealing system was built and mounted on a trailer. It consisted of a single stereo camera, an applicator system, and a means of providing a continuous supply of sealant to both a longitudinal and a transverse distribution system. The configuration of this prototype system was designed to meet the primary goals of detecting and filling a 1/16" wide crack at a speed of 5 mph.

The software for the crack detection and control system consisted of two major sub systems: a vision processing sub system and a real-time control sub system. The vision processing sub-system consisted of a camera and a Windows-based processing computer. The control sub system consisted of a real-time operation system (RTOS) computer interfaced to wheel encoders and dispensing hardware. This design allowed the RTOS computer to control and query all of the hardware in real time in order to correlate crack detection with dispensing. The future for automated crack sealing operations is promising as this research has demonstrated that many of the technical barriers to commercialization have been addressed, thus opening the door for increased productivity and worker safety.

Picture of Prototype Crack Sealing Hardware with Detail of Applicators (TRB 11-1472 pg. 3)

Life-Cycle Cost-Based Pavement Preservation Treatment Design by Dominique Pittenger, Musharraf Zaman, Caleb Riemer and Douglas D. Gransberg

The use of economic analysis, specifically life cycle cost analysis (LCCA), to achieve the cost effectiveness and return on investment that supports pavement preservation and transportation decision-making is one way to promote sustainability in transportation. Although LCCA is a powerful project economic evaluation tool, there is no prevalent method used by state agencies to conduct economic analysis at the pavement preservation level. No significant research has been done to quantify the actual service lives of the pavement preservation treatments themselves nor has a model been furnished to analyze their LCC. The authors thus try to address this issue by proposing a methodology for using field test data to quantify the service lives of pavement preservation treatments for both asphalt and concrete pavements. Additionally, they introduce the concept of LCC model based on equivalent uniform annual cost, rather than net present value, specifically addressing the relatively short term nature of pavement preservation treatments and allowing the engineer to better relate treatment LCC output to annual maintenance budgets. The research also developed a methodology for developing pavement preservation treatment-specific deterioration models and demonstrated how these provide a superior result to those based on empirical service lives. Finally, the research demonstrated how the new model could be utilized to assist a pavement manager in selecting the most economically efficient pavement preservation treatment for a given pavement management problem.

Correlation of Moisture Loss and Strength Gain in Chip Seals by Scott Shuler, Walter S. Jordan III, James M. Hemsley, Jr., Kevin McGlumphy and Isaac L. Howard

The research described in this paper presents laboratory test methods which measure adhesive strength gain as a function of moisture loss. Although the tests were somewhat different, results were similar and indicated strength in emulsion residues increases as the total moisture in the system is reduced. According to the authors, moisture loss of the emulsion was shown to be a better variable to determine traffic opening than cure time. The modification of ASTM D 7000 identified as Sweep-2 in this paper provides a method to determine the timing for chip seal brooming and opening to uncontrolled traffic. The test results determined the moisture loss of the chip seal which corresponds to adhesion needed to retain chips under traffic loads. The moisture content of the chip seal can be monitored during construction to determine when the desired moisture content is reached. The authors also concluded that each emulsion performs differently with each aggregate combination from the following test data:

	Aggregate Loss (%)			
Emulsion-Aggregate	Dry at 40% Cure	Dry at 80% Cure	*SSD* at 40% Cure	*SSD* at 80% Cure
E4-A1	61	15	63	8
E4-A2	70	16	57	12
E4-A3	55	8	52	3
E4-A4	82	10	80	15
E5-A1	25	20	18	9
E5-A2	72	30	63	27
E5-A3	68	43	42	46
E5-A4	77	37	64	50
E6-A1	75	17	82	25
E6-A2	76	18	81	20
E6-A3	78	21	75	18
E6-A4	77	16	80	17
E7-A1	55	3	41	4
E7-A2	66	18	63	2
E7-A3	70	4	52	1
E7-A4	48	30	45	6
E8-A1	32	4	43	5
E8-A2	50	0	63	2
E8-A3	68	1	65	2
E8-A4	60	5	57	4

Sweep-2 **Test Results Highlighting Aggregate Characteristics (TRB 11-1832 pg. 12)**

Unsealed Gravel Roads Management Systems Programming and Data Management by Khaled Ksaibati and George Huntington

Discussions at the 88th Annual Meeting of the Transportation Research Board in January 2009 identified a lack of an unsealed earth and gravel roads management methodology suitable for small, local agencies, particularly those with governmental structures like those of American counties in the rural west. This paper thus addresses issues related to the need for software and data

management structures and systems for managing unsealed roads, particularly for small, local agencies. Methods for managing data, generating maintenance schedules, and producing network-level outputs are described. Eight unsealed road maintenance tasks are proposed, namely, blading, reshaping, regravel, dust control, stabilization, isolated repairs, major work and drainage. According to the authors, primary aspects of implementing a gravel roads management system from a programmer or data manager‟s point of view are described, namely, Assessment, Inventory,
Database structure, Maintenance and cost tracking, Condition monitoring, Cyclic maintenance scheduling, Triggered maintenance scheduling and Network level outputs.

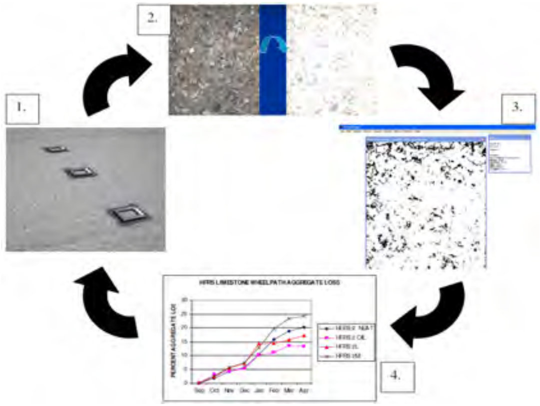
Quantitative Evaluation of Fog Seals on Pavement Skid Resistance with Indoor Accelerated Loading Tests by Wang Duanyi, Chen Xiaoting, Lei Chaoxu and Larry Galehouse

Fog seal, if done timely, is an effective and economical treatment. Meanwhile, it is widely known that the friction coefficient and texture depth of pavement are significantly reduced after application, which hampers the regular use of fog seal. The authors thus believe that by better understanding how fog seal affects skid resistance, new practices and technologies can be developed to solve the problem. A method was developed called tire-driving pavement function accelerated loading test system as the basic test platform. For the study, core samples from existing pavements were obtained to determine the parameters of the asphalt mixture such as air voids, gradation, etc. to design and fabricate specimens. Two fog seal applications were studied, namely, A-type fog seal application by spraying 0.6 kg/m2 of asphalt rejuvenator followed by 0.5 kg/m2 fine aggregate (maximum grain size is 1.18 mm) and A-type fog seal application by spraying 0.6 kg/m2 emulsified asphalt and no fine aggregate, both treated after 10000 loading cycles. It was found that the texture depth and friction coefficient decline after fog seal treatments. Accelerated loading test results indicated that when the spread rate of asphalt material is 0.5 kg/m2, the value of friction coefficient decreased the least. Accelerated loading test results also showed that the spreading of 1.18mm sized aggregate will provide the best effect. Also, aggregate spreading at a rate of 0.5 Kg/m2 was able to achieve an optimum performance. The test results also suggested that the performance of diabase was much better than natural sand.

The Tire-Drive Pavement Function Accelerated Loading Test System (TRB 11-1997 pg. 3)

The Monroe Michigan Chip Seal Case Study: An Evaluation of Multiple Chip Seals' Cold Weather Field Performance by Joe Brandenburg, Herb Wissel and Jason C. Wielinski

The purpose of the Monroe Chip Seal Case Study was to evaluate chip seal performance for multiple test sections comprised with different asphalt emulsion – aggregate type combinations with emphasis on aggregate retention, especially during winter months. Different emulsions and aggregates were evaluated to determine if there was an optimum combination for performance in this climate over the course of one winter. The test sections were placed on a section of North Dixie Highway near the intersection of US Turnpike in Newport, MI near Monroe. Field performance of the chip seals was quantified by aggregate retention measured through image analysis. Firstly, three random stations were identified and photographed in each chip seal section. These pictures were then catalogued and prepared for imaging analysis. Secondly, each photograph was then converted to a black and white image. Thirdly, the bitmap image was imported into the Scion Image software program. This file was then converted into a binary file where all black or dark pixels were assigned a pixel value of 255 and all white or lighter pixels were assigned a value of 0. The program then assigned an average pixel value for the entire image. The average pixel value along with the number of pixels (or area) was then used to calculate the average area of aggregate coverage. Finally, the aggregate coverage for each chip seal was then averaged and converted into a percent of aggregate loss calculation. The research concluded that adding 1.0% OD (Oil Distillate) to an anionic high float emulsion improved performance (aggregate retention) over emulsions without oil. Anionic limestone chip seals outperformed anionic gravel chip seals. There was no appreciable difference between limestone and gravel cationic chip seals. Also, there was no significant difference between latex modified and SBS modified emulsions for gravel seals. Limestone seals with latex modified emulsion performed slightly better than SBS modified chip seals



Field Performance Testing Methodology
(TRB 11-2028 pg. 9)

Pavement Preservation – A solution for Sustainability by Susanne Chan, Becca Lane and Tom Kazmierowski

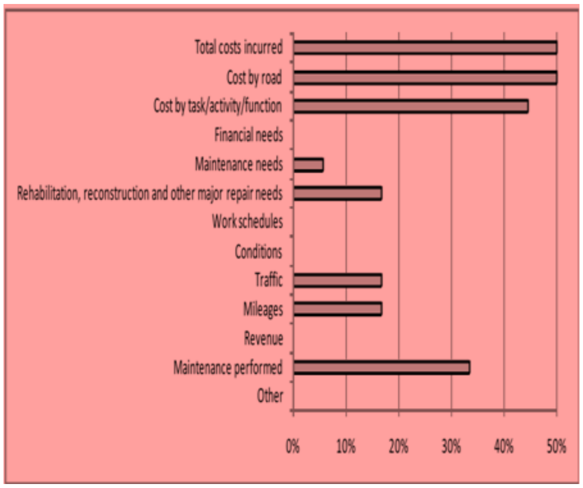
This paper throws light on the pavement preservation strategies of the Ministry of Transportation Ontario (MTO) in recent years in their effort to maximize cost savings in repair operations and maintain pavement condition. These preservation treatments include: crack sealing, slurry seal, micro-surfacing, chip seal, ultra-thin bonded friction course, fiber modified chip seal, hot mix patching and hot in-place recycling (HIR). This paper presents the benefits of pavement preservation by considering the service life of each treatment and calculating the associated energy consumption and GHG emissions per service year. Economic assessment and aggregate conservation assessment on the preservation treatment are also performed. The results indicate that pavement preservation strategies provide a significant reduction in cost, aggregate consumption, energy use and GHG emissions when compared to traditional rehabilitation and reconstruction treatments. The authors conclude that in order promote pavement sustainability, it is necessary to quantify the benefits of the treatment by utilizing life cycle cost analysis (LCCA) to evaluate the most cost effective treatment and utilize methodologies such as PaLATE to evaluate the environmental impacts. Currently, MTO is developing an Ontario based Green Pavement Rating System to quantify and encourage pavement sustainability. The main difference between MTO's Green Pavement Rating System and other systems is it focuses specifically on the pavement component rather than the entire road. Using a simple, points based rating system, MTO Green Pavement Rating System is designed to assess the "greenness" of pavement designs or constructed pavements, both flexible and rigid structures. Assigning a rating to the pavement design will enable the ministry to incorporate more sustainable technologies in pavements and encourage industry to do the same. In the proposed rating system, pavements will be assessed within four categories:

Category	Goal	Points
Pavement Design Technologies	To optimize sustainable designs. These include long life pavements, permeable pavements, noise mitigating pavements, and pavements that minimize the heat island effect.	8
Materials & Resources	To optimize the usage/reusage of recycled materials and to minimize material transportation distances.	13
Energy & Atmosphere	To minimize energy consumption and GHG emissions.	10
Innovation & Design Process	To recognize innovation and exemplary efforts made to foster sustainable pavement designs.	4
	Maximum Total:	35

Four Categories in MTO Green Pavement Rating System (TRB 11-2067 pg. 9)

Unsealed Gravel Roads Management: State-of-the-Practice in American Counties by Khaled Ksaibati and George Huntington

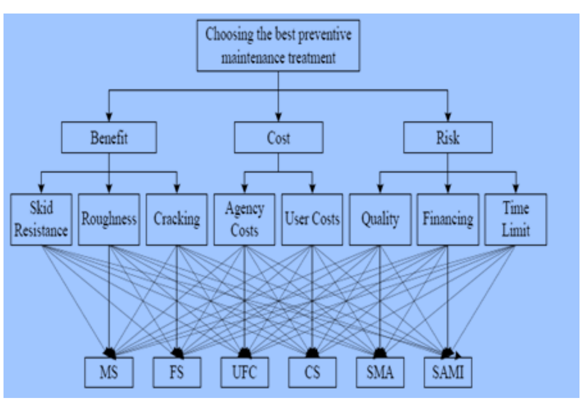
This paper discussed the current state of unsealed earth and gravel roads management, with a particular emphasis on the rural counties of the American west. As part of an effort to develop an unsealed roads management methodology, the Wyoming Technology Transfer Center has compiled considerable information about unsealed roads management practices both in the USA and abroad. The current state of roadway management by smaller agencies has been described by the help of the results of two recent surveys: one conducted at the National Association of County Engineers' (NACE) Spring Conference held in Fort Worth, Texas in April 2010 and the other conducted by the North Dakota Local Technical Assistance Program (ND-LTAP) in four states, Montana, Wyoming, North Dakota and South Dakota, during the 404 summer of 2009, with the assistance of each state's LTAP center. The authors observed that Maintenance scheduling was done without any consideration for user costs, based either on complaints or by simply maintaining each road in its turn, then repeating. Also, a frequently noted problem with unsealed roads management was over-maintenance. Reducing or eliminating this problem could result in substantial savings and improved network-wide service. The authors also suggest that if management systems, particularly cost and maintenance tracking methods, were improved, county road and bridge departments would be able to manage their unsealed roads more efficiently and present better arguments to decision makers when requesting funds and other support. As practiced by counties in the American west, there is plenty of room for improvement in achieving these goals in spite of the constraints imposed by severe limits on time and money.



Responses to *'What dirt and gravel roads reports do you generate?'* (TRB 11-2095 pg. 10)

Application of Analytic Hierarchy Process and Analytic Network Process in Preventive Pavement Maintenance Decision-making by Feng Zeng, Xiaonin Zhang and Jiangmiao Yu

In this paper, the authors presented a decision-making model for preventive maintenance by use of analytic hierarchy process and analytic network process. A practical example was selected to demonstrate the effectiveness of the two methods in the preventive decision-making, which is under general principles of comprehensive consideration of cost, benefit and risk possibility, followed by detailed considerations of pavement performance indexes, such as skid resistance capacity, roughness, cracking, owner costs, user costs, quality risk, financial risk and work period risk. Also, comparisons were made of the said indexes to identify optimal scheme for six preventive maintenance schemes, combined with sensitivity analysis. The results showed that the analytic hierarchy process was a practical tool suitable for preventive maintenance decision-making.

