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Thin Overlay Maintenance Treatment Application in Delaware Communities

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ABSTRACT

The performance of a pavement is affected by the type and quality of maintenance it receives, as well as when the maintenance is performed. Timely preventive maintenance can slow the rate of deterioration of pavement. Delays in maintenance and deferred maintenance can increase the quantity severity of defects. Therefore, preventive maintenance is becoming the norm for most local highway agencies. Such maintenance increases the pavements condition and service life and shows promise in reducing the long-term costs of highway pavement management. Pavement preventive maintenance treatments preserve rather than improve the structural capacity of the pavement structure, and keep the pavements in sound structural condition. In addition, in order to be cost effective, preventive maintenance should be applied before a significant amount of environmental distress occurs. This work seeks to evaluate the advantage of thin overlay by performing a comparative analysis of preventive maintenance methods, and by surveying the use of thin overlays used by local communities in Delaware. Ultimately, the result of this study can be used to start the development of a unified pavement maintenance program that can be implemented by local communities.

CHAPTER 1

INTRODUCTION

1.1. Background

According to Hicks et al. (1999), to maintain the highway pavement condition at the existing level, the required cost is nearly $50 billion per year on the National Highway System in the United States; however, the United States spends about $25 billion annually for maintenance. Furthermore, $200 billion is anticipated to bring highway pavements up from their existing condition level to good level. Accordingly, it is clear that traditional pavement maintenance approach, which is known as worst first philosophy, cannot provide a good quality system to the public user, there in engineers at the various levels of DOTs have tried various techniques to preserve our investment for roadways and highway facilities with limited budget. To maximize their effort, Pavement Management Systems (PMS) are commonly used to overcome the budget constraint. As Galehouse et al. (2005) highlighted the following in their research, "*a sound pavement preservation program can reduce costs while improving the overall quality of our pavement network if preventive maintenance treatments are applied before corrective maintenance is needed*", the benefits of preventive maintenance treatments for long lasting and effective pavements have been studied widely in pavement engineering, and proved through thousand research studies in pavement area.

1.2. Statement of the Problem

Presently, most communities in the state of Delaware have been using various forms of preventive maintenance for flexible pavements. It is not clear how these maintenance treatments are performing. There is no comparative analysis of the cost and effectiveness of the various treatment methods. Furthermore, there are no connections between the ratings and maintenance treatments used by communities and Delaware Department of Transportation (DelDOT) official pavement management policy.

1.3. Objectives

This work seeks to evaluate the advantage of thin overlay by performing a comparative analysis of preventive maintenance methods, and by surveying the use of thin overlays used by local communities in Delaware. Ultimately, the result of this study can be used to start the development of a unified pavement maintenance program that can be implemented by local communities, including the development of Pavement Distress Criteria to rate the local roads and pavements across the state.

1.4. Research approach

The research approach that was used to attain the objectives involves literature review of various preventive maintenance techniques and survey regarding thin overlay, and development of a decision tree for preventive maintenance techniques.

Essentially, the completion of the research involved the following:

1. Conducting a comprehensive literature review of various case studies in the U.S.
2. Conducting a survey with the help of responses from questionnaires sent out to various local communities' agents in Delaware.
3. Analyzing the results of the case studies and data from the surveys.
4. Development of a decision tree for preventive maintenance techniques.
5. Development of a selection procedure for the most appropriate overlay technique for Delaware.

CHAPTER 2

BACKGROUND

2.1. Introduction

The performance of a pavement is affected by the type and quality of maintenance it receives, as well as when the maintenance is performed. Timely preventive maintenance can slow the rate of deterioration of pavement. Delays in maintenance and deferred maintenance can increase the quantity severity of defects. Therefore, preventive maintenance is becoming the norm for most local highway agencies. Such maintenance increases the pavements condition and service life and shows promise in reducing the long-term costs of highway pavement management. Pavement preventive maintenance treatments preserve rather than improve the structural capacity of the pavement structure, and keep the pavements in sound structural condition. In addition, in order to be cost effective, preventive maintenance should be applied before a significant amount of environmental distress occurs. For example, once a substantial crack occurs on the pavement surface it is easier for water to infiltrate into the outer layer of the pavement and weaken the subgrade structure. Additionally, repeated freeze-thaw problems in the crack may develop and any expansive materials that get into the crack may increase the crack width. Therefore, as

Hicks et al. (1999) pointed out, *various treatments of the type and application for both preventive and corrective maintenance has been the theme of research studies for long time, and many publications have reported these findings*.

