THE UNIVERSITY OF TEXAS AT AUSTIN ✦ COCKRELL SCHOOL OF ENGINEERING

TEXAS PAVEMENT PRESERVATION CENTER

TxDOT Newsletter

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TRB 91st Annual Meeting

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Past and Upcoming Events

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 91st Annual Meeting attracted more than 11,000 transportation professionals from around the world to Washington, DC January 22-26, 2012. 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.

Courses for 2012

TPPC has developed two new courses for 2012. One of the courses is titled "Use of Thin Surfacing for Pavement Preservation," and the other is "Construction of Thin Hot Mix Asphalt Overlays." Both courses will be taught by Cindy Estakhri, TTI research engineer, and Dr. Yetkin Yildirm, director of the TPPC.

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).

Calibration of Seal Coat Application Rate Design by Jusang Lee, Hyung Jun Ahn, Todd Shields, Dwayne Harris and Shuo Li.

This paper presented an evaluation of aggregate and emulsion application rates of seal coats through three methods: International Roughness Index (IRI), friction tests and visual evaluation. The seal coat construction was done on three test lane sections in Indiana. The emulsion, emulsifier and aggregates used in this study were AE-90S, mixture of crude tall oil and sodium hydroxide (NaOH) and Indiana aggregate No. 12 limestone, respectively. The Aggregate Application Rate (AAR) and the Emulsion Application Rate (EAR) were determined from McLeod design method. In the design, a wastage factor of 10% was considered throughout the test sections.IRI values were calculated from profiles collected with a Class 1 high speed inertial profiler. The profiles in both wheel paths were measured prior to construction in 2008 and in the following 2 years (2009 and 2010). MRI, the average of two IRI for a wheel path, was also calculated. The MRI values did not change much as the thin seal coats did not alter the profile considerably and this small change went undetected by the IRI profiler. The friction tests were also done in 2008, 2009 and 2010.All the friction numbers (FN) of the test sections were above 20 (INDOT's minimum required FN).The correlation of AAR, EAR and volume ratios (ratio between applied emulsion volume and applied aggregate volume) with FN was also studied. It was found that for the EAR and AAR rates used in this study, there was no influence on the FN number of the test sections. Overall the IRI, friction and visual inspection did not show considerable differences in the seal coat performance, and thus, it was concluded that McLeod method showed acceptable performance. In order to correct the discrepancy in the AAR, an equipment correction factor was calculated using reliability techniques. No correction factor was introduced for emulsion distribution as the discrepancy was minimal. Immediate failure of one of the test sections showed that aggregate quantities should be high enough to protect seal coat from immediate damage and low enough to avoid unacceptable levels of accumulated fines content.

"Best-First" or "Worst-First" Which is the Best Policy by Nicholas Vitillo, Michael Boxer and Carl Rascoe.

The development and implementation of pavement management systems requires the procedure and analysis of annual paving programs. This research studied what order, "the worst pavement first" or the "best pavement first", will be beneficial as per budget requirements of the municipal council. The performance and economic analyses utilized various treatment classes (Do-Nothing, Pavement Preservation, Minor Rehabilitation, Major Rehabilitation, and Reconstruction),treatment triggers, treatment costs, budget types (lump sum and incremental budget categories),various budget levels (no funds, unlimited and typical budget level-$1M, $1.5M, and $3M), and mainly the prioritization schemes – "best-first" and "worst-first". This research uses a single performance model to age the pavement sections over a period of time. The model is shown in Figure 1.

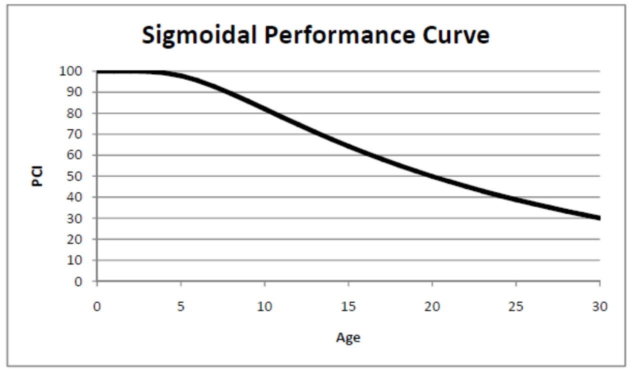


Figure 1 – Performance model

Network needs analysis was performed on each pavement network. The network needs analysis identifies which network sections need a treatment, the appropriate treatment for each network section and the corresponding cost to apply the treatment based on the area of the section and the unit cost per square foot of the section. Based on the data provided, there was no clear winner between the two strategies. Both approaches have their advantages and disadvantages. These are summarized in Table 1.

Table 1 – "Worst first" or "Best first"

1.	Worst – first Approach
	Advantages:
	1. Promotes the appropriate mix of fixes that addresses the network's needs. 2. Easier for County and Municipal Engineers to defend to the agency's governing body. 3. Identifies pavement sections that should be addressed before they fall below the trigger value that requires a higher treatment cost.
	Disadvantages:
	1. Does not always produce the "best" average network PCI. 2. Does not treat the highest percentage of the network area. 3. Costs more than the "best-first" prioritization scheme.
2.	Best – first Approach
	Advantages:
	1. Treats the highest percentage of the network area at the least cost per square foot. 2. Produces the highest average network PCI for most of the Fair and Poor Networks. 3. Costs less than the incremental "worst-first" prioritization.
	Disadvantages:
	1. Does not promote the appropriate mix of fixes that addresses the network's needs. 2. More difficult for County and Municipal Engineers to defend to the agency's governing body. 3. Allows pavements at the bottom of the treatment classification type to fall below the trigger value which requires a higher treatment cost

Effective Timing for Sequential Applications of Slurry Seal on Asphalt Pavement Performance by Luis Guillermo Loría Salazar, Elie Y. Hajj, Peter E. Sebaaly, Edward Cortez and Scott Gibson.

This research study evaluated the performance of pavements without and with sequential slurry seal application after construction and identified the optimum time for these applications. The study was conducted for the regions within Washoe County, Nevada. The study evaluated two types of pavements: newly constructed and pavements that receive overlays. Asphalt mixtures were generally dense graded HMA with a 0.50 or 0.75 inch nominal maximum aggregate size with AC-20, AR4000 or PG64-22 unmodified asphalt binders. The numbers of pavement sections that receive sequential slurry seal applications were 172, out of which 82 were newly constructed and 90 were pavements that receive overlays. These two categories were further subdivided into two: first, slurry seal after 0, 1, 3 or 5 years after construction, and second, slurry seal 7 or 9 years after construction. The performance of all pavements was measured in terms of Pavement Condition Index (PCI) using the microPAVER system. The identification nomenclature was organized as follows: for example, OL-0-7 would indicate overlay pavements that received the first slurry seal at year 0 and the second slurry seal at year 7. Similarly, NC-0-7 would indicate newly constructed pavements that received the first slurry seal at year 0 and the second slurry seal at year 7.

The slurry seal performance life is defined as the number of years for the slurry seal performance curve to reach the PCI of the existing pavement before treatment application. Whereas, the extension in pavement service life is the number of additional years the pavement will have at the end of its service life (i.e. PCI = 40) due to the application of the slurry seal. Figure 2 shows a typical performance model for no slurry seal approach and application of slurry seal approach. From figure 2 it can be inferred the slurry seal application increases the life of pavement by 3.2 years. This same approach was followed for other combinations of slurry seal timings on pavements. The cost benefit analysis of the slurry seal over no slurry seal was also done. The conclusions made were as follows:

- The application of the slurry seal after 0 or 1 year of construction was not useful for the user and agency in terms of benefit cost ratio.
- Regardless of the construction activity, optimum time for slurry seal application is first after year 3 and second after year 7.
- The pavements service life was extended for 2 to 4 years when the first slurry seal is applied in year 3 or 5 and a second slurry seal is applied in year 7 or 9.