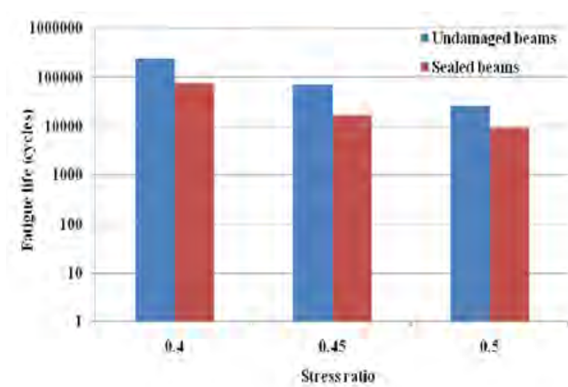


***micro-surfacing (MS), fiber-reinforced seal (FS), ultra-friction course (UFC), composite seal (CS), SMA-10 and SMA-10 plus SAMI**

A 4-layer decision-making framework of AHP (TRB 11-2398 pg. 8)

Assessment of Crack-Sealing Materials and Techniques for Epoxy Asphalt Pavement on Steel Bridges by Leilei Chen, Sang Luo and Zhendong Qian

This paper throws light on an assessment of a newly developed crack sealant for steel deck epoxy asphalt concrete pavement. The effects of different sealing techniques have also been evaluated. The workability, bulk performance, interfacial performance and cooperative performance of the developed sealant were assessed through viscosity test, tensile test, pull-out test, tensile bond behavior test and shear bond behavior test. The tests have shown that the developed sealant could satisfy the requirements and criteria of the steel deck pavement crack sealant well. Also, both of the bending fractures occurred at the epoxy asphalt mixture sections, and the bending strength of the sealed beams did not vary a lot from that of undamaged ones at 15 ℃ . The fatigue results of undamaged beams and sealed beams under different control modes showed that the fatigue lives of sealed beams are significantly smaller than that of undamaged beams. The fatigue equations of undamaged beams and sealed beams at 15℃ were regressed, and they have provided ways for the life prediction of the epoxy asphalt steel deck pavements before cracking and after sealing. The pull-off test, cooperative performance test and the fatigue test results have indicated that the fracture section weas at the interfacial between the sealant and the epoxy asphalt mixture. Authors thus conclude that efforts should still be made to improve the interfacial behavior of the sealant and the epoxy asphalt mixtures.



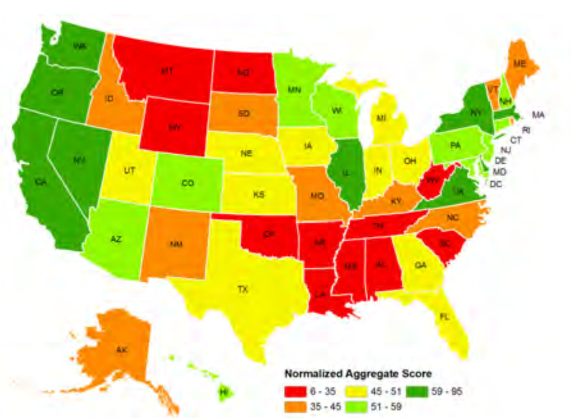
Fatigue test results of different beams (TRB 11-2419 pg. 11)

Quantifying the Economic Domain of Transportation Sustainability by Carol Atkinson-Palombo, Chris McCahill, Ryan O'Hara, Norman W. Garrick and Jason Zheng

To fully understand and integrate the ideas of sustainability with transportation, the authors of this paper see the need for proper metrics and performance measures. This paper demonstrates how the theoretical concepts of transportation sustainability can be transformed into a practical metric for assessing the performance of the United States' transportation system in terms of sustainability. The analysis is carried out for surface transportation at the state-wide level. The final results describe the relationship between urbanity, mode share, and the economic aspects of transportation sustainability. Using existing sustainability literature, a composite index framework was used to create a metric that can quantify and measure a broad spectrum of characteristics related to transportation sustainability. The authors have thus concluded that the best performing states in terms of the economic aspects of transportation sustainability are more urban and have lower automobile mode shares.

Domain	e	Element	i	Indicator
Environmental	1	Minimize consumption of renewable & non-renewable resources for transportation	1	Energy Consumption
			2	Infrastructure Materials Consumption
			3	Vehicle Materials Consumption
	2	Transportation and placemaking system is designed to maximize land use efficiency	4	Land Use
	3	Minimize transportation and place-making system's impact on ecological systems	5	Ecological Systems
			6	Greenhouse Gas Emissions
	4	Limit transportation related wastes & pollution	7	Pollution
			8	Waste Production
Social	5	Transportation meets access needs in a way that is consistent with human health & safety	9	Health
			10	Traffic Safety
	6	Planning and management of transportation incorporates different levels of government & community input	11	Government Interoperability
			12	Community Involvement
	7	Transportation and placemaking system promotes social interaction & social equity	13	Social Interaction
			14	Social Equity
	8	Transportation and placemaking system meets basic access needs of all individuals	15	Accessibility
Economic	9	Transportation is affordable for individuals	16	Affordability
	10	Transportation provides efficient movement of people & goods for economic activity	17	Mobility
	11	Transportation is financed in an equitable manner	18	Finance Equity
	12	Transportation is resilient to economic fluctuations	19	Resilience

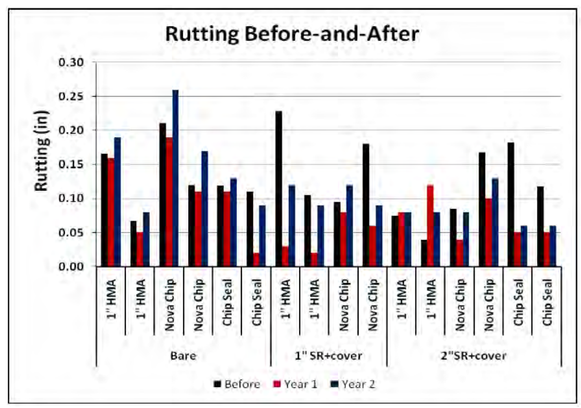
Composite Index for Transportation Sustainability (TRB 11-2875 pg. 5)



Normalized Aggregate Scores for the Economic Domain of Transportation Sustainability at State-Wide Level (TRB 11-2875 pg. 13)

Effectiveness of Thin Surface Treatment in Kansas by Md. Shaidur Rahman, Mustaque Hossain, Paul Nelson and Richard Miller

This paper discussed the effectiveness of several thin surface or preventive maintenance treatments on sixteen highway test sections in Kansas. The treatments studied included thin Hot-4 Mix Asphalt (HMA) overlay, ultra-thin bonded asphalt surface (Nova Chip), and chip seal. Effectiveness of the thin surface treatments for mitigating typical distresses was then evaluated by conducting before-and-after (BAA) comparisons using the Pavement Management Information System (PMIS) database maintained by the Kansas Department of Transportation (KDOT). It was observed that transverse and fatigue cracking significantly decreased and rutting conditions were improved after the thin surface treatments were applied. Roughness conditions improved on the 16 highway test sections treated with 1" HMA and Nova Chip, while the effects of chip seals on reducing roughness were not as obvious. Each of the cover treatments provided benefits for the first two years, which are cost effective. The authors suggest that the comparison would favor the least initial cost option because of the limited difference in performance between alternatives.



Effectiveness of thin surface treatments based on rutting (TRB 11-2953 pg. 9)

THE UNIVERSITY OF TEXAS AT AUSTIN ✦ COCKRELL SCHOOL OF ENGINEERING
TEXAS PAVEMENT PRESERVATION CENTER
TxDOT Newsletter
ISSUE 23 / SUMMER 2011

Summer 2011 – Issue 23

Inside This Issue:

Evaluation of the Curing Time and Other Characteristics of Prime Coats Applied to a Granular Base

Our Mission

The mission of the TPPC, in joint collaboration with the Center for Transportation Research (CTR) of the University of Texas at Austin and the Texas Transportation Institute (TTI) of Texas A&M University, is to promote the use of pavement preservation strategies to provide the highest level of service to the traveling public at the lowest cost. The executive sponsor for the TPPC is the Texas Department of Transportation (TxDOT).

Contact Us

Director: Dr. Yetkin Yildirim, P.E.
E-mail: yetkin@mail.utexas.edu
Website: www.utexas.edu/research/tppc

Past and Upcoming Events

TPPC Microsurfacing Courses

Microsurfacing training courses will be offered by the TPPC. The course is designed for engineers and inspectors and is entitled “Guidelines on the use of Microsurfacing.” The course recapitulates the pavement preservation concepts, specifically with reference to microsurfacing. It focuses on proper mix design selection and application of microsurfacing. TxDOT's experience with microsurfacing is also discussed. This course also includes discussion on the use and applications of cape seals.

TPPC Seal Coat Training Courses

Seal Coat training courses will continue to be offered by the TPPC. The course designed for inspectors, entitled “Seal Coat Inspection and Applications,” focused on proper inspection methods and the equipment used during chip seal construction. The other, “Seal Coat Planning and Design,” instructed engineers on planning, designing, and constructing chip seals.

For more information on the Seal Coat and Microsurfacing courses, please contact Dr. Yetkin Yildirim, P.E. at yetkin@mail.utexas.edu or (512) 232-3084.

Introduction

Background information

The overall performance and stability of pavements are of utmost importance to meet the needs of the growing population. To reduce the risk of premature failure and improve the stability of flexible pavements, prime coats are applied as a coating of low viscosity binder on top of a compacted granular base before application of subsequent courses (Freeman, Button and Estakhri, 2010). The application of prime coat material to the top of compacted granular bases is a standard operating procedure in the construction of asphalt pavements and is even considered mandatory at times.

Prime coat applied on the top of the prepared soil base is often left exposed to the weather for a few days so that the carrier evaporates, thereby curing the prime coat. Prime coat curing requirements vary significantly from state to state. In some cases, only a visual assessment is done to determine whether the prime coat has cured or not, but this practice is not satisfactory. Thus, it is extremely important to determine the minimum time required for curing and how the curing time would vary under different weather conditions for different prime coats.

Flexible pavements

An understanding of the importance and function of prime coats begins with an understanding of flexible pavements as a whole. A typical cross section of a flexible pavement with a prime coat which consists of five layers is presented below in Figure 1.

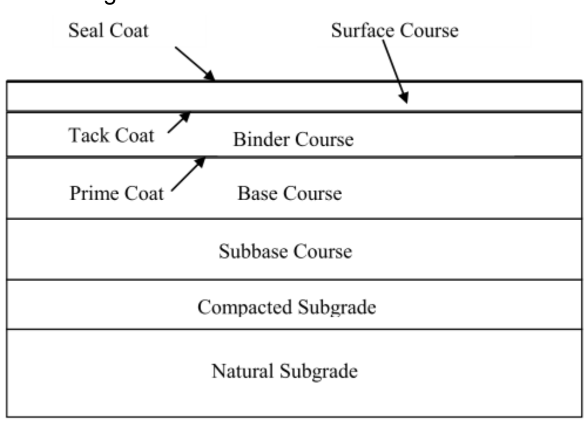


Figure 1 Cross section of a flexible pavement (Modified from Huang, 2004)

The surface course comes in direct contact with the traffic loads and mainly consists of multiple layers of hot mix asphalt (HMA). A seal coat is generally provided on top of the HMA layers to prevent infiltration of water or to provide skid resistance (Huang, 2004). The binder course also called the asphalt base course is mainly provided for two reasons: 1. HMA is too thick to be compacted to one layer so the binder course provides an additional layer. 2. Use of a binder course results in a more economical design.

A tack coat is provided between the surface course and the binder course to ensure a good bond between the layers. The base course consists of aggregates which cannot be damaged by moisture or frost. It should be stiff and thick enough to provide overall stiffness to the pavement structure as a whole. A prime coat is provided on top of the base course to protect the integrity of the granular base during construction and bind the granular base to the asphalt layer. The subbase course provides structural support, minimizes frost action damage and improves the drainage. The subgrade refers to the existing soil and it can be treated to improve its properties if it is not suitable for construction.

Prime Coats

After outlining all the layers of a flexible pavement, the function and importance of proper prime coat application can be better appreciated. ASTM defines prime coat as "an application of a low-viscosity bituminous material to an absorptive surface, designed to penetrate, bond, and stabilize the existing surface and to promote adhesion between it and the construction course that follows."

The main purpose of providing a prime coat is to prevent water from penetrating into the base, thus waterproofing the base. Along with this purpose, a prime coat performs various functions such as:

1. Binding the surface fines together so as to provide a good bond with the HMA layer
2. Increasing the bond strength between the compacted base and the HMA layer
3. Providing a stabilized base by penetrating and filling voids present in the base
4. Strengthening the base by binding together the finer particles of aggregate and permeating into the base
5. Temporarily protects the surface from unfavorable weather conditions and light traffic until the overlying courses are constructed
6. Preventing the lateral movement of the base during construction activities.

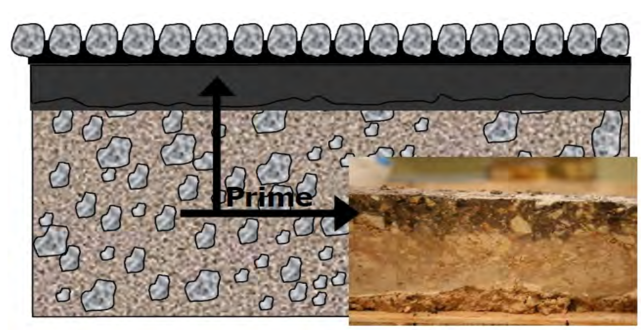


Figure 2 Schematic Showing Prime Coat Penetration into Base with Photographic Inset Showing Actual Penetration in a Laboratory - Compacted Limestone Base

Prime coat materials mainly consist of cutback asphalt, emulsions/emulsified asphalt or polymer based chemicals. Cutback asphalt is manufactured by blending asphalt cement with petroleum solvent, and emulsified asphalt consists of a suspension of asphalt cement in water.

For stabilized bases, the most widely used prime coat material worldwide is MC-30, a cutback, (Ishai and Livneh, 1984), due to its high penetration capacity. Cutback asphalts have been the most widely used prime coat materials for a long time, but when compared to other prime coats, cutbacks release a higher amount of volatile organic compounds (VOCs) into the atmosphere. For this reason, emulsions and polymer based materials are becoming more and more popular due to their less harmful effects on the environment. As per the information obtained from TxDOT, in Texas the most commonly used prime coat materials are MC-30, AEP, EC-30, CSS-1H and SS-1H. Out of this group, MC-30 is a cutback, AEP is an emulsified cutback, EC-30 is an environmentally friendly alternative to a prime coat and, CSS-1H and SS-1H are emulsions. Different prime coat types can be found from Figure 3 to Figure 5:

Figure 3- Spray Prime (MC-30, AE-P)

Figure 4- Worked-in (Cut-in) Prime

Figure 5- Covered (Inverted) Prime

The use of a prime coat can be omitted if the surface is not going to be exposed to wet weather and the base can be covered within seven days. Also, use of prime coats are not advised in the winter season when prime coats have difficulty curing, as placing the HMA layer on an uncured base is riskier than placing it on an unprimed base. The reason is that the excess prime on the surface can cause slippage of the pavement surface.

To ensure the functioning of a prime coat, it needs to be cured completely. Curing time is the time required for the evaporation of most of the carrier from the prime coat. Application of subsequent layers or allowing traffic to travel on the coated layer is only done after the prime coat is completely cured. The curing time of prime coats depends on a number of factors; namely, type of prime material, application method and rate, weather conditions, dilution rate, properties of the base material and other factors (Freeman, Button and Estakhri, 2010). Systematic investigation on prime coat properties is also crucial to make informed decisions.

A research study sponsored by TPPC was conducted at TxDOT to investigate the properties of prime coat most commonly used in Texas.

Considering the lack of data on the time required for curing of different prime coats and the extent to which each of these factors cited above affect the curing time, the primary objectives of this research are the following:

1. Determination of the curing times of prime coats most commonly used in Texas and how the application method and weather conditions affect the curing time, and

2. Compare the strength, permeability and penetration of the prime coats tested and also study the effect of application method on these properties.

Literature review

Upon reviewing the literature, it was found that extensive information has not yet been published in this field, despite the fact that prime coats have been in use for decades. Very little information has been published on prime coat application techniques, test methods to evaluate prime coats in the field and in the laboratory, relative performance of prime coats, selection of prime coats and also the appropriate curing times for prime coats under different conditions (Freeman, Button and Estakhri, 2010). In this part, a summary of all publications related to prime coats covering most of the aspects related to prime coat application are presented.

According to Mantilla and Button (1994), a prime coat should always be applied to a compacted granular base before the application of a bituminous surface treatment or an asphaltic pavement with a thickness less than 3 inches. A prime coat is also necessary in the case where there is a delay in the application of subsequent courses and the base may be damaged due to weather or traffic.