2.2. Pavement Maintenance and Treatment

Pavements begin to gently deteriorate right after implementation, and then rapidly deteriorate after they pass a certain point. Normally,that certain point is minimum level of fair condition, so preventive maintenance should be performed before pavements begin to rapidly deteriorate. Otherwise, corrective maintenance is required to bring the pavement condition to higher than good condition. Figure1.1. shows typical variation in pavement conditions as a function of time. In figure 1.1, 40% of pavement quality drops during 75% of pavement life, and then another 40% of same pavement quality drops during 12% of pavement life. Maintenance treatment that is performed when pavement condition is between excellent and fair condition is called preventive maintenance and which is performed when pavement condition is below fair condition level is called corrective treatment or rehabilitation. Usually, corrective maintenance cost is more than four times that of preventive maintenance cost to meet good condition level.

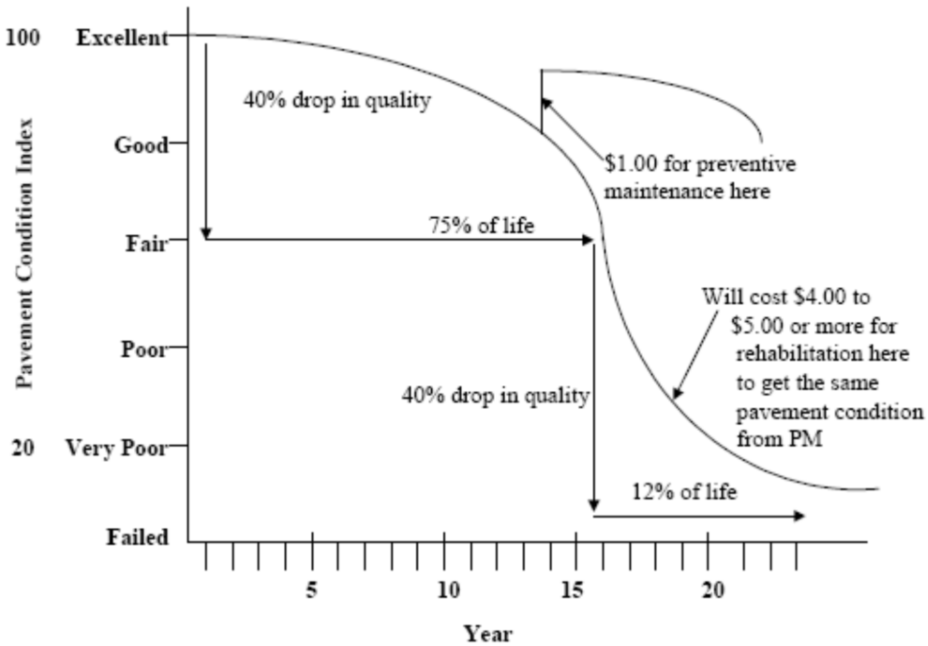

Figure 2.1. Typical Variation in Pavement Conditions as a Function of Time [Hicks et al., 1999]

Source: Selecting a preventive maintenance treatment for flexible pavement

Thin Hot Mix Asphalt (HMA) concrete overlay, Micro-surfacing (Slurry Seal), and Seal Coating (Chip Seal or Bituminous Surface Treatment) are preventive maintenance techniques typically applied to flexible pavements. Thin HMA overlay involves the application of a thin layer (typically not exceeding 1.5-in./35.1mm) of hot mix asphalt concrete over flexible pavement. The use of Stone Mastic Asphalt or Stone Matrix Asphalt (SMA) for overlays has been proposed recently. Proponents of this technique advocate the use of a “fine” SMA mix, which can be placed in thinner lifts for preventive maintenance, especially in the area of rut resistance.