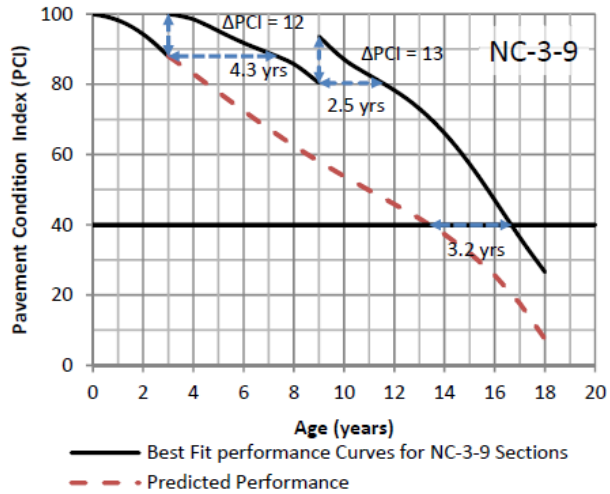


Figure 2 – Performance curves for a newly constructed residential section for the do-nothing condition and slurry seals applied in year 3 and 9.

Georgia's Pavement Preservation with Micromilling – a Follow up Study by Dr. James Lai, Sheila Hines, Peter Y. Wu and David M. Jared.

This study summarizes research performed on micromilling and an open-graded inlay project on I-95 and compares the result with previous research on I-75.The new Open Graded Friction Course/Porous European Mix (OFGC/PEM) layer cannot be placed over a conventionally milled surface due to two reasons: (1) Poor bonding between OFGC/PEM surface and conventionally milled surface (2) water can enter and get trapped in the valleys of conventional milled surface. A new layer of dense graded HMA can be placed over a milled surface but the cost of this approach is quite high. Micromilling can be done to produce a much finer surface texture than conventional milling with a ridge-to-valley depth (RVD) of less than 3 mm. The project included micromilling of six lanes of a mainline roadway (three lanes in each direction) to remove an existing OGFC overlay of approximately 5/8 in. to 7/8 in. thickness and resurface it with 90 lb./sq. yd. (3/4 in. – 7/8 in.) of 12.5 mm OGFC. The following conclusions and recommendations can be drawn from this study on micromilling on I-75 and I-95:

- The appearances of the micromilled surface on these two projects were quite different, with pockets of holes appearing on the milled surface at the I-95 project, but no such holes appearing on the I-75 project. A possible cause for the different appearances was that the prevalent coarse aggregates in the gap-graded SMA were more susceptible to being dislodged when the milling teeth struck them than the less prevalent coarse aggregates in a dense-graded mix.
- As mentioned in this paper, the ultimate decision for selecting an appropriate RVD parameter, whether it is the Mean RVD, p75, p80, p90, p95 or other RVD parameter, for compliance with the 3.2 mm RVD acceptance requirement should be based on the long-term performance of the OGFC/PEM placed on the milled surface.
- In the course of performing the quality control for the micromilled surface in the I-95 project, the raw data of the micromilled surface textures were

collected by the Laser Road Profiler (LRP) for every ½-mile segment for the entire project. It is recommended that these raw data be retained, since they can be used to generate various RVD parameters (Mean
RVD, p75, p80, p90, p95, etc.) for each ½-mile segment, and for even smaller segments. These RVD parameters can be used in the future to compare and correlate at various pavement locations with the long-term performance and the appearance of distresses on the OGFC overlay for establishing appropriate RVD parameters for compliance with the 3.2 mm RVD acceptance criteria, or for developing new acceptance criteria.

Louisiana's Experience in Open-Graded Friction Course Mixtures by Md Sharear Kabir, William "Bill" King Jr., Christopher Abadie, Patrick Icenogle and Samuel B. Cooper.

This research study evaluated the Louisiana Open-Graded Friction Course (OFGC) mixtures on the basis of their laboratory and field performance. The laboratory tests consisted of permeability, draindown, tensile strength ratio and loaded wheel test. OFGC is a porous, uniformly graded asphaltic concrete mixture that contains a high percentage of interconnected voids. They effectively drain the water to the edge of pavement and reduce tire noise. They reduce hydroplaning, spray and splash, improve roadway visibility and skid resistance of pavement under wet conditions. LADOTD constructed four OGFC test sections on US 71, I-20, US 61, and US 171 that were evaluated in this study.
A falling head flexible wall permeability test (ASTM P129) was performed on 150-mm diameter roadway cores collected from the above OGFC test sections. All the permeability values were above the minimum permeability of 328ft/day for OFGC mixtures. Drain down test performed on the loose OFGC mixtures showed that the draindown results were below the maximum limit of 0.3% by weight of total mixture. The permeability and drain down results are shown in Figure 3.

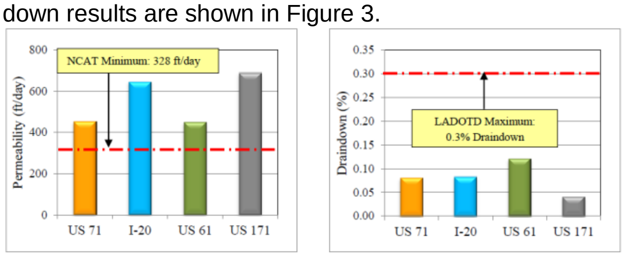


Figure 3 – Permeability and Drain down results.

After loaded wheel test (LWT) of 20,000 wheel passes, it was observed that US 71 and US 61 test sections experienced 3.4 mm and 5.3 mm rut depth respectively, whereas the US 171 specimen failed after 5300 wheel passes. The maximum allowable limit of rutting depth was 12 mm after 7500 passes as specified in the LADOTD specifications for OFGC mixtures. The US 171 section has shown good rut resistance in the field as opposed to results in the laboratory. The tensile strength ratio (TSR) test indicated that TSRs for I-20 and US 61 were significantly higher than the minimum specification requirement of 80% retained strength after one freeze-thaw cycle. US 171 mixture failed to pass this test. To access the frictional properties of the OFGC surface, Mean Profile Depth (MPD) values were compared. The results indicated that US 61 and US 171 meet the NCHRP recommendation whereas, I-20 is below the minimum recommended value. The results of the MPD test is shown in Figure 4.

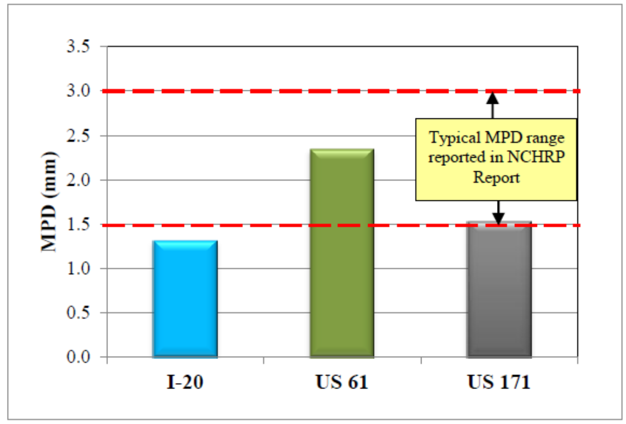


Figure 4 – MPD results.

Five year distress data of the pavements, less spray and splash of water and reduction in the wet weather accident number in the OFGC sections indicated that OFGC pavement surfaces are comparable to typical superpave sections.

Field Evaluation of Ultrathin 4.75-mm Hot Mix Asphalt Dense-Graded Overlay: Aggregate Properties and Pavement Surface Friction by Shuo Li, Yanna Sun, Yi Jiang, Samy Noureldin and Todd Shield.

This paper lists the results of a study initiated by INDOT to study the friction performance of 4.75 mm dense graded hot mix asphalt (HMA). Table 2 lists the four test sites constructed by INDOT in this research.