Design of prime coat materials

Senadheera and Vignarajah (2007) concluded that the design of any prime coat consists of three basic components:

- Selection of suitable priming method- Suitable priming methods can include mixing the prime coat into the top layers of the base or spraying of prime coat onto the base.
- Selection of prime coat material- Prime coat materials can be broadly divided into two categories, namely, cutback asphalt and emulsions or emulsified asphalt.
- Selection of an appropriate application rate- There are mainly four different ways in which prime coats can be applied to the prepared base. Senadheera and Vignarajah (2007) described these four methods as follows: 1. Spray Prime 2. Worked-in or Cut-in Prime 3. Inverted Prime or Covered Prime 4. Mixed-in Prime

Before the application of a prime coat, it should be established that the surface of the base is structurally strong, reasonably smooth and porous, and free from any dust.

Penetration of prime coats

One of the main purposes of the prime coat is to provide a good bond between surface treatment and base. The binders used in surface treatment courses do not have a viscosity low enough to penetrate the base layer. A prime coat, which is a low viscosity binder, when applied will act as an intermediary between the base and the surface coat so as to ensure a good bond between both. Thus, it is clear that adequate penetration is necessary for a prime coat to serve its purpose.

Figure 6 shows the penetration observed in emulsions and cutbacks. In this figure, the top left picture shows an emulsion (CSS-1H) which was applied on the surface and the top right picture shows that the emulsion did not penetrate at all into the sand after 24 hours and it peels off from the surface. Bottom left is the picture of MC-30 prime coat (cutback) application and bottom right shows the penetration obtained by MC-30 after 24 hours. It can be seen that the penetration obtained by cutbacks is more than that of emulsions.

Figure 6- Penetration observed in emulsions (top) and cutbacks (bottom)

Functional and structural role of prime coats

Prime coats do not provide any significant amount of structural benefit. The unbound layer of material is stabilized by the addition of a prime coat but it does not increase the load bearing capacity of a pavement significantly (Cross, Voth and Shrestha, 2005).

Environmental issues

Environmental issues can be broadly classified into air and water quality issues.

Air quality issues

Cutback asphalts are a major source of volatile organic compounds (VOCs) and VOCs are the primary pollutant of concern from asphalt paving operations. With the awareness of the detrimental effects of VOCs to the ozone layer increasing, there has been a reduction in the use of cutback asphalt as prime material.

Water quality issues

Hazardous chemicals may be present in prime coat materials in very small quantities (in concentrations less than the reportable quantity (RQ)). Generally, in a normal paving operation, these RQ values are never reached. The Resource Conservation and Recovery Act (RCRA) determines what the reportable quantities are, but it may be different (lower) in case of state/local jurisdictions and the suppliers or local agencies should be contacted in case of a spill (Cross, Voth and Shrestha, 2005).

Experimental Design and Testing Procedures

Material used:

Limestone base soil which is commonly found in Texas was used as the base material throughout the testing program. However, for this study, equal weights of rushed limestone passing through sieve #10 and retained on sieve #40, and passing through sieve #40 were mixed and used to prepare the specimens.

This study looks into cutbacks, emulsions, emulsified asphalt and polymer based prime coat materials. The most commonly used prime coat in Texas is MC-30. CSS-1H and SS-1H are the emulsions that have been included in this study. EC-30 is a completely organic prime coat material which is harmless to the environment. EC-30 will not clog spray machines, has little or no odor and can even be applied using a pressurized hand garden sprayer. Top Seal Black is an environmentally safe polymer based prime coat which is applied after dilution with water. Prime coats which were included in this study and the suppliers of these prime coats to TxDOT are listed below in Table 1.

Table 1 Prime coat materials used in this study

Prime Coat	Type	Suppliers
MC-30 (Medium Curing)	Cutback	Valero, TX
AEP (Asphalt Emulsion Prime)	Emulsified Cutback	Ergon, Waco, TX
EC-30 (Eco Cure)	Emulsion-Non bituminous	PrimeEco, TX
CSS-1H (Cationic Slow Setting Hard Base)	Emulsion	Ergon, Waco, TX
SS-1H (Slow-Setting Hard Base)	Emulsion	Ergon,Mt.Pleasant, TX
Top Seal Black	Polymer based Emulsion	Terra Pave International, TX

Specimen preparation procedure:

The method of specimen preparation can have a significant effect on the properties (curing time, strength and permeability) and thus is important while interpreting the results later on. Only two application methods, spray prime and mixed in prime, were included in this study. For this study an application rate of 0.20 gallons per square yard was used. Taking into consideration the size of the container and by making the necessary calculations, the amount of prime coat material required per specimen was determined to be 7.3 milliliters per square millimeter. The specimen preparation procedure is shown below in Figure 7.

1. Prepare Circular Can.

2. Put 300 g of base material into the can.

3. Compact the soil.

4. Spray or mixed-in prime coat.

5. Expose the specimen to weather to cure.

6. Run analysis.

Figure 7 Specimen preparation procedures

Testing procedure

Tests were performed to determine the curing time, strength, permeability and penetration of the specimens prepared using different prime coats.

Soil specimen were tested in three different weather conditions, namely Test Season 1, Test Season 2, Test Season 3, to reflect the weather condition in Texas, as shown in Table 2.

Table 2 Testing Seasons

Testing Season	Testing Period	Temperature (°F)		
		Maximum	Minimum	Average
1	October	87.6	47.5	69.6
2	November-December	81.4	30.2	58.1
3	February-March	88	20.5	55.4

Tests to Determine Curing Time

For each testing season, at least five different prime coats were tested. For each prime coat, samples were prepared using two application methods: spray and mixed-in.

Weather information was collected using weather station in TxDOT. Air temperature, solar radiation, humidity and wind speed are expected to have significant impact on curing time.

The curing time of all the prime coats was mainly affected by temperature and temperature had a negative correlation with curing time. MC-30 took the longest time to cure in all three different weather conditions and EC-30 cured the fastest in all three different weather conditions. Curing times of the various prime coats increased in the order EC-30<SS-1H<AEP<CSS-1H<MC-30. TSB has not been included in the comparison for curing times as

The average curing time for each specimen is shown below:

MC-30 sprayed specimens

Testing Season	Curing time (days)	Average Daily Temperature/ 12- Hour Daytime Temperature (°F)
1	8	69.6/75.6
2	11	58.1/66.9
3	12	55.4/61.6

MC-30 mixed-in specimens

Weather Condition	Curing time (days)	Average Daily Temperature (°F)
1	11	69.6/75.6
2	12	58.1/66.9
3	13	55.4/61.6

EC-30 sprayed specimens

Testing Season	Curing time (days)	Average Daily Temperature/12- Hour Daytime Temperature (°F)
1	1	65.9/71.6
2	7	57.8/66.7
3	8	57.2/63.3

EC-30 mixed-in specimens

Testing Season	Curing time (days)	Average Daily Temperature/12- Hour Daytime Temperature (°F)
1	3	65.9/71.6
2	8	57.8/66.7
3	9	57.2/63.3

CSS-1H sprayed specimens

Testing Season	Curing time (days)	Average Daily Temperature/12- Hour Daytime Temperature (°F)
1	7	70.4/77.4
2	9	57.8/65.0
3	10	57.2/63.9

CSS-1H mixed-in specimens

Testing Season	Curing time (days)	Average Daily Temperature/12- Hour Daytime Temperature (°F)
1	8	70.4/77.4
2	10	57.8/65.0
3	11	57.2/63.9

TSB sprayed specimens

Testing Season	Curing time (days)	Average Daily Temperature/12- Hour Daytime Temperature (°F)
1st Set	7	71.9/91.0
2nd Set	6	72.7/92.3

TSB mixed-in specimens

Testing Season	Curing time (days)	Average Daily Temperature/12- Hour Daytime Temperature (°F)
3	9	57.2/65.7

AEP sprayed specimens

Testing Season	Curing time (days)	Average Daily Temperature/12- Hour Daytime Temperature (°F)
1	7	71.7/78.0
2	7	57.7/67.3
3	9	57.2/65.7

AEP mixed-in specimens

Testing Season	Curing time (days)	Average Daily Temperature/12- Hour Daytime Temperature (°F)
1	7	71.7/78.0
2	8	57.7/67.3
3	9	57.2/65.7

Strength Test

Strength tests were done to understand how well prime coats would resist oncoming traffic loading and how they would behave under such loading conditions. This process can be explained in detail with the Figure 8. When a wheel moves on top of the aggregates, it applies a pressure to the aggregates which in turn applies a pressure on the prime coat. So it is important to compare the strengths of different prime coats to see how effective they will be in the field. The strength of the cured samples was determined using a pocket penetrometer.

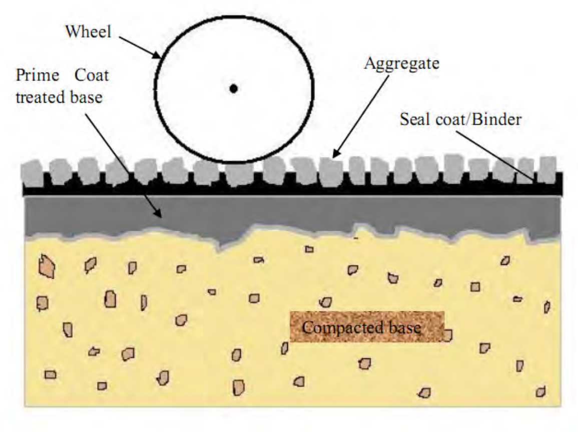


Figure 8 Pavement section showing penetration of prime coat

The values obtained from strength tests for both sprayed prime and mixed-in prime are presented together in Figure 9. The strength obtained was higher for mixed-in prime application than in sprayed application for emulsions CSS-1H (only slight increase in strength) and SS-1H (almost a 23% increase in strength). Thus, mixing emulsions into the top layer of the soil not only ensures sufficient penetration but also increases the strength. For EC-30, the strength of mixed-in specimens was slightly more than that of sprayed application. But in the field, EC-30 is always applied by spraying the prime coat on the surface because this method ensures maximum penetration. The strengths slightly decreased in case of MC-30, AEP and TSB when the application method used was mixed-in prime.

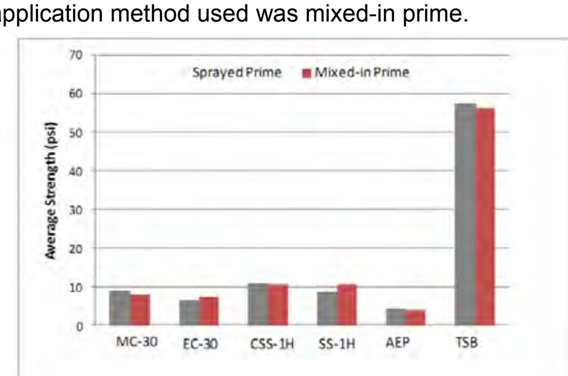


Figure 9 Comparison of strength for sprayed prime coats and mixed-in prime coats

Permeability Test

This study looks into how effectively each prime coat prevents the penetration of water into the base material.

This study looks into how effectively each prime coat prevents the penetration of water into the base material. The effectiveness of a prime coat in reducing the permeability will depend on the size and distribution of pores and how well the prime coat moves into these pores. The application rate, application method and depth of penetration will also influence the permeability.

The cured samples were taken and weighed. After weighing, 100 ml of water was poured onto the surface of each sample and was allowed to stand on the surface for 10 minutes. After 10 minutes, the amount of water still standing on the surface of the sample was decanted and weighed. This quantity when subtracted from 100 ml will give the amount of water that actually penetrated into the surface (V ml). From the amount of water absorbed, the coefficient of permeability was calculated in the following way:

Volume of water absorbed = V ml = V cm3

Time taken to absorb V cm3 of water = t seconds

= 600 seconds

Area of the surface on which water is in contact = A cm2

= 81.03 cm2

Assuming the hydraulic gradient to be constant,
Coefficient of permeability (cm/s), k, = V/At

These values were calculated for each sample and an average value was found for each prime coat. From these set of values, a comparison was made between the permeability characteristics of the prime coats tested. A comparison was also made to see how the application method affects the permeability rate.

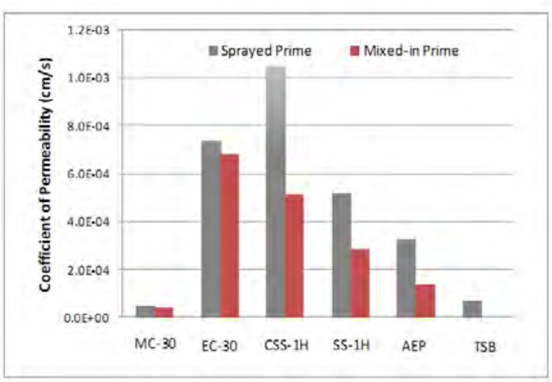


Figure 10 Comparison of permeability for sprayed prime and mixed-in application types

A comparison between the coefficients of permeability for the two different application types is presented in Figure 10. The coefficient of permeability is always lower for mixed-in prime coat when compared to the sprayed application. Since in the mixed-in prime application, the top layer is mixed with the prime coat, it covers the pores present on the base more effectively than in the sprayed application, thus reducing the permeability. But for TSB mixed-in specimens, a large number of cracks were seen along the sides of the container and therefore, the permeability for TSB mixed-in specimens could not be calculated. It can also be concluded from the above chart that emulsions such as CSS-1H, have a higher permeability when compared to cutbacks such as MC-30.

Penetration Test

Penetration achieved by a prime coat will determine how efficiently and effectively it can serve its purpose. Penetration achieved by prime coat must be adequate enough to ensure a good bond between the surface treatment and base. To study the penetration performance of the different prime coats that were tested, a sand penetration test was conducted. The testing procedure described below is commonly used by TxDOT to determine penetration depths of prime coats.

Initially, 62.5 grams of sand was taken and mixed with 1 gram of water. 3 oz. metal ointment tin containers were filled with this sand to a depth of 45 millimeters. Six such containers were made to test the six different prime coats used in this study. The sand in the container was then compressed to a compaction pressure of 100 psi using a load frame. 5 grams of the prime coat was measured and applied to the surface at a constant speed. The prime coat should be applied from a height of 40 to 50 inches from the top of the container. The specimen is allowed to stand for 24 hours. After 24 hours a vertical cross section of the sand and the visible penetration depth (in microns) is measured using vernier calipers. Figure 11 shows the process of cutting through the specimen to determine penetration depths of prime coats. A comparison was made between the penetrations achieved by the different prime coat materials.

Cutting through the surface of the specimen to determine penetration depth

Cross section of the cut specimen depicting the penetration

A comparison is shown in Figure 12. The penetration obtained was the maximum for EC-30 and minimum for CSS-1H and SS-1H. Emulsions have very little penetration when compared to cutbacks or polymer based prime coats. It just covers the surface without penetrating into the base. The penetration values decrease in the following order: EC-30>MC-30=TSB>AEP>CSS-1H=SS-1H.

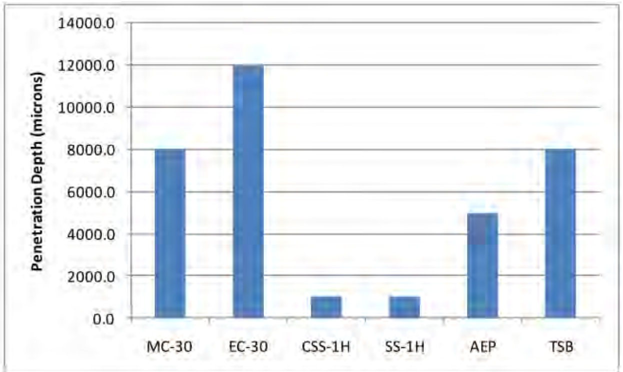


Figure 12 Comparison of penetration for various prime coat materials

Summary and Ranking

The time required for curing of different prime coats were determined under three different testing seasons. Based on the curing times, strength tests, permeability and penetration tests, a ranking in terms of performance in each of the intended functions is presented in Table 3. All prime coats are ranked from 1 to 5, with 1 being the best and 5 being the worst. The prime coat with the least curing time will be ranked 1, and the prime coat which takes the most number of days to cure will be given a ranking of 5. In the same way the prime coat with the maximum strength, least permeability and most penetration will be ranked 1 in their respective categories. Curing times, strength and permeability values are averages for both mixed-in and sprayed specimens. TSB was not included in the comparison for curing time as the testing for TSB was done when the weather conditions were different from the weather conditions existing for testing season 1, 2 or 3. Some of the materials have been given the same ranking because the values obtained for the respective properties have negligible difference.