Table 2.1. Frequency of Preventive Maintenance Treatment [NCPP]

Treatment	Year
Crack Sealing	2-4
Fog Seals	2-4
Chip Seals	4-8
Slurry Seals	4-10
Micro-surfacing	6-12
Thin and Ultra-thin HMA Overlay	8-15

Source: National Center for Preventive Preservation

Table 2.2. Estimated Life Extension (year) [NCPP]

Treatment	Good Condition (PSI=80)	Fair Condition (PSI=60)	Poor Condition (PSI=40)
Fog Seal	3-5	1-3	1-2
Chip Seal	7-10	3-5	1-3
Slurry Seal	7-10	3-5	1-3
Micro-surfacing	8-12	5-7	2-4
Thin HMA Overlay	10-12	5-7	2-4

Source: National Center for Preventive Preservation

Table 2.3. Preventive Maintenance and Treatment

Type	Description
Fog Seal	A fog Seal is a light application of diluted slow-setting asphalt emulsion to the surface of an oxidized pavement surface. Fog seals are low-cost and are used restore flexibility to an existing HMA pavement surface. The drawback of fog seals is that it can make roadway surface very smooth; thus, it can cause a loss of skid resistance [Muench et al., 2002].
Patches	Patches are a common method to treat an area of localized distress; therefore, it is the most frequent routine or preventive maintenance. Patches can be either full-depth where they extend from the pavement surface to the subgrade or partial where they do not extend through the full depth of existing pavement. Patching material can be just about any HMA or cold mix asphalt materials as well as certain type of slurries. Typically some form of HMA is used for permanent patches, while cold mix is often used for temporary emergency repairs [Muench et al., 2002].
Chip Seal/ BST / Seal Coat	The primary benefit of seal coat is that it greatly slows the whole asphalt degradation process. The natural destruction of pavement begins to oxidation of its chemical binder when it is exposed to ultraviolet, then this oxidation causes shrinkage of binder and cracking of its binder and aggregates, therefore, one of main purpose of seal coat/BST/chip seal is sun blocking. One important drawback of chip seal is loss of aggregates under high volume and high-speed traffic. Although the development of asphalt cements made it possible to use it on high volume and speed roadways, use of studded tire on non-icy surface during winter season can severely affect the loss of aggregates.
Slurry Seal/ Micro-surfacing	Micro-surfacing refers to the laying of a mixture of polymer-modified asphalt emulsion and crushed mineral aggregate on slightly rutted asphalt pavement surface. Micro-surfacing can be placed on layers of up to 2-inche. It is not desirable to apply micro-surfacing when either the pavement or air temperature is below 50^{o} F and falling because polymer-modified emulsion layer may get cold then it can affect the performance of it; however, it may be used when both pavement and air temperatures are above 45 degree F and rising. Also, if there is possibility that finished product will freeze within 24 hours, micro-surfacing should not be applied [Stidger, 2002]. Micro-surfacing is the advanced form of slurry seal.

Table 2.4. Pavement Treatment [Bolander P.W., 2005]

		Seal Surface	Seal Crack <1/4 in.	Protect from Spills	Prevent Raveling	Replace Fines	Rejuvenate	Improve Aesthetics	Improve Traction	Cost ($/y2)	Expected Longevity (year) <100 ADT	Expected Longevity (year) 100< ADT <500	Open to Traffic	Characteristics
Bituminous Sprays	Fog Seal	XX	X	-	X	-	-	X	-	0.15-0.45	2-4	1-3	Typically after 2h	Reduction of skid resistance
	Rejuvenation	-	-	-	XX	-	XX	-	-	0.45-0.65	1-4	1-2	Typically after 2h	Does not seal surfaces
	Fog Seal+ Rejuvenator	XX	XX	-	X	-	X	X	-	0.50-0.65	1-4	1-2	Typically after 2h	Reduction of skid resistance
Bituminous Sprays followed by Aggregate	Sand Seal	XX	X	-	X	XX	-	-	X	0.75-0.95	2-4	1-5	*Completely open after 2h	
	Restoration seal	XX	X	-	X	XX	-	X	X	0.60-0.75	2-4	1-3	*Completely open after 2h	
	Scrub Seal	XX	XX	-	X	XX	-	-	X	0.60-1.30	2-8	2-6	*Completely open after 2h	Need uniform surface texture
	Chip Seal	XX	XX	-	XX	X	-	X	XX	1.20-1.50	4-12	3-6	*Completely open after 2h	Loose of aggregates
Cold Bituminous Mixture	Driveway/ Parking Lot	XX	X	XX	X	XX	-	X	X	0.75-1.50	4-6	2-3	**Completely open after 2h	
	Slurry Seal	XX	-	XX	X	XX	-	X	XX	0.75-1.50	5-10	5-8	**Completely open after 2h	
	Micro-surfacing	XX	-	-	X	XX	-	X	XX	0.95-1.85	8-15	6-8	Typical after 1-2h	
	Cape seal	XX	X	-	X	X	-	X	XX	1.75-2.50	8-15	6-8	Typical after 1-2h	