Table 2 – HMA pavement Test sections

Road	No. of Lanes	Length	AADT	Trucks	Construction Time
I-465	6	4.0 miles	104,593	19,475	08/2006
US-27	2	4.0 miles	7,735	741	09/2009
SR-227	2	3.0 miles	1,964	77	09/2009
SR-29	2	9.0 miles	5,552	1,215	08/2010

A circular track meter (CTM) test was done to evaluate surface macrotexture properties. Loaded wheel trailer testing was done to monitor surface friction up to five years. Aggregate gradation and packing characteristics were examined to see their effect on pavement friction.
The research study concluded with a number of key findings. HMA mixtures are very sensitive to truck traffic. The surface friction reduction of 35% can be expected after 12 months of service. The typical friction number for a HMA is around 20 and true MPD is around 0.20 mm. The gradations for 4.75-mm HMA dense-graded mixes are commonly ARZ (above the restricted zone) or CRZ (crossover through the restricted zone) gradations. Since it is not realistic to produce a BRZ (below the restricted zone) gradation, it becomes important for the aggregate gradation to pass below the PCS control point to enhance the surface friction, particularly when the restricted zone is removed. Increasing the % Half Sieve and providing a non continuous gradation between 0.6-mm and 2.36-mm sieves may improve surface macrotexture properties. 4.75-mm HMA dense-graded mixes cannot perform as

well as coarse aggregate size mixes in terms of the friction performance. Special care should be exerted when 4.75-mm mixes are placed on high traffic volume, high speed roads.

A Framework for Microsurfacing Project Selection: The Key to Long-Term Performance by Douglas D. Gransberg and Dominique Pittenger.

This paper discusses a development of framework to decide which pavements are ideal for microsurfacing treatment and which pavements are not ideal. This study was a result of a survey of 44 US states and 12 Canadian provinces highway agencies combined with a comprehensive literature survey. Microsurfacing is used to address various pavement maintenance related issues like oxidation, raveling, rutting and low friction numbers of pavements. Microsurfacing is a thin surfacing that can be laid in a thickness of 2-3 times of the largest stone in the mix. This layer has following properties:

- Correction of minor surface irregularities.
- Rut filling.
- Higher durability.
- Work at night work or in cooler temperatures.
- Restoring surface friction to concrete bridge decks.
- Restoring surface friction to polished asphalt surfaces.

The survey and the literature research can be summarized in few key points. (1) Microsurfacing should not be used as a preservation strategy for cracked pavements. (2) It should not be used for bleeding surfaces. (3) It will perform better for the pavement distresses in order: Rutting, raveling, oxidation and friction loss. (4) The Life cycle cost analysis (LCC) showed that a chip seal would cost less than microsurfacing but surpassed service life of microsurfacing by just one year. Figure 4 shows the Microsurfacing project selection framework for asphalt pavements. The above research led to the conclusion that US states are not using microsurfacing as a major tool in pavement preservation while the Canadian provinces are using it as a major tool.

Performance Evaluation of Microsurfacing in Utah and Analysis of Performance-Reduction Factors by Bryan T. Wilson and W. Spencer Guthrie.

This research focuses on the service life of microsurfacing in Utah and the contribution of several factors in the performance reduction of pavements with microsurfacing. This project involved a study of 15 projects in Utah: 10 existing projects and 5 new construction projects.

The performance of the pavements was assessed with a pavement condition index (PCI), rut depth measurements and mean texture depth (MTD) measurements. Rut depth is a measurement of depression under the wheel paths caused primarily by the movement of subsurface layers. According to guidelines by UDOT and the Long-Term Pavement Performance (LTPP) Program, pavements with rut depths greater than 0.5 in. are considered failed, as water may pond in the wheel path and facilitate hydroplaning. MTD is a measure of the skid resistance of

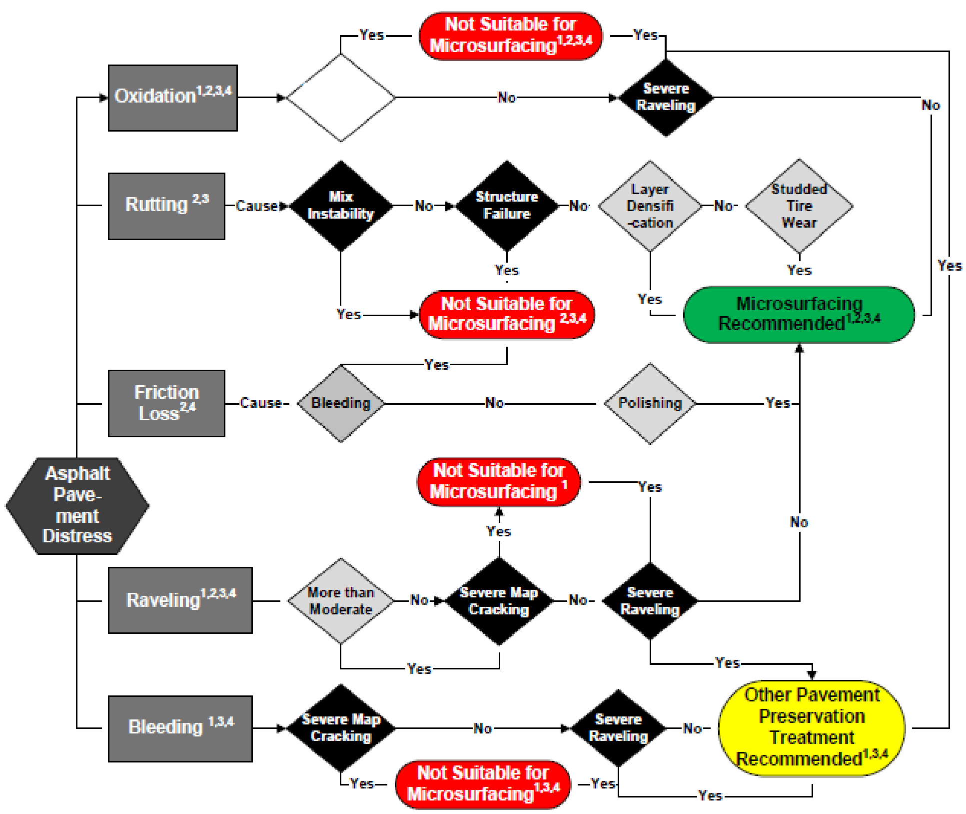


Figure 4 – Microsurfacing project selection framework for asphalt pavements.

the pavement surface. Microsurfacing can increase both micro-texture and macro texture of the pavement surface. MTD is easily measured using the sand patch test. The lowest reasonable MTD for high trafficked areas is 0.06 inches. PCI is a measure of pavement surface index. Distresses are caused by any combination of the following factors: loading, environmental stress, poor material quality, and poor design and construction. Common distress types include longitudinal cracking, transverse cracking, fatigue cracking, patching, and rutting. PCI is calculated by following the guidelines in ASTM D6433.

Performance reducing factors like climate, traffic and pre-existing pavement condition were also studied. Traffic induces stresses in the pavement and the repeated loading of tires causes the structure to fail. Passenger vehicles generally do not contribute much to pavement failure but trucks and semi truck vehicles cause the pavement to fail. Thus average annual traffic of trucks should be taken into account while accessing traffic effects in performance. Cold climate as in Utah can contribute significantly to the degradation of the pavement as well. Ice in the sublayer generally goes under a cycle of contraction and expansion resulting in the breaking of the pavement. Pre-existing cracks and rutting in the pavements can cause the microsurfacing to fail prematurely.

For each project, a section of the outer lane was selected as a testing site for measuring the performance of the microsurfacing. In most cases, these testing sites were 250 ft in length, however testing site lengths of 500 ft, 260 ft, and 60 ft were also used. The tests performed at each site consisted of a distress survey and skid resistance measurements. The data analysis includes plotting of PCI, rutting and MTD of the pavement with respect to time. These plots were analyzed qualitatively, describing the apparent trends in the data.