Table 3 Ranking of prime coats in terms of performance in intended functions

Prime coat	Curing Time	Dry Strength	Wet Strength	Permeability	Penetration
MC-30	3	2*	2*	1*	2*
EC-30	1	4*	3*	4	1
CSS-1H	2*	2*	3*	5	4*
SS-1H	2*	2*	2*	3	4*
AEP	2*	4*	3*	2	3
TSB	-	1	1	1*	2*

- 1 being the best for the intended purpose and 5 being the worst
- * indicates a tied ranking

Recommendations and future studies

The range of temperatures for which this study was conducted is small. The average daily temperature range was from 55°F to 75 °F. It would be beneficial to extend the temperature range to higher and lower temperatures to determine the effect of these temperatures on curing times. If more data was collected for curing times under a wider range of weather conditions, mathematical expressions could be derived that show the dependence of curing time on different weather parameters. Correlation analysis could be performed to determine which of the weather parameters have the more significant effect on curing time. And, using these correlations, multivariable regression analysis could be carried out to determine mathematical expressions for each prime coat.

Only six different prime coats were tested to determine the curing times in this study. Curing time also depends on the type of base material used, but throughout this study only one type of base material was used. The same study could be extended to a larger number of prime coats and base materials, and the effect of weather factors on the curing time could be evaluated for each one of them separately. Since, curing time for all the specimens depends on temperature, it would be interesting to know the exact effect of temperature on curing time. If an experiment were conducted in a controlled environment, the exact effect of the various weather parameters could be analyzed.

The application rate used throughout this study was a constant. Therefore, the effect of change in application rate on the curing time could not be evaluated. By using different application rates, the application rate gives the minimum curing time with the maximum strength and penetration could be determined for each prime coat.

Investigation of SafeLane Delamination on Bridge Deck in Fort Worth District

Dr. Yetkin Yildirim, P.E.
Director
Texas Pavement Preservation Center
The University of Texas at Austin
3208 Red River CTR 318
Austin, TX 78705
(512) 232-3083 phone (512) 232-3070 fax
yetkin@mail.utexas.edu
http://www.utexas.edu/research/tppc

Cindy Estakhri, P.E.
CE/TTI Building, Room 508
TTI/Recyclable Materials
Texas A&M University System
3135 TAMU
College Station, TX, 77843-3135
(979) 845-0278
c-estakhri@tamu.edu

INTRODUCTION

The Spur 97 bridge in Ft. Worth was surveyed on August 2, 2010. The thin asphalt overlay was constructed about six years ago and a sealant and aggregate application by the name SafeLane was applied on it in summer of last year. It was seen that by January, distresses started occurring. This study was conducted to determine the causes for distresses on the road and the mechanism of their occurrence. The evaluation of the two bridges started off with a meeting with TxDOT officials and a SafeLane representative in which the construction details were discussed which was followed by a visit to the bridge. The location of the road is shown in Figure 1. The bridge is composed of two parts. The location of the two bridges on the road is clearly seen from Figure 2. Figure 3 and 4 shows portion of the bridge on which the SafeLane application was done. The portion on which SafeLane was applied appears to be darker than the rest of the road section and can be clearly identified.

Figure 1: Location of the road

Figure 2: Location of the two bridges on the road

Figure 3: The first bridge - the darker shade shows the portion where SafeLane overlay was applied

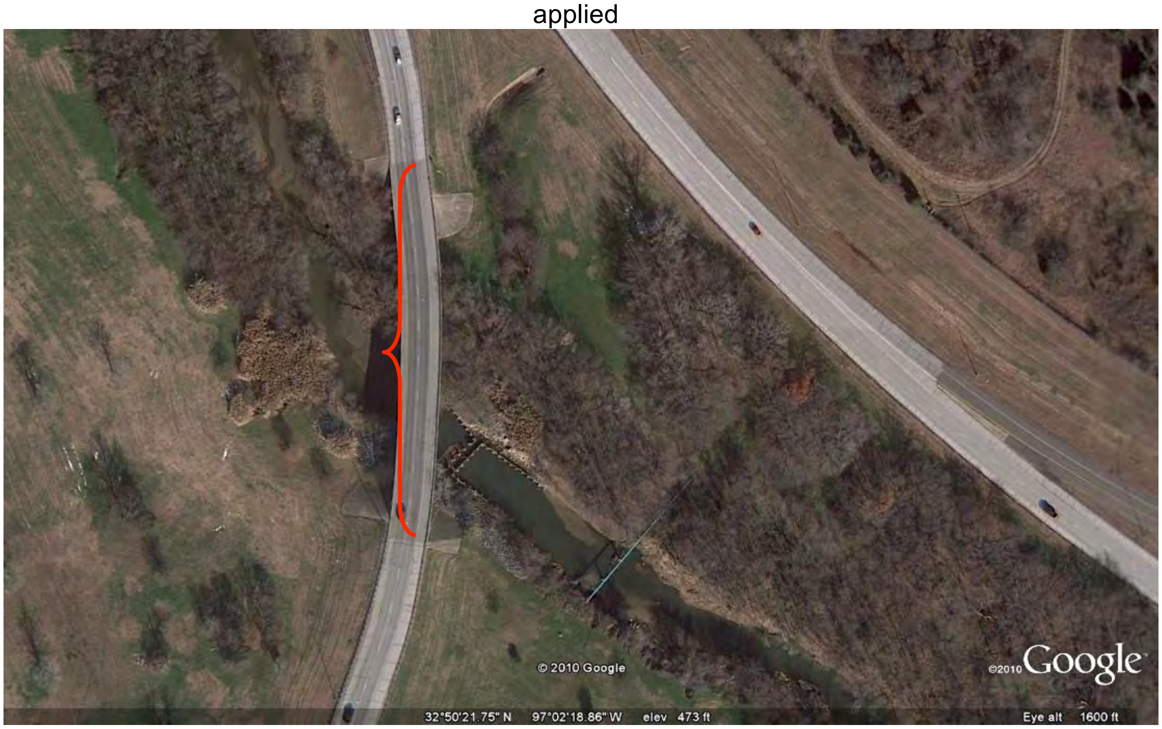


Figure 4: The second bridge - the darker shade shows the portion where SafeLane overlay was applied

Because of the large number of accidents that occurred in this region, a surface overlay product known as SafeLane was applied to reduce slippery conditions on the road surface. The application of this product led to a substantial decrease in the number of accidents. But, after a few months the first peel off from the surface was observed. The product had been successfully installed in five projects in Texas and this was the first incident of peel off in the history of SafeLane application. The peel off from the surface can be clearly seen in the pictures shown below.

Figure 5: Distresses observed on the road

Figure 6: Peeling off of the SafeLane overlay

INTRODUCTION TO SAFELANE

SafeLane is a patented polymer pavement overlay that helps reduce ice or frost formation on its surface while protecting infrastructure from corrosion and chloride intrusion.

A polymer epoxy is mixed with aggregate and applied to pavement surfaces. This aggregate has the unique ability to store deicing liquids and release them when weather conditions demand it. SafeLane overlay:

- Creates an anti-icing, anti-skid, anti-slip surface
- Seals treated surfaces to protect them from water and chloride intrusion
- Creates traction all year long
- Results in safer, more durable surfaces that are easier to maintain

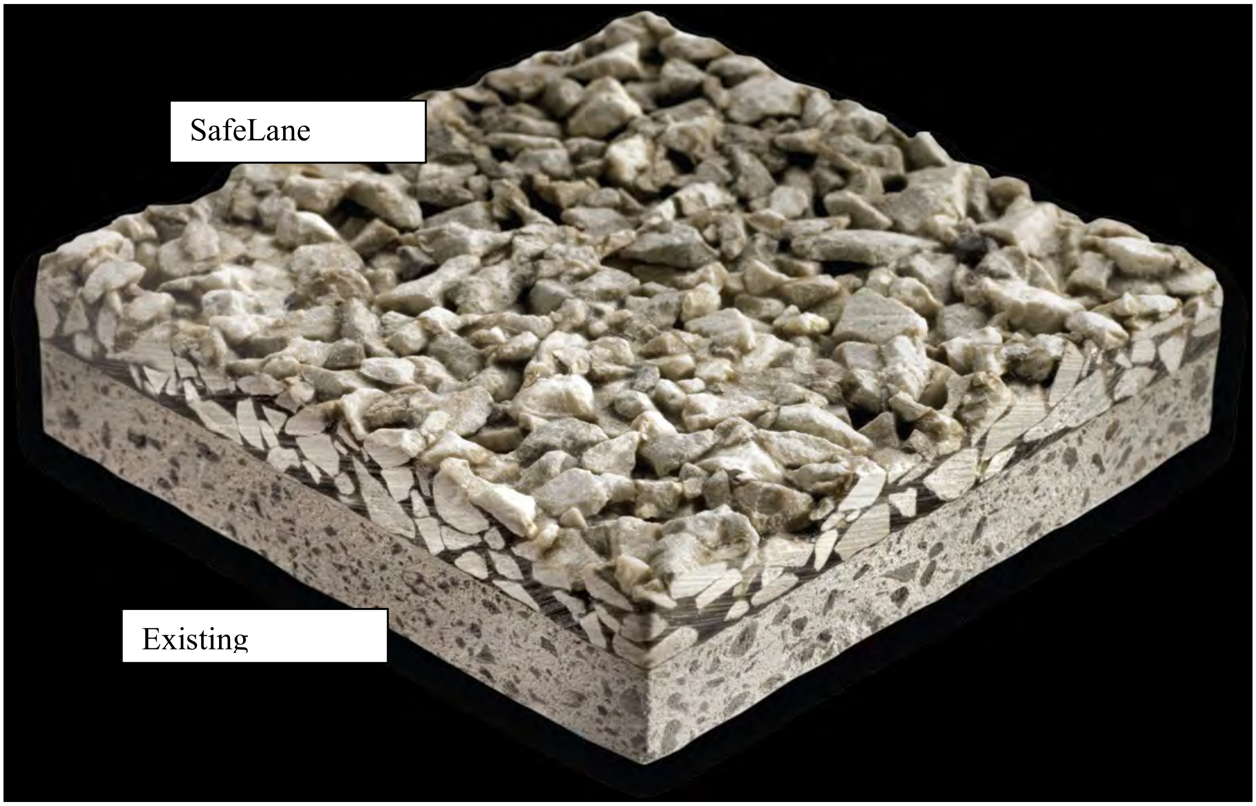


Figure 7: Safelane Surface

An analysis of SafeLane overlay's performance during the 2005-6 season found no weather-related accidents at any of the nine test sites that were studied. Before SafeLane overlay installation, these sites had produced a combined average of 35 weather-related accidents. SafeLane overlay seals treats surfaces, increases friction in any weather, helps reduce the formation of black ice and frost and prevents snow from bonding. The result is safer, more durable roads and bridges that are easier to maintain.

The two-component epoxy polymer acts as a barrier to prevent water and chloride intrusion. It also prevents moisture permeation that can lead to the degradation of road surfaces. It can be used over existing surfaces or to protect new road surfaces and the underlying infrastructure. It also decreases labor and costs related to pavement maintenance and repair.

The potential SafeLane overlay application includes bridges or overpasses, dangerous intersection or curves, entrance and exit ramps, approaches to toll barriers, parking decks, bike paths, sidewalks, airport runways, public transportation boarding areas, etc. Almost 90% of the projects involve application of SafeLane on concrete pavements with a few on asphalt pavements as well. All in all there were three projects on asphalt pavements in Texas.

OBSERVATIONS

Construction Details:

As mentioned before, the road was constructed almost six years ago. An asphalt layer was constructed above a concrete base layer, and above the asphalt layer, a thin layer of SafeLane application was done. Before the application of SafeLane, the road was milled for about half an inch along the wheel paths and between the wheel paths. The application of SafeLane was based on the specifications made by the company itself since TxDOT did not have any specifications for the same. A contractor chosen by TxDOT handled the application procedures which consisted of applying SafeLane in two passes over the milled section of the road. In the first application, one-third of the mixture was applied, which comes to 4 gallons per 100 square feet, and on the next pass the remaining two–third was applied. The aggregates were then thrown onto the applied mix. The second layer was applied only after the first layer was completely cured which took about one hour at 80 degrees F. After both the layers were in place the road had about 10 gallons per 100 square feet of epoxy and 4 pounds of aggregate.

Following the first winter after the installation procedure the following observations were made:

- The SafeLane layer was peeling off at places and could be separated from the asphalt surface. That is, the SafeLane layer was seen to be separating out from the asphalt layer.

Figure 8: Peeling off of SafeLane overlay

- While peeling off the whole SafeLane layer acted as a single unit and did not separate out.

Figure 9: Peeling off of SafeLane overlay as a single unit

- When a hammer was used to separate out the SafeLane layer and asphaltic layer, it was seen clearly that there was moisture between the two layers.

Figure 10: Moisture seen between the asphalt and SafeLane layers

- A number of pot holes were seen on the right lane and there was a considerable amount of fine dust around them.

Figure 11: Fine dust seen around the potholes

- It was observed that there were a large amount of distresses on the initial pavement section where there was no SafeLane application.

Figure 12: Distresses on the pavement section

- Between the milled section and the not milled section of the pavement, under the SafeLane, moisture was seen to be accumulating.

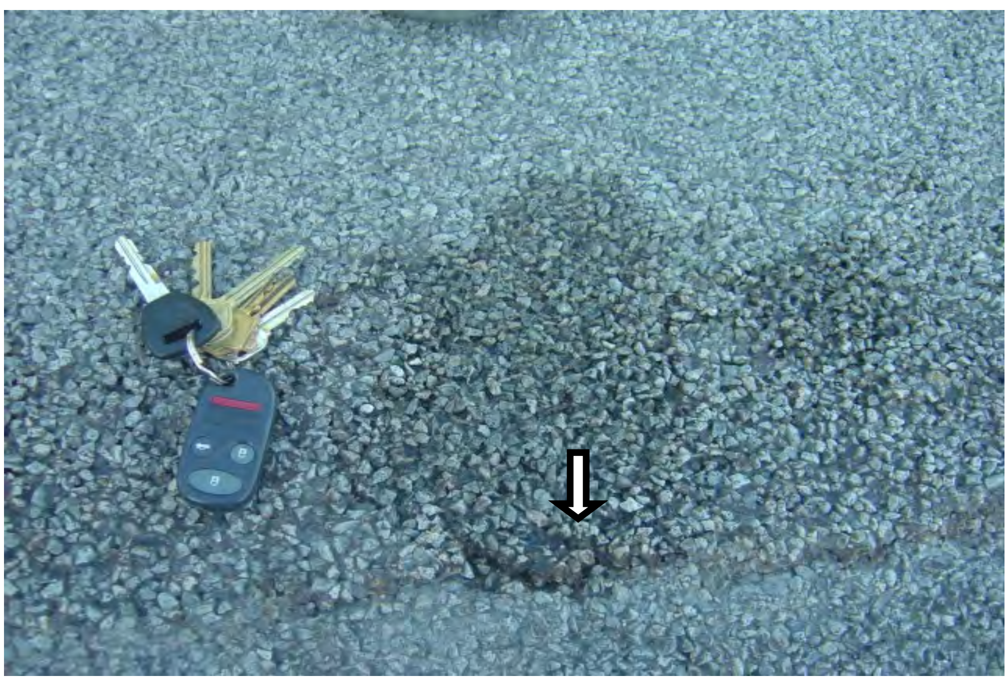


Figure 13: Moisture accumulation at the junction

Figure 14: Moisture accumulation at the junction of milled and not milled sections

- It was observed that between the two bridges there was maintenance work done on the lane in which a majority of the problems were seen. This work seems to have been done recently and as a part of the maintenance work the old overlay from this portion was removed and replaced with a new material.

Figure 15: Portion of road between the two bridges where maintenance work was done recently

CONCLUSIONS

From the survey conducted the following conclusions can be made:

- When the epoxy overlay is placed over the asphalt layer it seals the deck. Thus if moisture is trapped inside the asphalt layer underneath the SafeLane layer then it will seal the moisture and won't let it escape no matter how high the temperatures are. This could be one of the main reasons for stripping to occur, and the peeling off of the SafeLane layer could be an after effect of this stripping. That is, the SafeLane layer was seen to be separating out from the asphalt layer because of the moisture that was trapped between the two layers. Also it can be clearly seen that the SafeLane layer in itself is in good shape but the problem is with the asphalt layer as this is the one that is disintegrating.
- The fact that a portion of the road between the bridges had undergone maintenance work as a part of which the old material was removed and replaced by a new material clearly shows that there was some serious

problem existing with the old pavement section. This may be the reason for the peeling off of the SafeLane overlay.