XX=Primary Function, X=Secondary Function
* Typically to open to reduced traffic speeds or non-turning traffic in less than 1 hour
** Typically to open to reduced traffic speeds or non-turning traffic in less than 2 hour

Source: Seal Coat Options: taking out the mystery

2.2.1. Thin Overlay

Chip seals do not add structural strength; furthermore, detached aggregates detract from roadway user satisfaction and cause damage to vehicles on highways. Slurry seal and micro-surfacing require relatively high cost without structural strength. However, HMA overlay adds structural capacity, seals cracks, improves ride quality, enhances skid resistance, reduces noise, and improves drainage. No other treatment can provide these benefits; furthermore, competitive treatment cost effectiveness is another advantage of overlays considering long-term performance. Overlays can be placed in various thicknesses. Table 2.5. shows pavements' functional problems and their cause, which may be solved by overlay treatment. Thick overlays add substantial strength to a pavement structure when existing pavements' structural capacity is deteriorated. Thin overlays (1.5-in./35.1mm or less) also partly add structural capacity to a pavement, and, as long as pre-treatments (sealing or milling) are applied before overlay implementation, all benefits that are mentioned above can be expected on thin overlays. Overlays can also be placed very thin, close to about 0.5-in. thick. The increase in structural capacity would vary depending on the thickness and condition of the existing pavement.

Table 2.5. List of Recommended Overlay Solution to Functional Problems [Colorado Department of Transportation, 2005]

Functional Problem	Cause	Possible Solution
Surface Friction	Polishing or Bleeding of Surface	Thin overlay or micro-surfacing, milling maybe required
Hydroplaning	Wheel Path Rutting	Thin overlay or micro-surfacing, milling maybe required
Surface Roughness	Distortion Due to Swell and Heave	Leveling overlay with varying thickness
Transverse and Longitudinal Cracking	Traffic Load, Climate and Material	Conventional overlay and full depth repair may remedy thin problem
Potholes	Traffic Load	Conventional overlay and full depth repair may remedy thin problem
Raveling of the Surface	Climate and Materials	Thin overlay or micro-surfacing or hot-in-place recycling
Raveling of the Surface	Inadequate Freeze Thaw Resistance	Removal of entire layer affected by stripping

Source: CDOT Pavement Design Manual

Table 2.6. and figure 2.1. below that the advantage of thin overlay in cost per mile per year of roadway treatment. From the cost-effectiveness aspect, thin overlay is quite competitive. Figure 2.1. shows that thin overlay construction cost is less than chip seal and micro-surfacing, which are commonly used in the U.S. However, table 2.6. shows that thin overlay is the least cost effective treatment, because the construction cost per year was not considered in table 2.6. That means thin

overlay is cost effective for a long period of time, although initial construction cost is expensive.

Table 2.6. Cost of Thin Maintenance Surfaces [Jahren, C. T., Nixon, W. A. and Bergeson, K. L., 2003].