This research brought out key points in assessing the performance evaluation of microsurfacing in Utah. The projects maintained a satisfactory PCI until 3 years on low end and 7 years on high end. This wide range is contributed by the pre-existing condition of the pavement surface. The treatments placed on non-cracked roads showed fair PCI until 8 years and more. The traffic result showed that performance was better in high traffic sensitivity roads. This result was only due to the better construction practices in those areas. The effect of climate on performance couldn't be studied due to a smaller amount of data. Thus, it was concluded that the life of a pavement may be extended and long-term costs greatly reduced through routine maintenance of the wearing surface with microsurfacing.

Microsurfacing in Texas by Benjamin Broughton and Soon-Jae Lee.

This research study looked into the current microsurfacing practices in Texas with regard to project and contractor selections. The current practices in Texas were compared with those in the existing literature. A survey of DOT personnel, contractors and emulsion suppliers was done to better understand the current trend in microsurfacing. The literature survey, case studies, analysis of material selection, construction practices, equipment practices and performance measures to improve microsurfacing were studied to better understand the complexities in microsurfacing.

The survey was sent to 138 personnel within Texas Department of Transportation (TxDOT) and 39 responses were received. One person from each of the four contractors currently performing microsurfacing in Texas responded to the survey, as well as one of the two major emulsion suppliers. Questions on the survey fell into one of four categories: Mix Design and Material Selection, Equipment Practices, Construction Practices, and Performance Measures. Respondents were also asked to identify up to three microsurfacing sites in Texas and rate the performance of the projects. The researchers visited four sites out of sites mentioned in the survey by respondents.

The current methodology for mix design is included in the report 1289-F from the Texas Transportation Institute. Most of the respondents cited project selection as an important factor in comparison to mix design/material selection. "NCHRP Synthesis 411" reports that uncertainty in the amount of microsurfacing every year discourages contractors from investing in the resources needed to develop microsurfacing capability. A more stable market for microsurfacing should give more contractors the confidence to enter the industry. Based on site visits and a TxDOT survey, microsurfacing is believed to be good for some of the distress shown in Table 3.

Table 3: Distress that microsurfacing corrects

Distress	Yes (%)	No (%)
Loss of Friction	97	
Bleeding	92	
Rutting	90	
Surface Texture Variations	89	
Streaking/ Color Variations	80	
Raveling	58	
Fatigue Cracking		100
Reflection Cracking		97
Potholes		97
Delamination		94
Permeability		79
Poor Transverse Joints		76
Poor Longitudinal Joints		73
Corrugation/Poor Ride Quality		60

The project selection for microsurfacing can be done best by good contractors who have the required field experience in judging which may be the potential sites for microsurfacing and communicating the same to TxDOT personnel. Depending solely on contractors for project selection leaves TxDOT in a precarious situation. Therefore, TxDOT should give training to its personnel to improve in project selection.

Micro-Surfacing: Is Asphalt Film Thickness a Chemistry or a Design Problem by Walter S. Jordan III, James M. Hemsley and Gaylon Baumgardner.

This research focuses on the optimum asphalt film thickness (AFT) for microsurfacing. A higher AFT in microsurfacing may lead to situations of bleeding and deformation problems while a lower AFT may result in raveling and durability problems. It is believed for a given AFT, a "medium" exists with the optimum emulsion content used in the design of a micro-surfacing application. This experimental research investigated the correlation of AFT in micro-surfacing treatments to the results of Wet Track Abrasion Tests (WTAT) and Schulze-Breuer and Ruck (SBT). Information from the mix design included optimum emulsion content, water content, mineral filler content, WTAT and SBT.

The aggregate area used in the design is calculated usig the equation below:

$$SA = 2 + 0.02a + 0.04b + 0.08c + 0.14d + 0.30e + 0.60f + 1.60g$$

Where:

$a, b, c, d, e, f,$ and g are constants with according sieve number

The AFT is calculated using four different methods given in Table 4.

Table 4 – Calculation of AFT

Name of Equation	Equation
Kandhal et.al. *(14)*	$AFT = \frac{W_{b/agg}}{SA * \rho_W * G_b}$
NCAT *(15)*	$AFT = 1000 * \frac{V_{asb}}{SA * W}$
Iowa DOT *(16)*	$AFT = 10\frac{P_{be}}{SA}$
Minn. DOT *(17)*	$AFT = 4870 * \frac{P_{be}}{SA * P_S * 100}$

AFT – Asphalt film thickness (mm)
$W_{b/agg}$ – weight of binder per aggregate (%)
SA – Surface Area (ft^2/lb)
W – Weight of aggregate (%)
V_{abs} – Volume of asphalt absorbed (%)
G_b – Specific gravity of binder
P_{be} – Percent effective binder (%)
P_s – Percent of aggregate (%)
ρ_w – density of water (g/m^3)

Figures 5 and 6 show the results of WTAT versus AFT and SBT versus AFT, respectively. Aggregates with a higher surface area (i.e. 45 ft2/lb and greater), using optimum conditions of around 12 % emulsion, 7 to 9 % water, and 1 % mineral filler produces low AFT, low WTAT on one hour and six day, and produces acceptable (greater than or equal to 11) SBT values. Aggregates with other combinations tend to have higher AFT, however, they produce acceptable one hour and six day WTAT's and SBT's set by ISSA regulations. Thus the research confirmed that there is a correlation between film thickness and the optimum emulsion content in the microsurfacing mix.

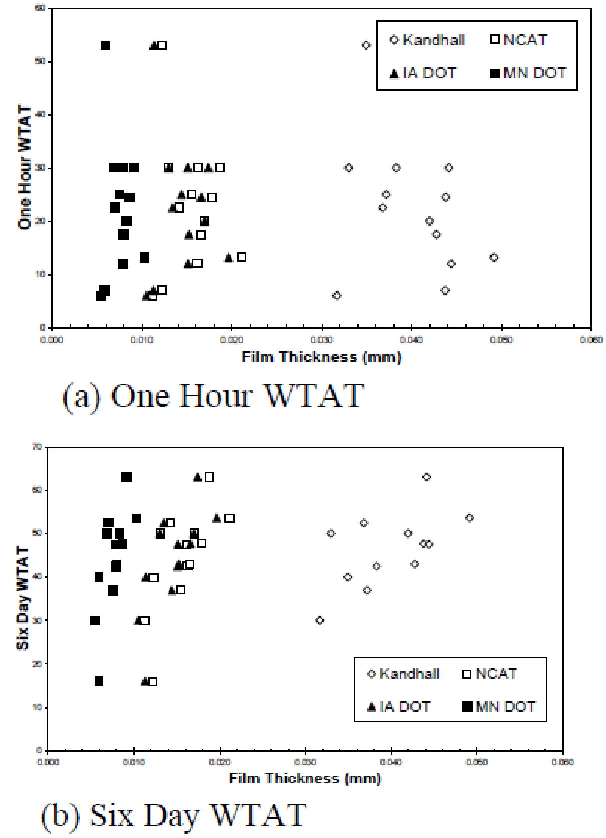


Figure 5 – WTAT versus AFT

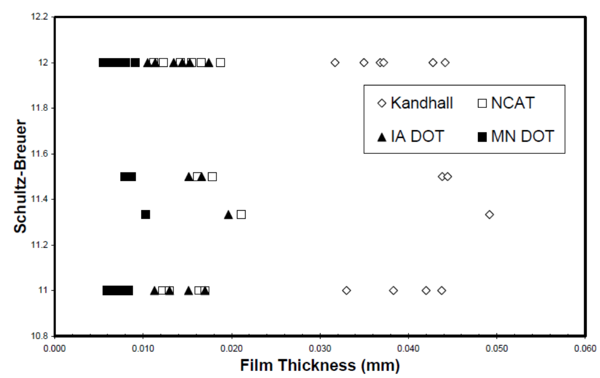


Figure 6 – SBT versus AFT

Modeling pavement texture deterioration as a pavement preservation management system tool by Caleb Riemer and Dominque Pittenger.