- The asphalt material below the SafeLane application seems to be striping. The fine dust like materials observed near potholes is evidence of the stripping. All around the potholes, fine dust was present which could be due to striping of the old thin asphalt overlay due to the traffic. When we look at the particles we can see that this fine dust is assumed to be coming out of the asphalt layer. From the above two points we can conclude that the problem is with the old thin asphalt layer.
- A number of distresses were observed on the old pavement section where the SafeLane overlay was not provided which clearly shows that there were a number of problems with the existing pavement section. And we can conclude that if we put SafeLane overlay over an old pavement, it may lead to trapping of moisture between the two layers which will finally lead to separating out of both the layers.

RECOMMENDED FIELD VALIDATION TESTING PROGRAM

Several areas now show the delamination pattern shown in the previous photos a bove. A forensic study was initiated through the Texas Pavement Preservation C enter to

a) Identify the cause of the problem
b) Evaluate if the situation is stable or will failures continue to occur
c) Determine what TxDOT or the contractor should do now
d) Determine what actions to take to avoid this problem in the future.

Observations from Nondestructive Testing

An air coupled GPR survey was completed in Aug 2010 to attempt to identify the presence of moisture or other subsurface deflects that may be contributing to the problem. Three passes over the two deteriorated decks were completed. The d ata were collected at least two weeks after any significant rainfall, during extreme ly hot conditions. A typical GPR figure is shown in Figure 16. The key points are

- No clear excess moisture was present in the data, either under the epoxy surface or in the HMA layer
- There does appear to be possible problems at the bottom of the HMA where low density or stripped material may be present (blue areas)
- The strong reflection 4 to 6 inches below the surface is presumably from the top layer of steel in the bridge deck. These are very strong reflections, with in some areas the steel is very close to the top of the concrete
- No clear reflections from top of the concrete

Possible Causes of Delamination

Three possible causes are proposed at this moment. A field test program is proposed to evaluate each one:

a) Surface contamination caused by either the shot blasting dust not being completely cleaned, or the shot blasting causing a weak layer at the top of the HMA. In either case the epoxy would not bond well to the HMA
b) Moisture trapped in HMA. If it rained significantly prior to placing the epoxy then moisture may have been trapped in the low density areas in the HMA. Once this is sealed and the hot weather occurs then the surface will blister with moisture trapped beneath the epoxy trying to get out.
c) Initial distress in the form of longitudinal cracks over existing defects in the deck. It could be that the deck itself is badly cracked and this caused reflection cracks in the HMA. In fact with the steel being so close it may have cracked the concrete at the top of the deck. Once overlaid reflection cracks occur in the epoxy surface. Water enters the cracks during rain and enters the low density areas in the HMA. During hot times this water is trapped and eventually leads to pop-outs. The asphalt material below the SafeLane application also may be stripping. The fine dust like materials observed near potholes is evidence of the stripping. All around the potholes, fine dust was present which could be due to striping of the old thin asphalt overlay due to the traffic. When we look at the particles we can see that this fine dust is assumed to be coming out of the asphalt layer.

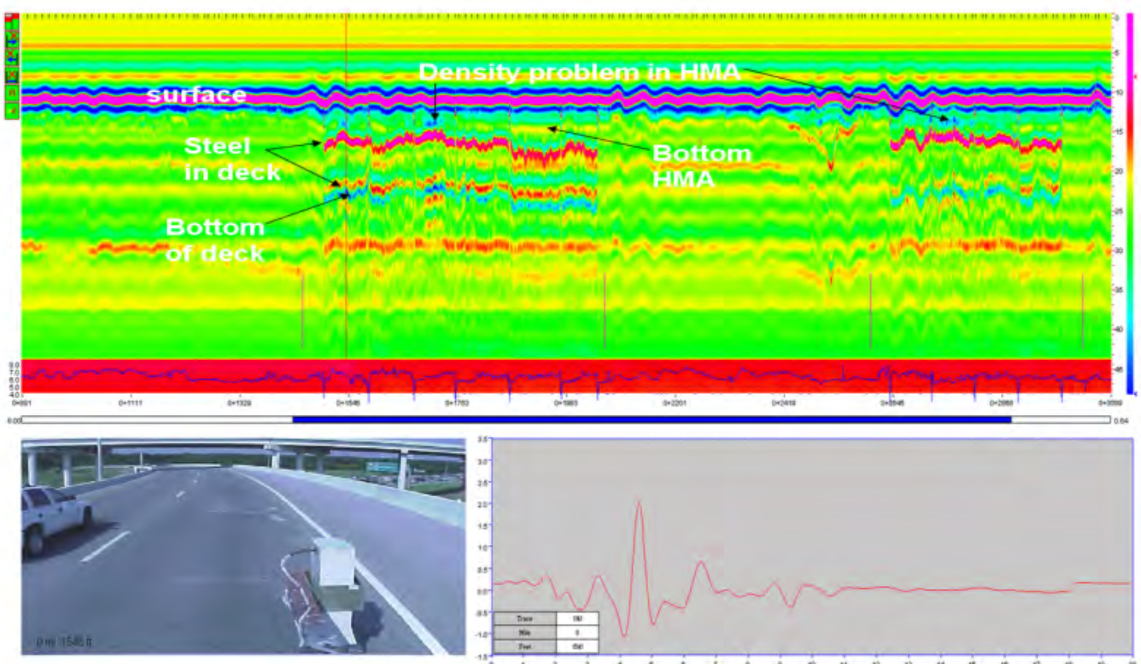


Figure 16: GPR Trace from Bridge Deck.

RECOMMENDED FIELD INVESTIGATION

These are aimed at determining which of the possible failure modes is most feasible. The equipment to be used will be

1) TTI core rig with 6 inch core barrel
2) TTI Hilti dry drill with 3 inch core to notch the surface so the pull off tests c an be conducted
3) Pull off test equipment (to evaluate bond of Safelane to underlying surface)
4) Spatula, geologists pick and zip lock bags

Testing should be conducted in outside lane on both decks.

The testing sequence at each location near failure or longitudinal cracks is as follows:

1) Core a shallow hole 0.5 inches deep (thru epoxy into HMA) a distance of 12 inches from a failure and another 24 inches from a failure
2) Glue on a pull off attachment
3) Take one 6 inch core thru crack if present, core down to concrete. Inspect surface of concrete; does crack initiate in PCC?
4) Take two 6 inch cores away from crack
5) Conduct pull off test
6) If failure is nearby then peel back the surface and collect any residue from layer interface

Three locations will be selected near failure: two locations near longitudinal crack and one location with no failure. See Figure 17 for possible locations.

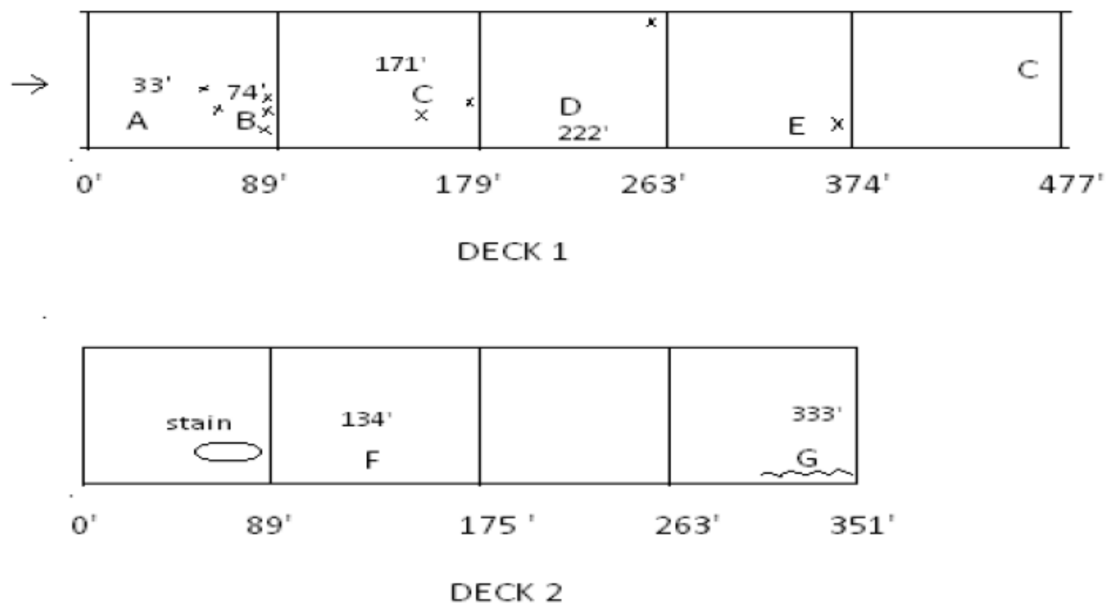


Figure 17: Proposed Field Sampling Plan

A, D, and F - Two 6-inch cores only. Check condition of HMA

- Check condition of Deck

B, C Locate Next to Failed Area (C is where deck is exposed)

a) Drill ½-inch deep with Hilti

b) Glue on Pull-off

c) Take 2 6-inch cores

d) Conduct pull-off test

e) Bag all samples

E, G Locate Longitudinal Crack

a) Hilti ½-inch dry, 12 inches from crack and 24 inches

b) Glue on pull-off

c) Take 2 6-inch cores, one over crack and one 12 inches away, Check condition of deck under crack.

d) Conduct Pull-off test

e) Peel back epoxy, dig out any material on surface and zip loc.

PAVEMENT PRESERVATION TREATMENT PERFORMANCE

Dr. Yetkin Yildirim, P.E.
Director
Texas Pavement Preservation Center
The University of Texas at Austin
3208 Red River CTR 318
Austin, TX 78705
(512) 232-3083 phone (512) 232-3070 fax
yetkin@mail.utexas.edu
http://www.utexas.edu/research/tppc

Joe W. Button, P.E.
Senior Research Fellow
Texas Transportation Institute
Texas Pavement Preservation Center
Texas A&M University
College Station, Texas 77843-3135
(979) 845-9965
J-Button@tamu.edu

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.

BACKGROUND

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)

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)

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)

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 evaluated. Enhancement of performance through pavement preservation should be 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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Removing Excess Asphalt

Initial test of ultra high pressure water a success

By Chris Sasser
Texas Transportation Institute

Summertime in Texas means rising temperatures, long days, and the emergence of maintenance forces ready to take on over 186,000 lane miles of roadways. The Texas Department of Transportation (TxDOT) spends close to $180 million maintaining the state's roadways, and seal coats are a very part of TxDOT's preventative maintenance program. But what happens when the maintenance needs maintenance?

A recent test study lead by Darlene Goehl, a pavement and materials engineer in the TxDOT Bryan District, sought to find a cost-effective option for correcting "bleeding" or "flushing," which is a common problem with seal coats and surface treatments in Texas.

"Bleeding or flushing occurs when excess asphalt binder is pushed to the pavement surface, covering the aggregate," explains Texas Transportation Institute Research Engineer Cindy Estakhri. "What you will see is a black and frequently sticky surface, which can lead to a loss of skid resistance."

The demonstration project was conducted on March 3 on a half-mile stretch of farm-to-market roadway in Grimes County, Texas. The process involved using a truck called "The Blaster Vac" that shot super high-pressure water at 34,000 psi into the flushed roadway to remove the excess asphalt, where it was then vacuumed up. Rampart Hydro Services from Pennsylvania provided the truck, which is commonly used to remove rubber from airport runways.

"This is the first time this technology has been used in Texas," said Goehl. "We picked a test section that exhibited heavy flushing across the roadway, not just in the wheel paths. It truly is a worst-case scenario type of road that is able to give us a true measure of how this technology works."

The removal width of the truck's sprayer and vacuum is two-feet, and after one pass the observers were able to notice a significant amount of asphalt removed from the roadway.

"One of my concerns was that the water would blast not only the asphalt, but also the aggregate down to the base," said Goehl. "This test showed that not to be the case, and that the aggregate was restored."

Texas Tech Assistant Professor of Civil Engineering William Lawson agreed with the assessment, noting an unexpected benefit. "If you look at the results closely, not only did it nearly restore the seal coat to its original condition, but the high-pressured water also increased the angularity of the aggregate, which will improve friction."

Lawson was the research supervisor on a project (TxDOT RMC 0-5230) that studied short-term solutions to "bleeding" asphalt pavements. The use of ultra high-pressure water cutting to remove excess asphalt was one of the published recommendations from this research project.

“Certainly this test is encouraging,” said Goehl. “This technology has the potential to save the state time and money by performing maintenance on a roadway instead of having to do a full rehabilitation project.”

For more information, please contact Darlene Goehl at (979) dgoehl@dot.state.tx.us or William Lawson at William.D.Lawson@ttu.edu.
A PDF of a project summary report of TxDOT research project 0-5230 can be accessed at ftp://ftp.dot.state.tx.us/pub/txdot-info/rti/psr/5230.pdf.
The Blaster Vac specifications can be found at http://www.rampart-hydro.com/rubber-removal-equipment.htm

EVALUATION OF REJUVASEAL AS A PAVEMENT PRESERVATION TREATMENT IN THE LAREDO DISTRICT OF TEXAS

By

Cindy Estakhri, P.E.
CE/TTI Building, Room 508
TTI/Recyclable Materials
Texas A&M University System
3135 TAMU
College Station, TX, 77843-3135
(979) 845-0278
c-estakhri@tamu.edu

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TEXAS TRANSPORTATION INSTITUTE
The Texas A&M University System
College Station, Texas 77843-3135

INTRODUCTION

Objective

The Texas Department of Transportation (TxDOT) has an extensive preventive maintenance program and an integral part of that program includes seal coats (or chip seals). In general, and when budgets allow, TxDOT's goal is to apply a seal coat, microsurfacing or thin overlay to a pavement surface every 7 years. Recently, however, budget shortfalls are causing this cycle to be extended beyond 7 years.

To make the best use of available maintenance funds, the Laredo District initiated an experimental program to evaluate a spray-applied rejuvenator seal called Rejuvaseal. The goal of the district is to evaluate this product and it's effectiveness at being able to extend the pavement service life thereby extending the seal coat cycle from 7 years to maybe 9 or 10 years. The district placed several test sections and TxDOT's Construction Division partnered with Texas Transportation Institute to evaluate the performance of the material.

The objectives of the study were as follows:

- Evaluate the effectiveness of Rejuvaseal at
    - Sealing pavement surface,
    - Rejuvenating aged asphalt,
- Evaluate effect of Rejuvaseal on friction, and
- Evaluate effect of Rejuvaseal on performance.

Background

Due to the action of traffic and the environment, asphalt pavement systems eventually begin to deteriorate. Without timely maintenance, this deterioration leads to pavement defects which cause structural and safety concerns such as surface raveling, dryness, brittleness, roughness, loss of friction, cracking, spalling, and skid resistance (Grobler et al. 2003). One attractive method to extend pavement service life would be to apply a cost- effective rejuvenating treatment to an existing road as a means of preservation.

The interest in pavement preservation has increased along with the need for less expensive treatment materials, preventive maintenance, and the ongoing improvements in both construction and post-construction technology. Some of the most common types of preservation treatments for asphalt concrete pavements are: (1) thin asphalt concrete overlays, (2) surface seals, (3) crack sealing, and (4) fog seals and/or rejuvenators. These treatments retard pavement deterioration, renew usefulness of the existing surface, seal cracks to prevent surface water infiltration and retard crack propagation. (Prapaitrakul et al. 2007).This report describes a field performance evaluation of one such rejuvenator called Rejuvaseal for treating asphalt pavements, sealing pavement surfaces, and rejuvenating aged-hardened asphalt.

Experimental Program

In December of 2008, a spray-on application of Rejuvaseal was applied to several different pavements in the Laredo District. The pavements selected include the following:

US 90. This roadway was a Type C HMA surface exhibiting oxidative aging and some cracking.

RM 2523. This roadway was a seal coat surface in good condition but ready for another seal coat (using 7-year cycle guidelines).