Treatment	1996 cost /yd ^{2}	1997 Cost / yd ^{2}	Comparison to Seal Coat Cost
Micro-surfacing	$1.29	$1.48	1.82
Fog Seal	$0.11	$0.11	0.13
Seal coat	$0.71	$0.81	1.00
Slurry seal	$0.92	$0.92	1.14
1-inch ACC overlay*	$2.27	$2.50	3.09
2-inch ACC overlay*	$3.55	$3.91	4.82

Note: Includes the cost of traffic control and mobilization. Local system costs may be lower.
*Include the cost of adding shoulder aggregate

Source: Thin Maintenance Surfaces

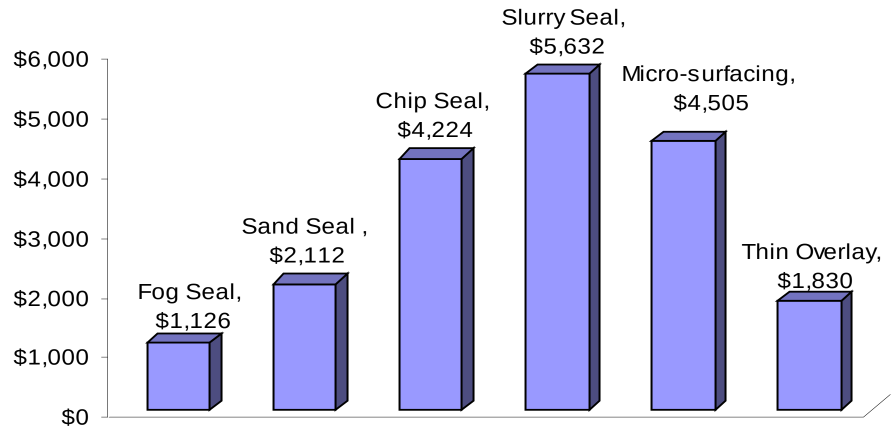

Figure 2.2 Cost/ Mile/ Year of Roadway of Surface Treatments (24 ft. width) [What exactly is your preventive maintenance program preventing?]

Source: The Flexible Pavements of Ohio, Report on Smoothseal

(Information compiled by the Minnesota Asphalt Pavement Association, year 2001)

2.2.2. Ultra-Thin Bonded Overlay

One type of thin overlay is Ultra-Thin Bonded HMA Wearing Course (UTBWC) that is composed of a layer of HMA laid over a heavy asphalt emulsion layer. This approach was developed by *Screg Routes et Travaux Publics* in France in 1986 and introduced in the United States in 1992. The thickness of the ultra-thin surface layer ranges from 0.375 in. to 0.75 in. (9.5 mm to 19 mm). UTBWC should be placed on a structurally sound rigid or flexible pavement that may exhibit minor surface distresses. One of the benefits of UTBWC is that after application the road can be opened to traffic in about 15min. However, since UTBWC treatment involves laying a very thin course of HMA on asphalt emulsion, construction conditions, such as weather, air temperature, and traffic density, are critical; thus, spread and compaction processes must be done immediately after the application of UTBWC and should be finished before the mix temperature drops below 185F^{o} (85C^{o}) [Hanson, 2001].

The ultra-thin bonded HMA should not be placed on existing flexible pavement with longitudinal cracking that exceeds the medium severity level as defined by the *Distress Identification Manual for the Long-Term pavement Performance Program.* Also Hanson (2001) mentioned in his research that *block cracking, edge cracking and reflection cracking at the joint should not exceed the moderate severity level, and any cracks greater than 0.25 in. should be cleaned, routed and sealed.* The system does not strengthen the structure a pavement, so any structural problems should be repaired prior to the application of UTBWC [Hanson, 2001].

The following conclusions are drawn in Hanson's research based on a review of the literature, conversations with DOT and industry personnel, and personal inspection of a number of ultra-thin bonded HMA overlays

- *UTBWC provides excellent aggregate retention.*
- *UTBWC has excellent bond to the existing pavement surface. Delamination of the system from the surface is generally not a problem.*
- *Since the ultra-thin bonded HMA wearing course surface has excellent macro texture qualities, UTBWC will provide a surface with a high level of skid resistance. And, because of its high macro texture surface, it should also provide a surface that will reduce hydroplaning problems.*

Cracks in the existing pavement will reflect through the surface.