This study develops deterioration models for six different commonly used pavement preservation techniques. The deterioration models include the variation of microtexture and macrotexture over time. The data was collected from a 3 year field test of sections of 6 different techniques applied over identical substrate and subjected to same environmental and climatic conditions. The data was measured on a monthly basis. The models can be effectively used to enhance safety criteria which include the surface texture deterioration over failure limits. These models can also be used in financial planning and life-cost cost analysis of different pavement preservation techniques. Over the course of time it is possible for a pavement that remains structurally sound to become unsafe due to skidding problems. Thus it is essential to address the surface texture deterioration of a pavement at the right time. The right time for rehabilitation of surface texture can be easily found beforehand if the rate of deterioration of the surface texture is known.

This study utilizes ongoing research in Oklahoma involving twenty-three different pavement preservation treatments. The primary tests used during the research project were the ASTM 274 E Ribbed Tire skid tester for measuring skid number, which was determined to be an index value for microtexture, and the New Zealand sand circle test method TNZ T/3 used to measure macrotexture. Figure 7 shows the both microtexture and macrotexture of the road.

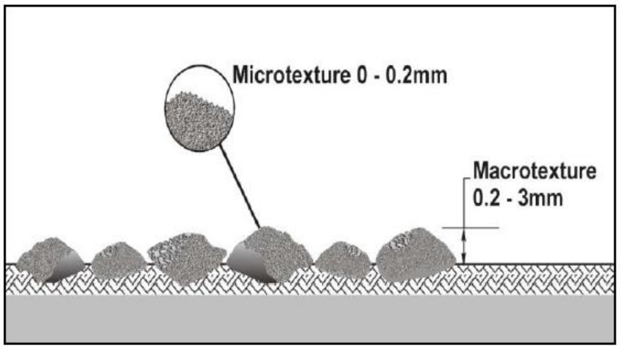


Figure 7 - Microtexture and Macrotexture of the road

Table 5 shows the fitted deterioration models for macrotexture and microtexture of the surface. The negative sign in the models demonstrate that these quantities decrease with time. The initial texture corresponds to the start value of the texture at the beginning of 3 years. These models can be effectively used in the pavement management system implementation. A hypothetical example with a 12 month duration is used to illustrate the proposed process for integrating pavement texture into the pavement management process:

(1) Develop deterioration models.

(2) Set failure criteria (ex- 0.9mm used in New Zealand).

(3) Extrapolate the deterioration curve to the failure value and back up the required 12 months to initiate a project one can determine a macrotexture trigger value of 0.969 mm.

(4) 1.0mm is chosen which generates an alert 16 months prior to failure, giving the engineer a period greater than required project development and authorization period to initiate action to preserve this pavement.

A case study: Using a performance-based approach to integrate pavement preservation into pavement management system by Sui G Tan and DingXin Cheng.

This paper emphasizes the benefit of using performance driven techniques to decide funding policy in pavement preservation management systems. In this case study, StreetSaver® was chosen for its flexibility to test multiple performance target scenarios, its capabilities to predict pavement conditions based on an individual performance curve of a pavement section, and the ease of setting up pavement preservation strategies in pavement management systems (PMS).

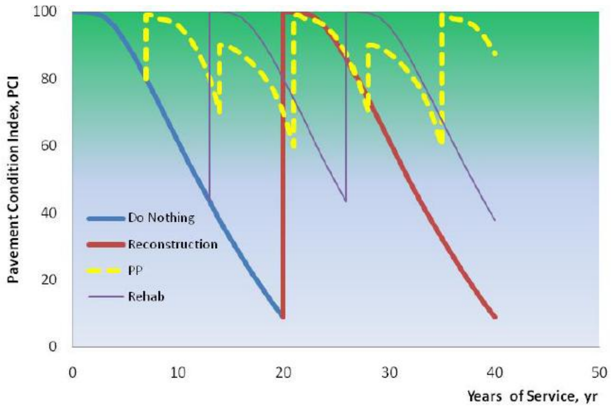
Table 5 – Deterioration Models

Pavement Preservation Treatment Technique	**Macrotexture Deterioration**	
	Logarithmic Equation	R^2 Values
Open Graded Friction Course	$y = -0.499\ln(x) + 2.9017$	0.77
Open Graded Friction Course w/ Fog Seal	$y = -0.625\ln(x) + 3.2829$	0.77
Mill and Inlay	$y = 0.038\ln(x) + 0.4864$	0.23
Fog Seal	$y = -0.034\ln(x) + 0.95$	0.21
Penetrating Asphalt Conditioner (P.A.C.)	$y = -0.084\ln(x) + 1.4699$	0.52
P.A.C. w/ Asphalt Planer	$y = -0.077\ln(x) + 1.1715$	0.56
Chip Seal (5/8") w/ Fog Seal	$y = -0.386\ln(x) + 2.8431$	0.90
Chip Seal (5/8")	$y = -0.636\ln(x) + 3.8985$	0.85
Chip Seal (3/8")	$y = -0.509\ln(x) + 2.4198$	0.85
Shotblasting (Blastrac)	$y = 0.0028\ln(x) + 1.3458$	0.001
Shotblasting (Skidabrader) w/ Fog Seal	$y = -0.064\ln(x) + 1.7158$	0.34
Shot-blasting (Skidabrader)	$y = -0.054\ln(x) + 1.7522$	0.21
Shotblasting (Blastrac) on Concrete	$y = -0.03\ln(x) + 0.7103$	0.28
Shotblasting (Skidabrader) on Concrete	$y = -0.075\ln(x) + 1.1123$	0.56

Pavement Preservation Treatment Technique	**Microtexture Deterioration**	
	Power Equation	R^2 Values
Open Graded Friction Course	$y = 29.67x^{0.0724}$	0.49
Open Graded Friction Course w/ Fog Seal	$y = 28.597x^{0.08}$	0.56
Mill and Inlay	$y = 56.652x^{-0.046}$	0.47
Fog Seal	$y = 41.347x^{0.0418}$	0.45
Penetrating Asphalt Conditioner (P.A.C.)	$y = 34.135x^{0.0839}$	0.70
P.A.C. w/ Asphalt Planer	$y = 32.82x^{0.0974}$	0.79
Chip Seal (5/8") w/ Fog Seal	$y = 36.399x^{-0.071}$	0.38
Chip Seal (5/8")	$y = 44.065x^{-0.115}$	0.71
Chip Seal (3/8")	$y = 54.729x^{-0.162}$	0.77
Shotblasting (Blastrac)	$y = 52.16x^{-0.031}$	0.27
Shotblasting (Skidabrader) w/ Fog Seal	$y = 49.868x^{-0.023}$	0.12
Shot-blasting (Skidabrader)	$y = 51.286x^{-0.031}$	0.27
Shotblasting (Blastrac) on Concrete	$y = 49.115x^{-0.008}$	0.03
Shotblasting (Skidabrader) on Concrete	$y = 39.681x^{0.01}$	0.02

The first question that arises is how the pavements should be prioritized in receiving preservation. There are three types of techniques used: "Worst First", "Pavement Preservation Approach", and "Network Optimization". In the worst first approach the most degraded pavements are put first on the list while in the pavement preservation approach the pavements in good conditions are put first. The network optimization techniques are more scientific and mathematical. It gives out the best group of pavements fit for preservation, method of preservation and time of year in which it should be preserved. No matter what approach we use, the final product is a list of pavement sections that should be treated first. Figure 8 shows the comparison of serviceability of different treatment strategies. A pavement management system must have the capabilities to:

- Set performance targets (objectives), and allocate different funding levels to achieve the network performance accordingly.
- Subscribe to either "near optimal" approach or "true optimization" system to maximize benefits and minimize costs.
- Fully integrate pavement preservation strategies.
- Achieve long term benefits of pavement preservation strategies.