FM 481. This was a Type CC LRA (cold mix) that was exhibiting cracking.

IH 35 Shoulder. Type D HMA surface.

IH 35 W Frontage Road. Seal coat surface with sealed cracks.

Roadways were treated with the Rejuvaseal in December of 2008. Core samples were taken before and after application of the Rejuvaseal and tested to evaluate the effect of the product on the laboratory properties of the cores. In-situ pavement testing was performed to evaluate the effects of the Rejuvaseal on the pavement surface texture and frictional properties.

REJUVASEAL TREATMENT APPLICATION PROCESS

Asphalt Pavement Surface Treatment Using Rejuvaseal

As shown in Figure 1, typical surface sealing operations of this type generally consist of a sprayed application of a bituminous-based material to the surface of an existing asphalt concrete pavement. Surface seals are used on asphalt pavements within the first few years of their existence as a means of extending their service life. They are also used to prevent oxidation and binder hardening of the asphalt binder and to seal minor cracks. These seals are also claimed to slow the progression of raveling and aggregate loss. The pavement should be broomed before the sealing material is applied.

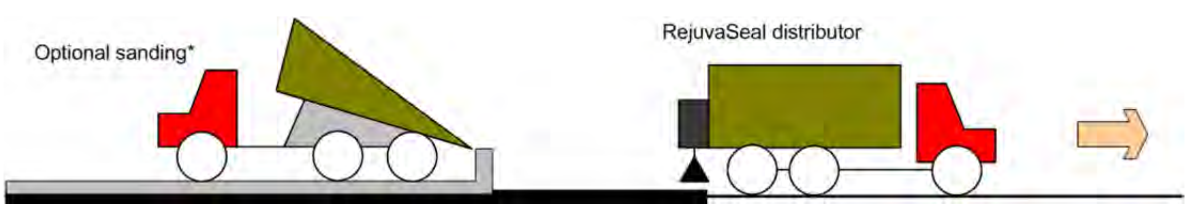


Figure 1. Typical Construction Sequence for Restorative Surface Sealing

(*Light Sanding is Sometimes Used).

Rejuvaseal is proclaimed to seal, protect, and revitalize an aged asphalt pavement surfaces (Fwa 2006). While a conventional seal coat simply lies on top of the pavement surface, the Rejuvaseal treatment is supposed to penetrate into the top surface of the road and thereby reduce the viscosity and brittleness in the top 3/8 inch of asphalt binder (Figure 2). It also supposed to increase ductility and flexibility. Asphalt surfaces treated with Rejuvaseal may become fuel, water, and chemical resistant. However, a strong coal-tar odor is emitted which may not allow its application in residential areas.

Characterization of Rejuvaseal

Rejuvaseal material is a liquid similar in consistency and fluidity to water. Comparisons of specific weights with other fluids are 9.0 lbs/gallon for Rejuvaseal, 8.4 lbs/gallon for water, and 7.0 lbs/gallon for diesel fuel. As such, it handles and sprays like water. Rejuvaseal is a three component material composed of ASTM D490 RT 12 Coal Tar (35%-50%), Petroleum Distillate (32%-42%) and rejuvenator (15%-40%).

When applied, the coal-tar portion of the product remains on the surface of the asphalt pavement where it cures into a hard, flat black solid. This keeps the asphalt surface resistant to attack by water, gasoline, diesel fuel, and hydraulic oil. The latter may soften the surface if left there for more than 24 hours but when removed, the asphalt should return to a more hardened state. The rejuvenating oil portion of the product is allowed to penetrate from 1/8 inch to 1/2 inch into the asphalt binder surface which should result in a reduction of viscosity and increase in ductility. Finally, the petroleum solvent, which is used to thin the tar and make it sprayable should evaporate within 24 hours.

Rejuvaseal Treatment of Field Sections

As stated earlier, the Rejuvaseal treatment consists of a sprayed application of bituminous-based material to the surface of existing asphalt concrete pavements for the purpose of replenishing the lighter oils and softening a weathered-hardened surface. A series of six field tests at various locations in the Laredo District were treated with Rejuvaseal in December of 2008. Details of the roadway test sections are shown in Table 1.

The best time to apply Rejuvaseal is before a pavement surface shows the onset of severe or adverse distress. A typical candidate is an asphalt pavement in the 2 to 7-year age range with no base failure, good profile, but showing the early signs of surface deterioration. Because the US 90 site met such an aged condition, it was selected as one of the field test sites.

The surface sealing procedure for using Rejuvaseal included:

- Sweep streets before the Rejuvaseal is applied as shown in (Figure 2)
- Apply Rejuvaseal with an asphalt distributor as shown in (Figure 3)
- Hand spray corners and hard to reach areas
- Allow the Rejuvaseal treated site to cure.

Table 1. Test Section Description.

Proj. Ref.	Hwy	Limits	Rdbd.	Rdbd. Desc.	Last Asph. Treat. Date	Reference Marker Limits		County	Pavement Issue	Center Line Length , ft lb/sy	Sand Appl Rate gal/sy	Rejuva seal Applic ation Rate	Date Appl in 2008	Notes
						From	To							
1A	US 90	From: Stricklen St. To: 0.5 Mil North	L1 (NB)	TY C HMA	2004	416+1.6	416+1.1	Val Verde	Oxidation & Skid	0.22	0.064	2640	12/2, 12/3	Both 1A & 1B took ~ 6 hrs to cure
1B	US 90	From: 0.5 Mi. N. of Stricklen To: 1.0 Mi. N. of Stricklen	L1 (NB)	TY C HMA	2004	416+1.1	416+0.6	Val Verde	Oxidation & Skid	0.22	0.064	2640	12/2, 12/3	Did not sand last 500 ft x 24 ft on North End
2	RM 2523	From: Val Verde/Kinney Co. Line North To: 0.25 Miles	K6 & K1	Seal Coat	2001	502+0.00	501+1.75	Kinney	SC Cycle Renewal Date - Good Condition	0	0.067	1320	12/2	No sand added, Open to traffic in 1 hr
3	FM 481	From: Maverick/Uvalde Co. Line To: 0.25 Miles South	K1&K6	TY CC LRA	2007	536+1.75	538+0.0	Maverick	Cold Mix Cracking	0.45	0.069	1320	12/5	NB lane with sand, SB lane without sand. Traffic on it in an hour and a half.
4	FM 481	From: 8 Miles S. of Mav./Uvalde Co. Line To: 0.25 Miles North	K1&K6	TY CS LRA	2007	538+0.0	538+0.25	Maverick	Cold Mix Cracking	0.28	0.082	1320	12/3	NB lane with sand, SB lane without sand. Traffic on it in an hour and a half.
5	IH 35 Shldr	From: 0.25 Miles N. of La Salle/Frio Co. Line To: Frio Co. Line	R' rdbed	TY D HMA	1999	82+0.234	82+0.484	La Salle	Appear. no work on ML Cont. for shldr.	0.27	0.065	1320	12/4	Wide right shoulder sanded.
6	IH 35 W FR	From: 2.03 Miles S. of FM 133 Intersection To: 0.25 Miles North	K6 & K1	*Seal Coat	1991	54+0.00	54+0.25	La Salle	Crack Sealed - Long. - & SC surf.	0.25	0.070	1320	12/4	Both lanes done at one time. Opened to traffic in 4 hrs. Sand only on SB.

Notes:

1A Commence work at Stricklen Intersection and go North toward 'Y' Intersection.
6 High percentage of longitudinal cracking.
2 Bridge Length Exception (Bridges are seal coated).
6 Last record found for SC = no projects in DCIS.

As shown in Figure 2, the surface was first swept free of debris prior to application of Rejuvaseal.

Figure 2. Broomed Test Site.

Application rates vary based on several factors such as inspection and test patch results, oxidation rates, and surface porosity. Porosity plays a major role in determining application rates. In this case, Rejuvaseal was applied (Figure 3) using a specialized coal-tar sealer distributor machine at the rate shown in Table 1. Larger areas can be applied using a distributor truck; while smaller area may require the use of a smaller, more compact machine.

A Specialized Coal-tar Sealer Distributor (b) Rejuvaseal Treatment

Figure 3. Rejuvaseal Distributor and 1st Layer Treatment.

Figure 4 shows the state of curing for the Rejuvaseal treated section 1 hour after application. The surface of the test section was still wet and some traces of car wheels were observed as well as the ability of dislodging unbound surface particles. This indicates that the treated surface should be kept free of traffic until the product has completely cured. Normally, the Rejuvaseal cures in approximately 12 hours. It is, however, recommended to allow from 12 to 24 hours for proper drying. The drying/curing time is related to the degree of porosity and oxidation levels of the asphalt surface.

(a) Trace of Car Wheels

Figure 4. Curing Status of the Rejuvaseal Treated Section after 1 Hour.

(b) Surface Particles from Uncured Rejuvaseal

Figure 5 shows the appearance of the Rejuvaseal-treated section compared with that of the untreated section.

Figure 6. The Appearance of a Treated and Untreated Section of US 90.

Figure 7 shows a close-up view of a cracked area before and after Rejuvaseal treatment. Even though Rejuvaseal penetrates into the matrix of the asphalt to potentially restore asphalt viscosity and binder flexibility, the coal tar in the Rejuvaseal does appear to have the ability to provide some sealing for minor cracks. .

(a) Cracked Untreated Section (b) Rejuvaseal Treated Section

Figure 7. Close-up View of Cracked Area before and after Rejuvaseal Treatment.

EVALUATION OF FIELD CORES FROM REJUVASEAL-TREATED SECTIONS

Test Program

Roadway cores were taken from the test sections before and after treatment to evaluate the benefits of the rejuvenator. TxDOT's Pavement & Materials Systems group collected roadway cores and some were sent to the Flexible Pavements Branch and some to TTI to perform laboratory testing. Table 2 shows the tests that were performed on the field cores.

Table 2. Laboratory Tests Performed on Field Cores.

<table>
<tr><th>Laboratory Tests Before and After Treatment</th><th>Property to be Evaluated</th><th>Performing Laboratory</th></tr>
<tr><td>Density</td><td>Informational</td><td>TxDOT</td></tr>
<tr><td>Absorption</td><td>To evaluate the sealing capability of Rejuvaseal</td><td>TxDOT</td></tr>
<tr><td>Overlay Test</td><td>To evaluate potential improvements in cracking resistance due to Rejuvaseal.</td><td>TxDOT</td></tr>
<tr><td>Permeability</td><td>To evaluate the sealing capability of Rejuvaseal</td><td>TTI</td></tr>
<tr><td colspan="3">Tests on Extracted and Recovered Binder</td></tr>
<tr><td>Dynamic Shear Rheometer (DSR)</td><td rowspan="4">To evaluate the penetration depth of the Rejuvaseal and effect on binder properties.</td><td>TxDOT</td></tr>
<tr><td>Penetration</td><td>TxDOT</td></tr>
<tr><td>Absolute Viscosity</td><td>TxDOT</td></tr>
<tr><td>Softening Point</td><td>TxDOT</td></tr>
</table>

To evaluate the penetration depth and effect of the Rejuvaseal on the binder properties, the DSR, penetration, absolute viscosity, and softening point of the recovered binder were measured. Treated cores were sawed in to 3/8” slices through the top 1 ½ inch of the cores (see

Figure **8**). The recovered binder from each slice was individually analyzed. The slices were used to detect the presence of treatment materials and their effects on the original binder.

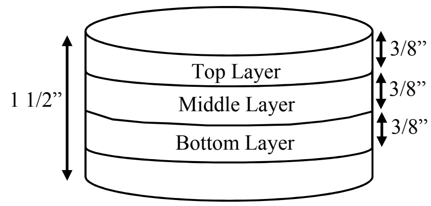


Figure 8. Schematic Showing Cores as Sliced for Evaluating Extracted and Recovered Binder Properties.

Core Density & Absorption

The densities of the cores were calculated before and after the treatment except for the cores with seal coat. The density of the untreated cores taken from sections with HMA ranged from 91.1 to 95.9%. After the treatment, the density ranged from 92.0 to 95.7%. The density of the untreated cores taken from the section with LRA surface layers ranged from 77.4 to 80.2%. After the treatment, the density ranged from 77.9 to 80.1%. No significant change in core density was identified after the treatment. There was no indication that absorption was reduced after the treatment.

Overlay Tester

The cracking susceptibility of the sections was evaluated with the overlay tester according to Tex-248-F. The number cycles to failure for the majority of the treated and untreated cores were less than 40 cycles. TxDOT currently does not have a specification for dense-graded or LRA mixtures for the overlay test; however, a mixture with a number of cycles to failure greater than 300 may be considered less prone to cracking. The only section with a number of cycles greater than 300 cycles had a surface seal coat. This section was recognized as being in “good condition” before the treatment according to TxDOT personnel.
Therefore, according to the overlay test results, the locations with dense-graded and LRA mixtures may be still prone to cracking even after the treatment. The section with the seal coat in “good condition” was not prone to cracking even before the treatment according to the overlay test.

DSR & Aging Ratio

The recovered binder from the untreated cores had high DSR results for typical recovered asphalt (> 6.100 kPa). The only untreated cores with adequate DSR values were the cores with LRA. However, the DSR results of the LRA treated cores were higher than the LRA untreated cores. This means that the treatment did not reduce the stiffness of the binder.

In other sections, the improvement in DSR values was only detected on the top layer. If the rejuvenator was absorbed, it was only absorbed by the top 3/8" of the pavement. The treatment was not scraped off the surface of the core before testing to determine if the properties of the mix improved. So, it is also possible that the rejuvenator was not absorbed and stayed on the surface.

Penetration

The producer requires a 15% increase in the binder penetration results after the treatment. The majority of the treated cores satisfied this requirement on the top two layers. However, these treated cores had low penetration results (< 20) and these treated sections may still be susceptible to cracking.

The LRA section was the only section that had acceptable penetration results before the treatment. However, the penetration results after the treatment was similar to the results before the treatment.

Absolute Viscosity & Softening Point

The supplier of the product requires a 20% decrease in binder viscosity after the treatment. The extracted binder of all the core layers of a Type C HMA section satisfied the requirement. The requirement was also meet by the core top layer of the Seal Coats and LRA sections.

Only the section with Type D HMA showed a significant decrease in its softening point after the treatment.

Permeability test using the falling head permeameter

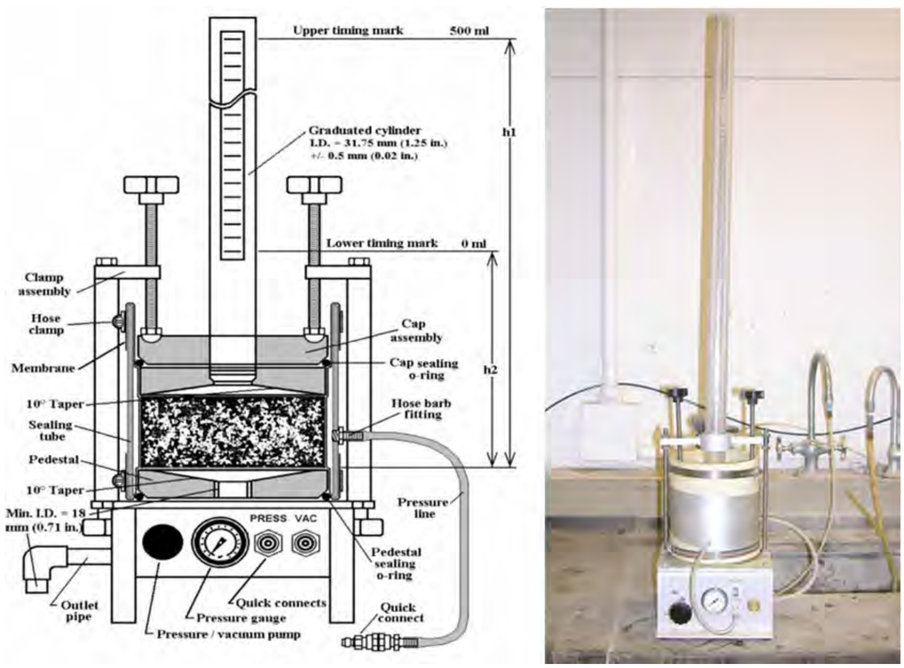
The permeability test on core samples collected from Rejuvaseal-treated field test sections was conducted in the laboratory using ASTM PS 129-01 "Standard Provisional Test Method for Measurement of Permeability of Bituminous Paving Mixtures Using a Flexible Wall Permeameter". Figure 9 shows the schematic diagram of a falling head permeability test apparatus used to determine the rate of flow of water through a cored specimen. Water in a graduated cylinder is allowed to flow through a saturated asphalt sample, and the interval of time required to reach a known change in head is recorded. The coefficient of permeability of the field core sample is then determined based on Darcy's law. In this test procedure, it is assumed that the water flow is one-dimensional and laminar.