. Figure 8 - Serviceability of Different Treatment Strategies

The traditional fixed budget approach is compared with the performance based approach through a case study performed on two cities in the California Bay Area. The following quantities are compared between the two approaches:

- Total funding - life cycle cost present worth budgeted funding over the analysis period.
- PCI – Network wide average pavement condition index.
- RSL – Network average remaining service life at the end of the analysis period.
- Deferred Maintenance - Total deferred maintenance value of the network at the end of the analysis period.

The target driven approach was found to give better results than the conventional approach. Table 6 summarizes the results of the case study.

Table 6 – Traditional versus target driven approach.

	City of Pinole		City of San Leandro	
	Fixed Traditional Budget	Performance-Based Target Driven	Fixed Traditional Budget	Performance-Based Target Driven
Maintain Current Funding	×	✓	×	✓
Maintain Current PCI	×	✓	×	✓
State of Good Repair	×	✓	×	✓

Preservation strategies for the flexible pavement network of the Washington state department of transportation by David R. Luhr, Jianhua Li, Jeff S. Uhlmeyer and Joe P. Mahoney.

This paper suggests a framework to develop rehabilitation strategies for Washington state department of transportation (WSDOT). Four basic steps are used by WSDOT to address this mission: (1) monitoring the condition of the road network on a continuing basis; (2) managing the pavement network into the lowest Life-Cycle Cost; (3) creating preventive strategies to extend pavement life and reduce costs; and (4) generating 2 year and 10-year plans for preservation of the road network based on rehabilitation needs and available resources.

The roads are monitored by giving a pavement an index between 0 and 100 in three areas: pavement cracking/patching, rutting and roughness. Life cycle cost analysis is an analysis procedure in which all possible alternatives are compared on the basis of lowest life cycle cost. The cost includes initial construction cost, rehabilitation cost and any other cost during its life time. The time value of the money is also considered in this analysis. The analysis shows that a pavement can be rehabilitated with lowest cost in a certain time window of 1-3 years. Rehabilitation before that time or after that time will only increase the cost incurred on that pavement. The most important economic factors are discounted Equivalent Uniform Annual Cost (EUAC) and Equivalent Single Axle Load (ESAL) Efficiency Factor. Figure 9 shows the historical EUAC for asphalt pavements within each of WSDOT's six regions, considering urban and rural conditions separately.

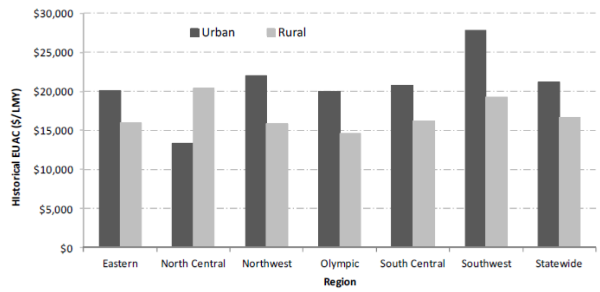


Figure 9 - EUAC for asphalt pavements within each of WSDOT's six regions.

The quality of the pavements can be maintained with reduced funding by using innovative techniques in the preservation strategies like pavement recycling, warm-mix asphalt, implementation of performance graded binders, infrared thermography for asphalt paving and cold in place recycling. The tight budget in WSDOT calls for the use of preventive strategies in the pavement preservation techniques. For example, the premature distress in the pavement surface should be addressed early to save the money. Short distressed section(less than 0.5 mile) should be rectified first. One way to improve the backlog of the WSDOT in rehabilitation can be the use of chip seals for low volume roads. To remove the back log, 2 year and 10 year plans for pavement preservation are made (Figure 10).

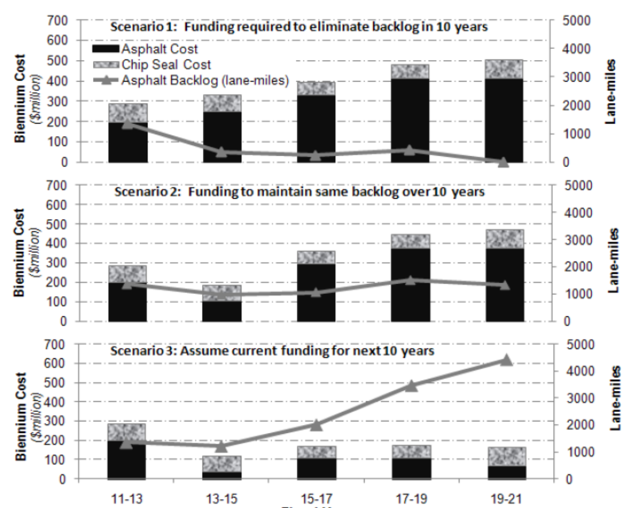


Figure 10 - The estimated cost and backlog lane-miles of WSDOT flexible pavement network under the three funding scenarios for next 10 years.

An Evaluation of Warm Mix Asphalt Additives and Reclaimed Asphalt Pavement on Performance Properties of Asphalt Mixtures by Mohamed H. Rashwan and R. Christopher Williams.

This paper presents a discussion about the efficiency of warm mix asphalt mixtures over conventional HMA mixtures. Warm mix asphalt (WMA) technologies and reclaimed asphalt pavement (RAP) have been developed to address the issue of ecological deterioration. In this study, the performance of three major warm mix technologies: Advera, Evotherm J1 and Sasobit are compared to HMA with respect to dynamic modulus and permanent deformation (flow number). Each mixture was developed using a performance grade 64-22 binder and two types of aggregates: limestone or quartzite. The possibilities of development of a WMA mixture with 30 % RAP content with comparable properties to HMA were also examined.

The experimental set up for this study is shown in Figure 11.The general trend for the dynamic modules test was that E*(dynamic modulus) increased with increasing frequency and decreased with increasing temperature.

The Advera mix has the highest E* values among the WMA mixtures followed by the Sasobit mixture with the Evotherm mix exhibiting the lowest E* values. All the mixtures have E* values lesser than the HMA mixture. The inclusion of RAP increases the E* values for each of the mixtures.

The flow number test was done on 64 test specimens which represented 16 mixtures in this study. The output of this test include cycles to failure, displacement and strain at failure in addition to displacement and strain at flow number. The control mixtures exhibited higher flow numbers compared to the three WMA technologies investigated. Moreover, the incorporation of RAP increased the FN considerably, more than 3,500 for the 30% RAP control compared to less than 500 for the 0% RAP control. The rutting resistance of WMA mixtures was lower than the HMA mixture based on the flow test results. Thus it was concluded that preparing WMA asphalt mixtures using Advera or Evotherm J1 or Sasobit at 120°C is feasible with no concerns regarding workability or compactability even in mixtures where 30% RAP was incorporated.