Permeability evaluation

The effectiveness of Rejuvaseal on permeability is reflected in Figure 10 which shows the permeability test results before and after Rejuvaseal treatment for FM

481, IH35, and US 277. As expected, Rejuvaseal-treated pavements reflected lower permeability values than those of untreated pavements. No flow was observed on seal coated cores.

Figure 10 also illustrates the relationship between permeability and mean texture depth (surface texture). There is no clear trend noticed between the permeability values and mean texture depth. It should be noted that the permeability is related to the degree of "connectivity" of the pores inside the asphalt matrix, and not to the roughness of the surface texture.



(a) Schematic Diagram (b) Actual Apparatus

Figure 9. A Falling Head Permeability Test (After Chowdjury et al. 2003).

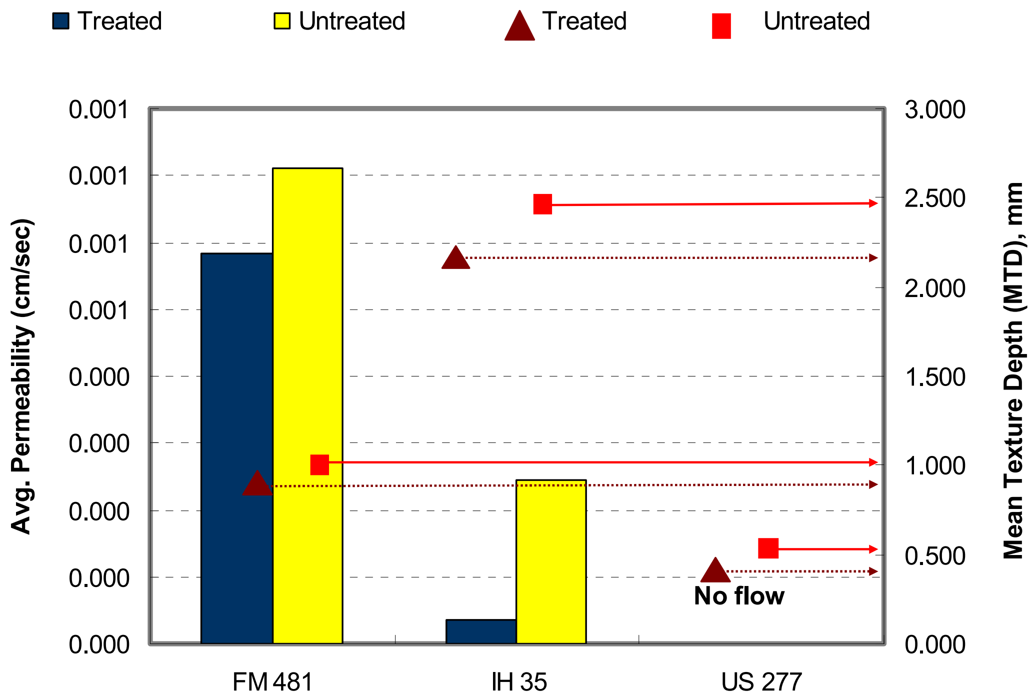


Figure 10. Field Core Permeability versus Rejuvaseal Treatment.

Summary

Laboratory test results indicate that the Rejuvaseal has a "softening" effect on the age-hardened binder in the top 3/8-inch core slices that were tested. The differences between the untreated and treated cores for some of the results are more likely related to variability in test procedures, cores, and material properties than to the treatment.

No improvement was seen in the cracking resistance of the pavement cores based on the Overlay Test data; however, this is not surprising since the penetration depth of the product is only in the top 3/8-inch of the pavement surface.

Laboratory permeability data indicate that the Rejuvaseal provides some sealing capability as a reduction in permeability was observed for FM 481 and the IH 35 shoulder.

FIELD PERFORMANCE EVALUATIONS

Testing Program

Field evaluations for the Rejuvaseal treated and untreated sections included the following:

- Surface texture of the treated and untreated sections as measured with the Circular Texture Meter (CTM).

- Permeability as measured with the field water flow test.
- Skid resistance before treatment and 1 week, 4 months, and 7 months after treatment as measured with TxDOT's skid trailer.

Surface Texture Measurements

The surface texture of Rejuvaseal-treated field test sections was measured using the circular texture meter (CTM) technique ASTM E 2157-09 "Standard Test Method for Measuring Pavement Macrotexture Properties Using the Circular Track Meter". As shown in Figure 11, the CTM technique involves taking measurements at discrete locations along the pavement (Prowell and Hanson 2005). It uses a charged couple device (CCD) laser mounted on a rotating arm to measure the profile of a circle 284 mm (11.2 in) in diameter or 892 mm (35 in) in circumference. The profile is divided into eight segments of 111.5 mm (4.4 in). Once in place, the unit triggers a computer that rotates the arm and measures texture height for one complete revolution. The average mean texture depth (MTD) is determined for each of the segments of the circle. For each sections, eight different measurements were taken and the reported MTD is the average of all eight segment depths.

Figure 11. Surface Texture Testing Using Circular Texture Meter.

Surface texture of each of the Rejuvaseal-treated and untreated field test sections was conducted at two different locations ("between the wheel paths" and in the "wheel path") using a circular texture meter. The average mean texture depth (MTD) was obtained eight times at each location and each individual MTD value was an average of 8 readings during the test.

Figure 12 and Figure 13 show the change of MTD for each test section at both "between wheel path" and "in wheel path". All Rejuvaseal-treated pavement section showed lower MTD values than those of untreated pavements at all test sections except for the IH 35 shoulder site.

In Figure 12 and Figure 13, values obtained at the RM 2523 test site had the highest percent improvement in MTD after the Rejuvaseal treatment followed by a slightly less improvement on IH 35 feeder road. A significant decrease in texture depth was observed for RM 2523 which was a seal coat surface. The Rejuvaseal seems to have filled the voids and thus helped seal the pavement surface. It also increased the embedment depth of the seal coat aggregate, which could minimize aggregate loss.

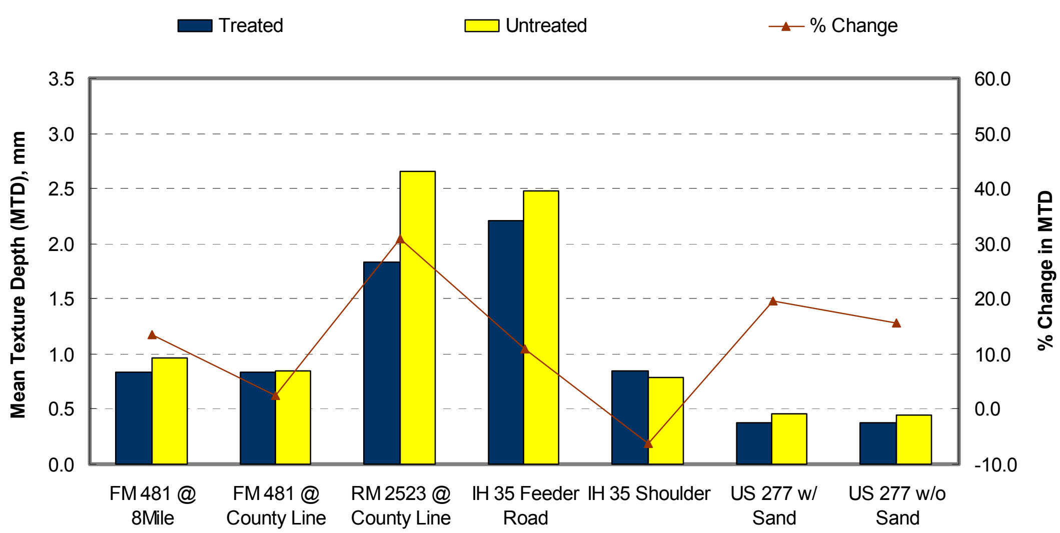


Figure 12. Surface Texture Comparisons between Rejuvaseal-treated and Untreated Field Test Sections (Between Wheel Paths).

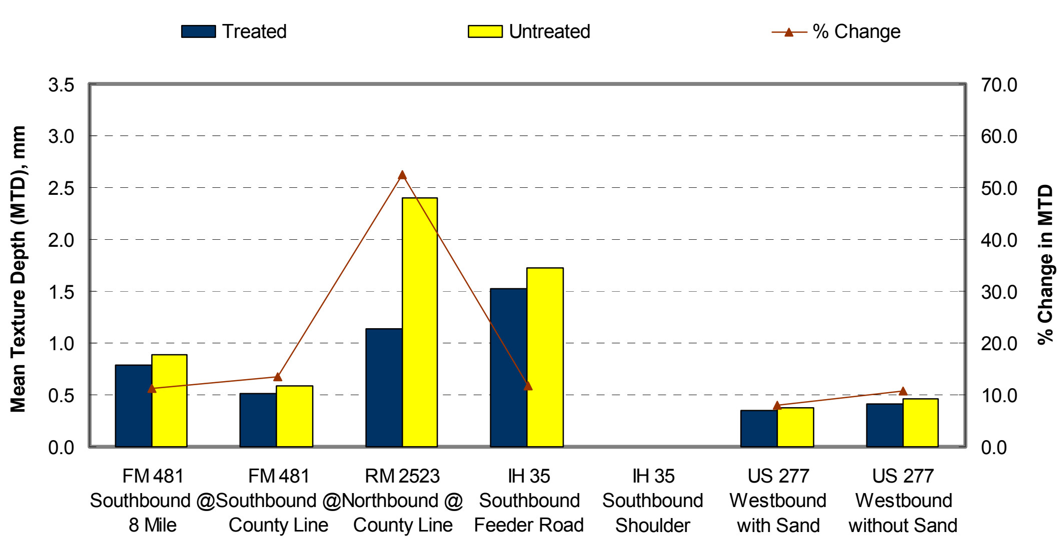


Figure 13. Surface Texture Comparisons between Rejuvaseal-treated and Untreated Field Test Sections (In the Wheel Paths).

Figure 14 shows the comparison of MTD between both "between wheel path" and "wheel path" for each test section. MTD values at "wheel path" are lower than those measured "between wheel the path" irrespective of Rejuvaseal-treated and untreated pavements. This indicates that surface textures "between wheel paths"were coarser than those in the "wheel path".

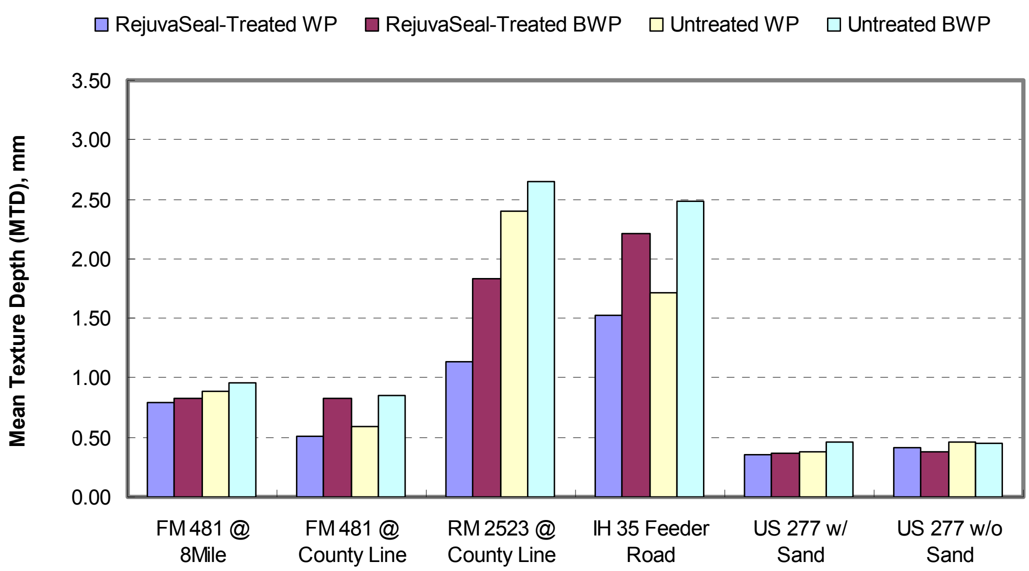


Figure 14. Comparison of Surface Texture of "Wheel Path" and "Between Wheel Path" of Rejuvaseal-Treated and Untreated Pavements at Each Test Site.

Field water flow test

Field water flow test, Tex-246-F "Permeability or Water Flow of Hot Mix Asphalt", was performed on the pavement test sections. As presented in Figure 15, the test evaluates the time required to discharge a given volume of water channeled onto the pavement surface through a 6 in. diameter opening. This time corresponds to the water flow value (WFV) and is expressed in seconds.

Figure 15. Field Water Flow Test

The field water flow did not produce any useful results. The test is typically performed on permeable friction course mixes which have a high rate of water flow. The test did not prove to be suitable for the dense-graded mixtures which were under evaluation in this study.

Skid Testing

TxDOT performed skid testing on the Laredo pavement sections to evaluate the effects of Rejuvaseal on the frictional properties of the pavement. Skid tests were performed on the pavement sections prior to the treatment with Rejuvaseal and then again approximately one week, 4 months, and 7 months after application. Some of the pavements had untreated sections, and sections treated with a conventional fog seal to provide a comparison. The results for all of the skid testing are presented in Figure 16 through Figure 21.

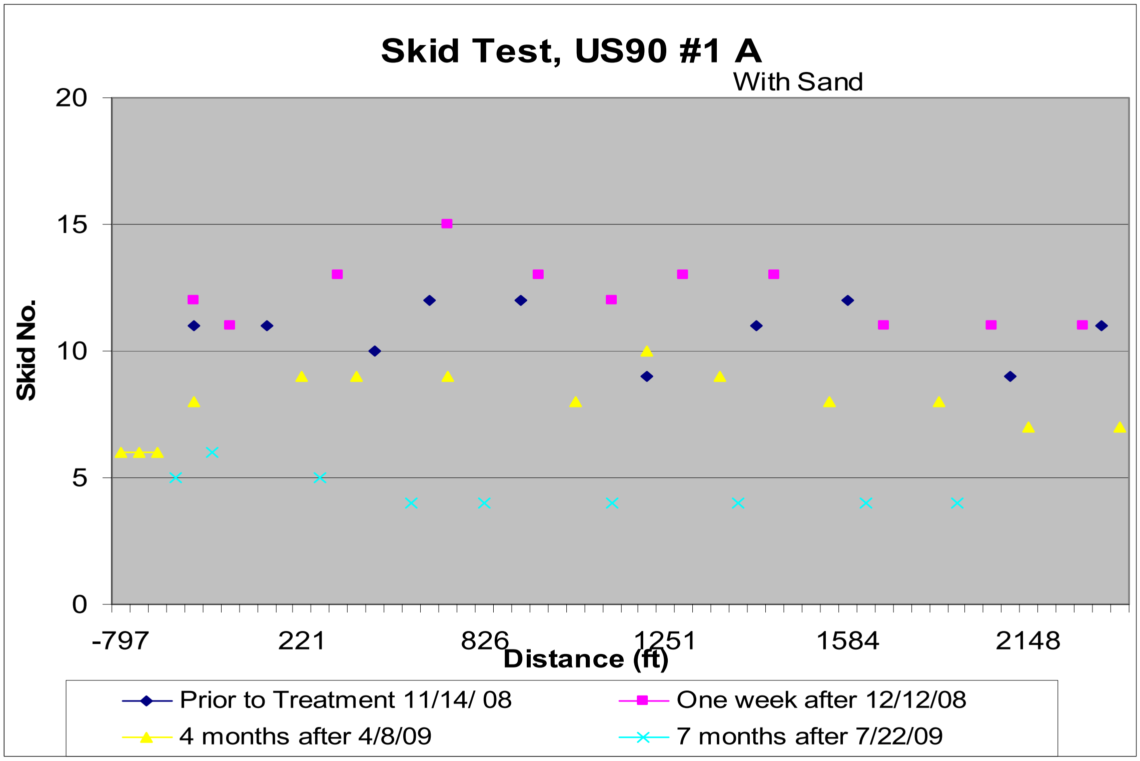


Figure 16. Skid Testing Results for US 90 (with Sand Application).