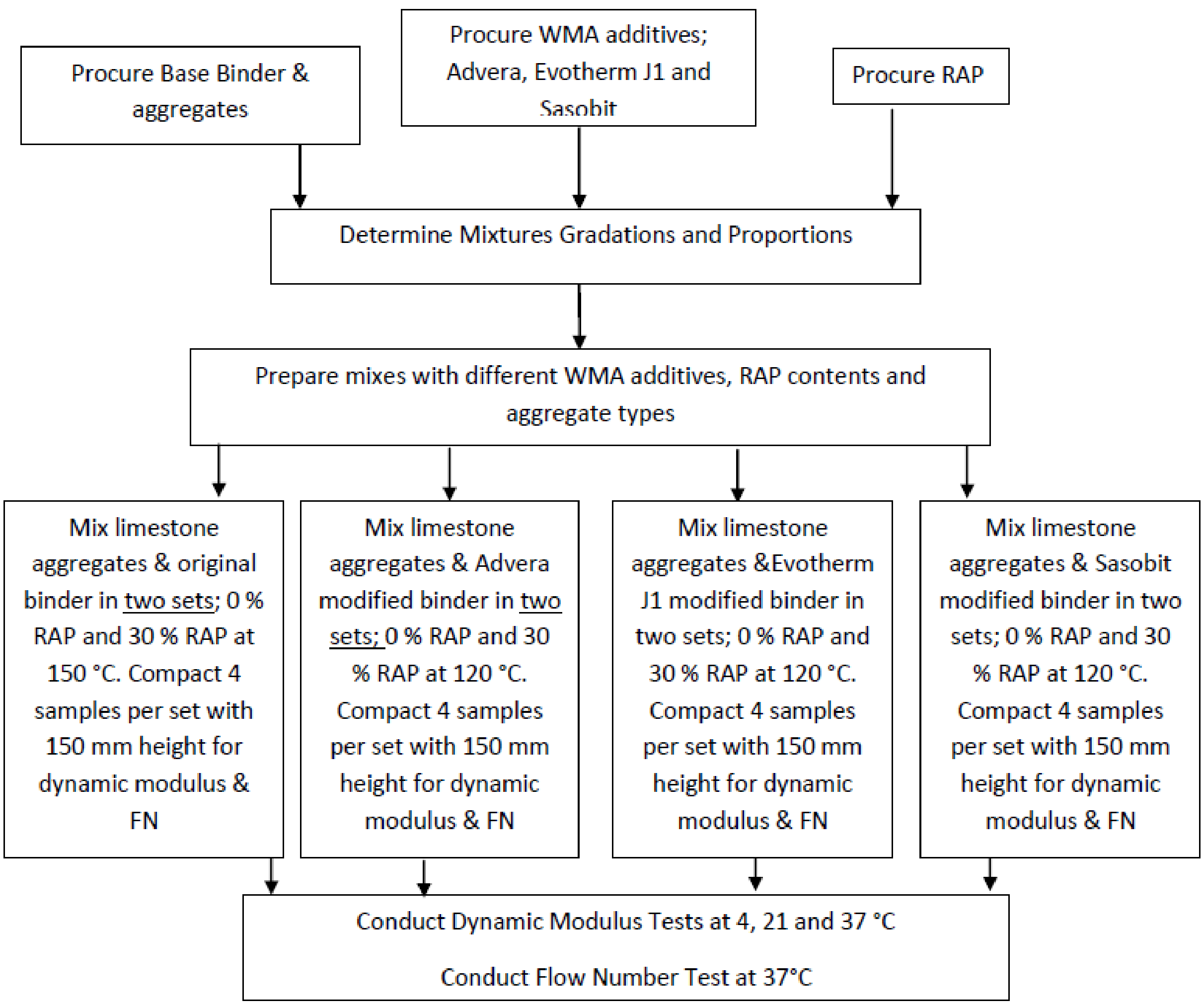


Figure 11 – Experimental set up.

Performance and Workability Characteristics of High Performance Thin Lift Overlays Incorporating High RAP Content and Warm Mix Asphalt Technology by Dr. Walaa S. Mogawer, Alexander J. Austerman, Dr. Robert Kluttz and Michael Roussel.

This paper studied the effect of high RAP content, WMA and PMA binders on the stiffness, resistance to reflective cracking, moisture susceptibility, and workability of High Performance Thin Asphalt Overlays (HPThinOL) mixtures. These HPThinOL mixtures have a thickness of one inch or less. These layers are used where there is a high need for rutting or fatigue resistance. PMA cost is more than the conventional binders and moreover the high amount of PMA required in HPThinOL makes this mixture very expensive. A cost reduction can be achieved if we used high RAP content rather than virgin asphalt binder. The experimental plan is as shown in Figure 12.

The study objectives were defined as:
1. Develop a 9.5 mm Superpave HPThinOL mixture using solely virgin materials.
2. Develop similar 9.5 mm Superpave HPThinOL mixtures incorporating a high percentage of RAP, WMA technology, and PMA binders individually and also collectively.
3. Measure the effect of RAP, WMA technology, and PMA binders on the dynamic modulus (stiffness) of the mixtures.
4. Measure the reflective cracking resistance of the mixtures using the Texas Overlay tester.
5. Measure the moisture susceptibility and rutting resistance of the mixtures using the Hamburg Wheel Tracking Device (HWTD).
6. Evaluate the effect of high RAP content, WMA, and PMA on the workability of the HPThinOL mixtures.

The dynamic modulus testing is done to determine the stiffness of the mixture after addition of PMA binder or RAP. The dynamic modulus data indicated a consistent trend, regardless of the mixture type (control or 40% RAP) or the inclusion of the WMA technology. Generally, the unmodified PG52-28 control mixtures exhibited the least stiffness. Next stiffest was the PG64-34 followed by the 200PEN + 7.5% SBS mixtures then the PG58-28 + 7.5% SBS mixtures and then the PG70-22 + 7.5% SBS mixtures which exhibited the highest stiffness of all the mixtures tested. The higher stiffness mixtures may be more susceptible to cracking if placed over a pavement that will be exposed to a high amount of deflections. The data indicated that the addition of 40% RAP to the control mixture increased the mixture stiffness as compared to the control mixture without RAP for all binder types.

The mixtures were subjected to moisture susceptibility test in the Hamburg Wheel Tracking Device (HWTD). The HWTD data indicated that the use of a polymer modified binder and/or the addition of RAP may improve the moisture susceptibility and rutting characteristics of the mixture. The use of the WMA technology in combination with the PMA and/or RAP may result in reduced mixture moisture susceptibility and rutting performance. The workability test results indicated that the addition of 40% RAP did not significantly decrease the mixture workability of the PMA mixtures, whereas the workability of the control binder mixtures was reduced. The introduction of the WMA technology to the mixtures did marginally improve the workability of all mixtures tested and may be attributed to the reduced mixing and compaction temperatures utilized for these type of mixtures.

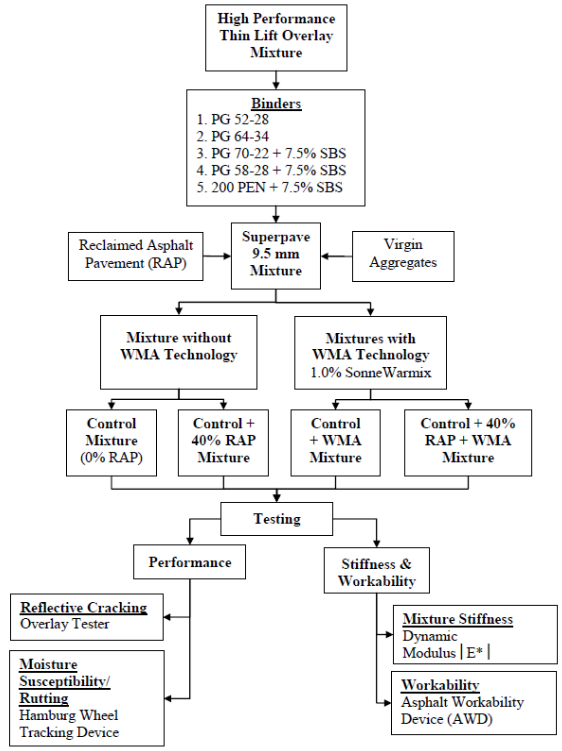


Figure 12- Experimental Set up.

A Methodology for Cost/Benefit Analysis of Recycled Asphalt Pavement (RAP) in Various Highway Applications by Burt Andreen, Harry Rocheville and Khaled Ksaibati.

This study evaluated RAP as an alternative to virgin asphalt for pavements in Wyoming. This study was funded by Wyoming DOT. The research found that RAP works as a dust suppressing agent without affecting the serviceability of the roads. The RAP was analyzed in three possible uses: RAP in Hot Plant Mix, RAP in base, and RAP on gravel roads. All the savings and benefits are normalized per ton of the RAP. The method includes factors such as savings from dust loss, layer coefficients, haul, and decreased need of virgin aggregates. In Wyoming, due to drilling activities, the amount of vehicle traffic has greatly increased. But as the county has a limited budget and drilling activities are not permanent, the need to pave the roads in conventional ways does not arise. The use of RAP will not only reduce the dust pollution but will also benefit life cycle cost.

In order to fulfill the objective of this study, the research team utilized cost information from an I-80 project where WYDOT utilized RAP in the base and asphalt surface layer. In addition, WYDOT provided Sweetwater County with RAP so that it could be incorporated in a gravel road with very heavy truck traffic. The cost and benefits obtained at this location were used to develop the methodology to determine which application was more cost effective. The benefit analysis includes four sub divisions which are summarized in Table 7.

Table 7 – Benefit template analysis for RAP.

Step	Factors	Road Application
A	**Savings from Dust Reduction:** *(Surface Area (yd^2))(Application Rate (gal/yd2/mile))(Price ($/gal))* / *(Total Aggregate (ton/mile))(Percent Dust Reduction)*	$/Ton RAP
B	**Savings from Layer Coefficients:** *(Blended Base Layer Coefficient)(Price Virgin Aggregate ($/ton))* / *(Crushed Base Layer Coefficient)*	$/Ton RAP
C	**Negative Savings from Haul:** *(Distance (miles))(Haul Rate ($/(Ton X mile)))*	$/ Ton RAP
D	**Savings from Virgin Aggregate:** *(Virgin Aggregate ($/ton)) – (Blended Aggregate ($/ton))*	$/ Ton RAP
E	**Total Benefit (A+B+C+D)**	**$/ Ton RAP**

The case study done in three possible uses of the RAP gave encouraging results. For every ton of RAP in HMA mixture, $40.87 was saved. There was also savings of $17.07 for every ton of RAP used on gravel roads. For every ton of RAP used in road base, $15.71 was saved. This analysis shows that regardless of the construction use of RAP, a savings is always realized.

Optimal Scheduling of Pavement Preventive Maintenance – A Beijing Study by Qiang Yang, Lijun Sun, Lee D. Han and Zhang Chen.

This paper investigates how to keep pavements in good conditions in this time of reduced budgets. The answer to this problem was right preventive maintenance (PM) at the right time. This paper presents a strategy to schedule the PM on the pavements of Beijing, China. The study also finds the right PM technique to be applied on pavements based on Life cycle cost analysis. This research can also be used in pavement management practices to schedule the PM activities.

The options for different types of PM are vast, so a computer algorithm is developed. Suppose there are *m* PM strategies and *n* triggering pavement conditions, thus there are *m x n* scenarios possible (treatment-timing combination). Out of these strategies, the strategy with the highest cost-benefit ratio will be selected from the computer algorithm as the most optimal solution. The pavement condition index (PCI) ranging between 0 and 100 is a good indicator of the pavement deterioration over time. The decrease in PCI can be modeled as :

$$PCI = PCIo\{1 - exp[-(A/y)B] \},$$

where *PCIo* is the PCI in the initial year, which is 100 in normal cases, *y* is the age of the pavement, and *A* and *B* are regression parameters.

The life cycle benefit cost ratio is the ratio of total benefit and the total cost in the analysis period. The total cost consists of maintenance cost and the user cost. The maintenance cost is given as :

$$\sum_{1}^{n} Pi \times hi \times A / (1+r)^{ti}$$

where MC is the present worth value of the total life-cycle maintenance cost, *N* is the total number of PM activities in the analysis period, *Pi* is the unit price of treatment , *hi* is the thickness of treatment i, *A* is the area of the concerned pavement, *r* is the interest rate, and *ti* is the time treatment *i* is applied to the pavement since the pavement is constructed.

The case study was performed on pavements in Beijing, China. For each pavement family with a different traffic level, pavement surface layer thickness, and subgrade type, one project-level optimal PM strategy was found. The analysis period was selected as 25 years, which was approximately the length of three pavement rehabilitation cycles according to historical data. There were four choices for the PM treatment in local conditions: (1) Microsurfacing (2) 2.5 cm overlay (3) 4 cm overlay (4) 6 cm overlay. If the timing of the placement of the PM is taken as PCI=85, 80 and 75, then there are total 12 choices. Life cycles cost analysis of each choice was also done. The major findings were as follows:

- Microsurfacing and 2.5 cm overlay are the most frequently used PM.
- PM treatments are applied when the pavement is in good condition (PCI = 85).
- Due to early application of PM, the frequency of PM is 3-5 years and with deterioration of the pavements, this frequency becomes much less.
- Optimal PM strategy for pavements with different subgrade types and traffic levels are quite different.

Stochastic life cycle cost analysis for pavement preservation treatments by Dominique Pittenger, Douglas D. Gransberg, Musharraf Zaman and Caleb Riemer.

The life cycle cost analysis (LCCA) of the pavement preservation techniques can help a lot in the decision making process in pavement design. The use of deterministic LCCA tends to neglect the uncertainty in the input factors like price of the commodity and the pavement life. To rectify the problems, a stochastic approach based on probability can be used to predict the LCCA.

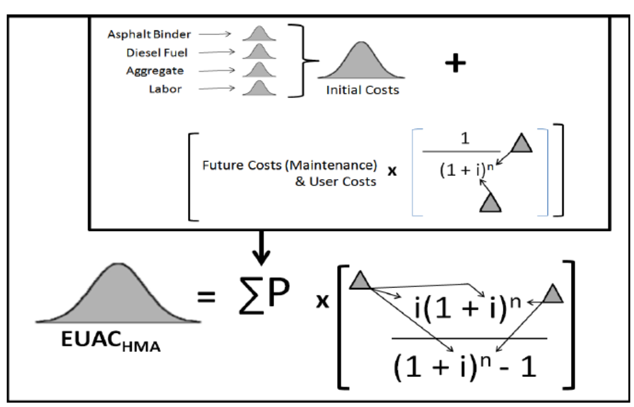


Figure 13 - Stochastic Equivalent Uniform Annual Cost (EUAC) Approach.

This study followed FHWA guidance for conducting LCCA.

- Deterministic and Stochastic Input Value Determination: The input values which are uncertain in nature should be modeled probabilistically (See figure 20). Other variables should be modeled as deterministically to simplify the analysis.
- Service Life (Analysis Period) and Discount Rate: The uncertainty in the service life creates sensitivity in the LCCA analysis. Therefore it should be treated with probability distribution approach .A triangular probability distribution seems to fit the service life in years (see Figure 13). This study uses the previous 30 years of discount rate data from the Federal Reserve, fitted to the appropriate probability distribution.
- Selecting Appropriate Probability Distributions: The “fitting” process is enabled by statistically-based goodness-of-fit tests, such as Anderson-Darling (A-D) and chi-squared tests. Software is available that completes the process in seconds.
- Risk Analysis: The risk analysis is done to account for the uncertainty in input parameters. The future outcomes represent the equivalent uniform annual cost (EUAC) values for different pavement preservation techniques. A Monte Carlo simulation is used in this study to perform the risk analysis.

The results of the stochastic analysis should be analyzed carefully and the sensitivity due to the probabilistic approach should be measured. Table 8 gives the result of the stochastic analysis.

Table 8 - EUAC LCCA Results, Stochastic Method.

HMA EUAC ($/lane-mile)				
		Variable-Year Commodity Data Sets		
		1-Year	2-Year	5-Year
Best Fit Commodity Distributions	Mean	4,743	4,712	4,563
	St. Deviation	550	551	575
	5th Percentile	3,876	3,850	3,682
	95th Percentile	5,681	5,679	5,560
	Max. Value	7,215	6,872	7,683
Normal Commodity Distributions	Mean	4,742	4,712	4,565
	St. Deviation	557	552	580
	5th Percentile	3,844	3,823	3,632
	95th Percentile	5,669	5,630	5,542
	Max. Value	7,191	7,129	7,382

It was concluded in the research that stochastic analysis gives a range of output values rather than a single value as in deterministic analysis. The high uncertainty in the cost of material commodities like asphalt in the market establishes the stochastic method as the best method to find the LCCA.