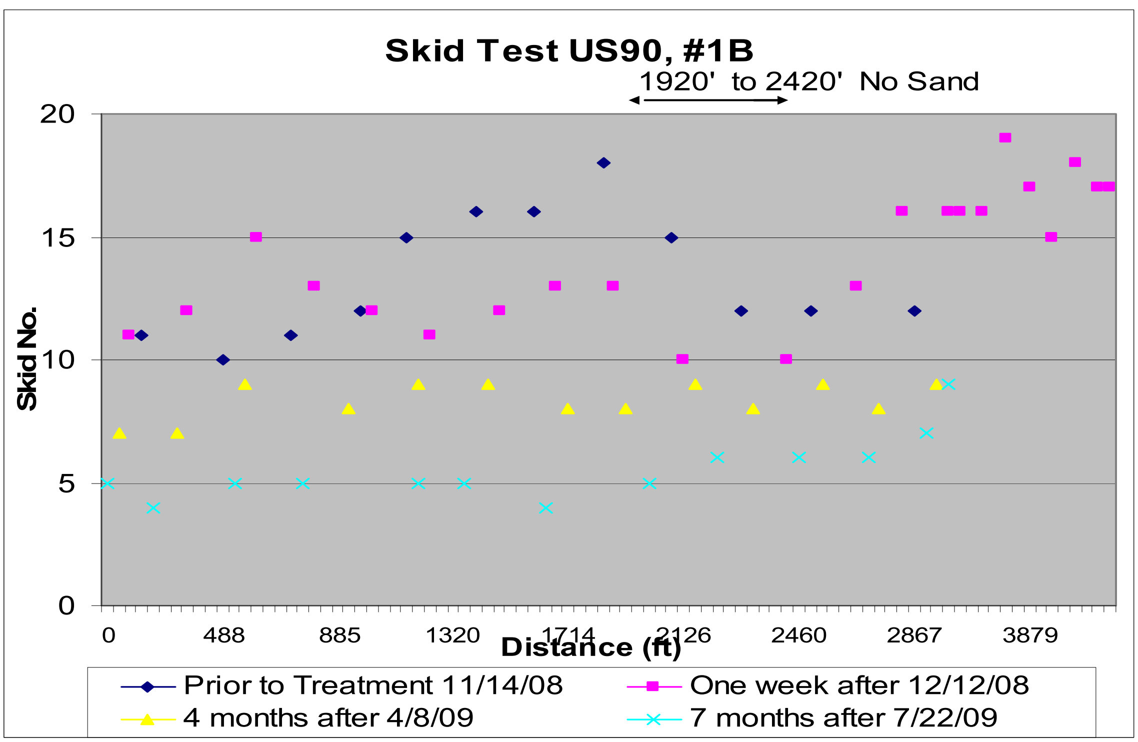


Figure 17. Skid Testing Results for US 90.

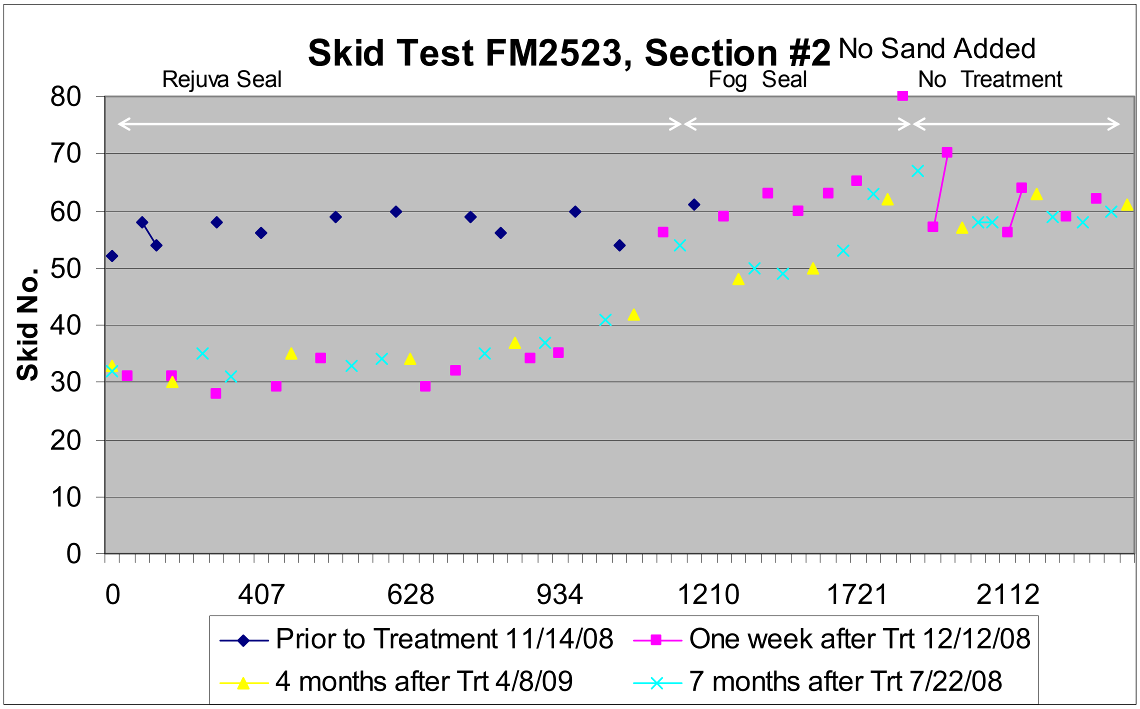


Figure 18. Skid Testing Results for RM 2523.

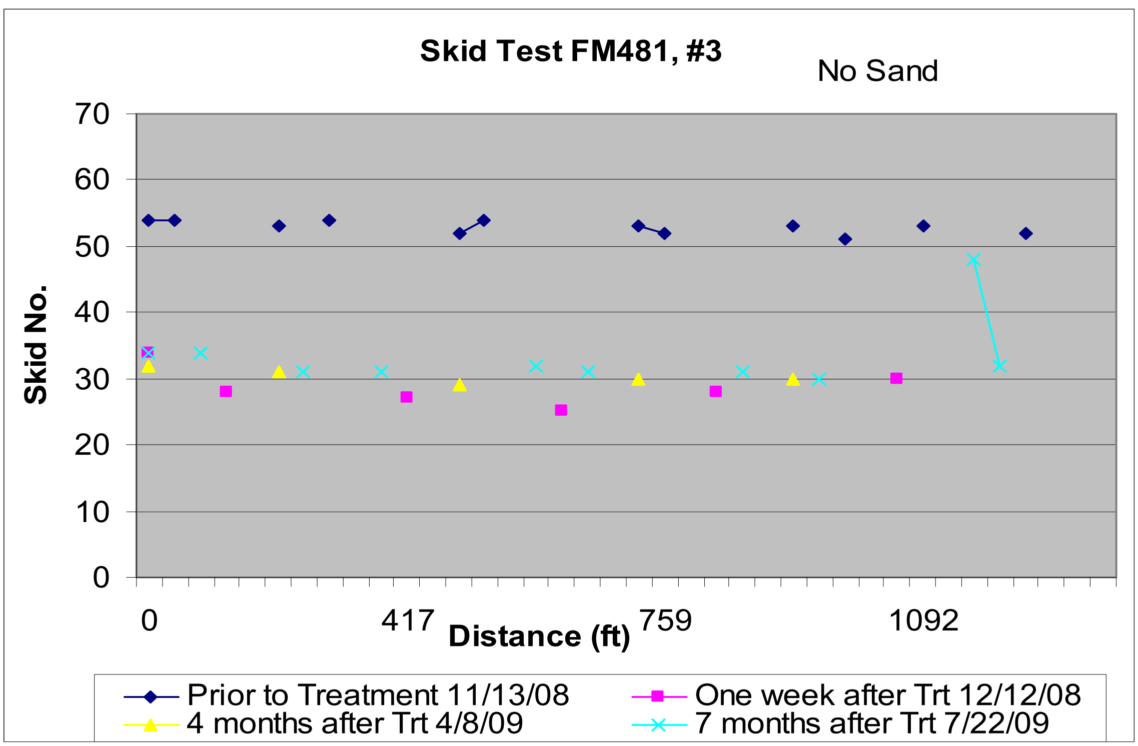


Figure 19. Skid Testing Results for FM 481.

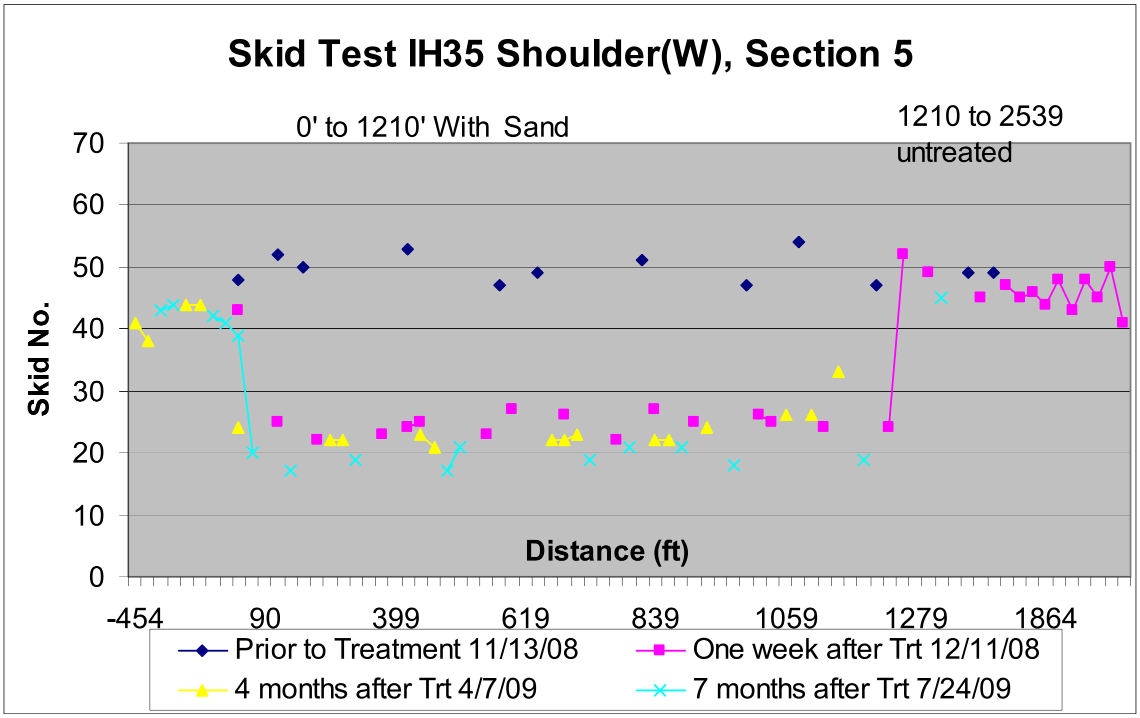


Figure 20. Skid Testing Results for IH 35 Shoulder.

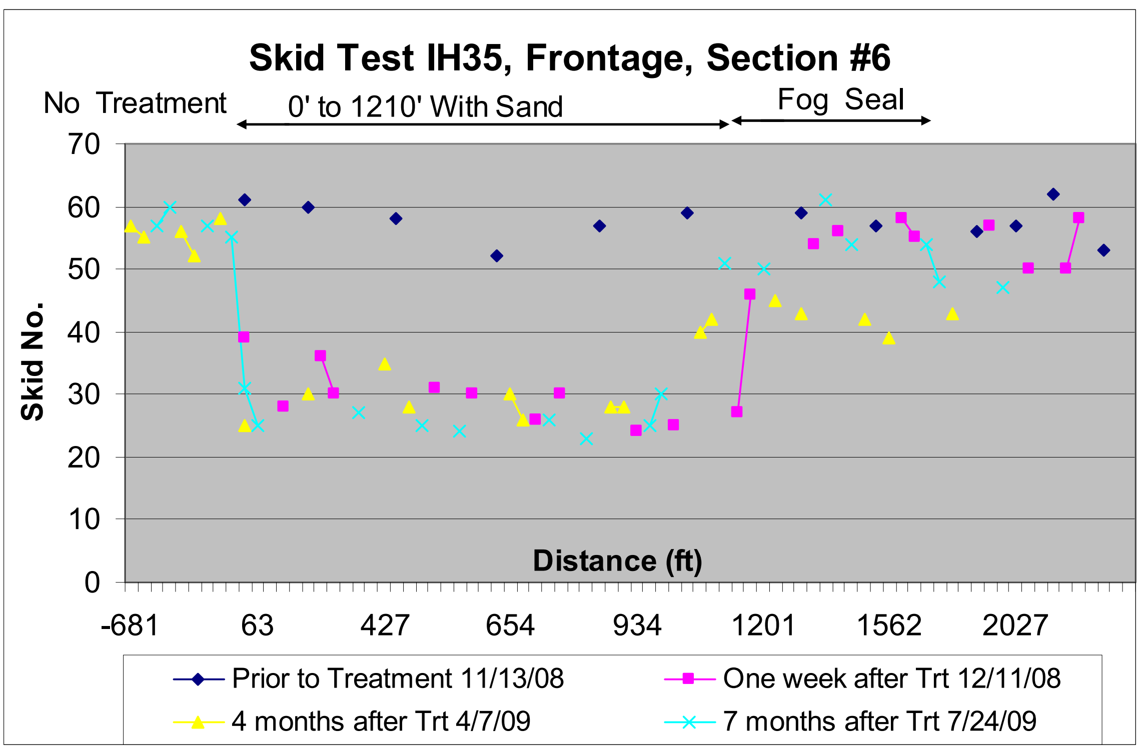


Figure 21. Skid Testing Results for IH 35 Frontage Road.

For three of the pavements, the Rejuvaseal seemed to cause a significant reduction in skid resistance that was not restored even after 7 months in-service. Conventional fog seals also caused a reduction in skid resistance but that friction was restored by the 7-month tests.

CONCLUSIONS

The performance of Rejuvaseal at six existing asphalt test sites was evaluated as a pavement preservation treatment. Enhanced performance was assessed in terms of integrity of the sealing surface, rejuvenating of the aged asphalt binder, and effect of Rejuvaseal on skid resistance. The post-construction evaluation included measurement of surface texture, permeability, recovered binder properties, and skid resistance.

Preliminary findings indicate the following:

The Rejuvaseal reduced the permeability of some of the asphalt concrete pavement sections; particularly, on those that had a high air void content.

The Rejuvaseal decreased the surface texture of the treated pavements. A significant decrease in surface texture was noted on the seal coat pavement section. This indicates that the product is filling the voids in the pavement surface providing some sealing to the surface. In addition, it would have the potential to arrest pavement raveling associates with rock loss on seal coats or loss of fines in asphalt concrete surface.

Laboratory test results indicate that the Rejuvaseal has a “softening” effect on the age-hardened binder in the top 3/8-inch of pavement cores. Laboratory test result differences between the untreated and treated cores with some of the results are more likely related to variability in test procedures, cores, and material properties than to the treatment.

No improvement was seen in the cracking resistance of the pavement cores based on the Overlay Test data; however, this is not surprising since the penetration depth of the product is only in the top 3/8-inch of the pavement surface.

For three of the pavements, the Rejuvaseal seemed to caused a significant reduction in skid resistance that was not restored after 7 months in-service. Conventional fog seals also caused a reduction in skid resistance that was eventually restored by the 7-month tests. For the pavements which had a poor skid resistance prior to treatment, the Rejuvaseal did not have a significantly negative impact. On one of the pavements, where sand was applied after treatment, an improvement in skid resistance was observed.

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Texas Pavement Preservation Center
Center for Transportation Research
The University of Texas at Austin
1616 Guadalupe St.
Austin, TX 78701
Tel: (512) 232-3084 Fax: (512) 232-3070
http://www.utexas.edu/research/tppc