2.2.3. Non-typical mixture

2.2.3.1. Smoothseal

Smoothseal is asphalt concrete that blends high-quality aggregates with polymer-modified asphalt to produce a dense-graded and durable mixture. Usually the thickness of the system ranges from 0.625 in. to 1.50 in. (17.1mm to 38.1mm). There are two types of Smoothseal, type A and type B, and they are differentiated by particle size and asphalt binder contents. Type A is a mixture of asphalt sand and mason sand with an 8.5 % asphalt binder content, and type B is a mixture of coarse aggregate of 0.5 in.(12.7mm) maximum size and sand size particles with a minimum asphalt binder content of 6.4 %. The official web site of Flexible pavement of Ohio (http://www.flexiblepavements.org) recommends that thickness of type A, for medium traffic and urban application, should be from 0.625 in. to 1.125 in. (17.1 mm to 28.5 mm) and thickness of type B, for all applications including heavy and high speed applications, should be 0.75 in. to 1.50 in. (19.0 mm to 38.1 mm) [Hansen, 2003].

Also the official web site of Flexible pavement of Ohio mentioned that *"Smoothseal is used to restore the protective wearing course of a pavement from raveling and weathering, to improve ride quality of deteriorated pavement surface, to add structural integrity on high-volume roads, and to endure reflective cracking."*

2.2.3.2. Rubberized asphalt

Rubberized asphalt concrete mixture is another example of the use of unconventionally modified binder. American Society for Testing and Materials (ASTM) defines rubberized asphalt as "*a blend of asphalt cement, reclaimed tire rubber, and certain additives in which the rubber component is at least 15 percent by weight of the total blend and has reacted in the hot asphalt cement sufficiently to cause swelling of the rubber particles*." In Arizona, rubberized asphalt generally consists of 18 to 20% ground tire rubber blended with paving-grade asphalt. The asphalt rubber binders used in Arizona are very viscous; therefore, drain-down of the binder is seldom a problem with these mixtures, also this problem cause extra expenditure to clean batch after construction. For this reason asphalt rubber mixtures have higher binder contents than many conventional mixtures.

The binder contents for gap-graded mixtures and open-graded mixtures are generally between 7.5% and 8.5% and between 9% and 10% respectively. Although the increased binder content increases the flexibility of both mixtures and noise reduction in urban areas, the increase of binder also increases the cost of application [Hansen, 2003].

The primary benefit of rubberized asphalt is recycling of waste tire, and another environmental benefit of the mixture is that it decreases noise level. It is reported that rubberized asphalt application on high-volume highways reduces the noise up to 5 decibels. Just as other modified binder resist rutting better than conventional binder, rubberized asphalt also has better resistance, and it is reported that the rubberized asphalt improves skid resistance.

Table 2.7. shows cost comparison between conventional, modified, and rubberized asphalt application.

Table 2.7. Typical year 2000 in place costs for both hot mix and chip seals [State of California Dept of Transportation, 2003]

Mixture	HMA ($/ton)	Chip Seal ($/m^2)
Conventional Asphalt	33-38	1.2-1.5
Modified Asphalt	38-44	1.5-1.8
Rubberized Asphalt	49-55	3.0-3.6

Source: Asphalt Rubber Usage Guide

2.2.3.3. Stone Matrix Asphalt

During the European Asphalt Study Tour in 1990 (Larson, 1990), it was found that a Split Mastic or Stone Matrix Asphalt (SMA) had been successful at providing a highly rut-resistant, durable asphalt surface mixture. Therefore, several agencies in the U.S. worked together to place test sections in the U.S. in order to gain valuable insight and experience with this relatively new mix design. Maryland alone has constructed more than 85 SMA projects and uses SMA as a standard practice on projects that have more than 20,000 Average Annual Daily Traffic (AADT) and traffic speed of 55 miles per hour or greater. Georgia also uses SMA both on all interstate highways and on high volume state roadways as a matter of policy [Watson, 2003].

Since SMA represented new mix design technologies in the U.S., Watson conducted a condition survey within a few years of initial construction to evaluate Stone Matrix Asphalt projects constructed throughout the country and to make recommendations for changes if required. The SMA projects were constructed from 1991 to 1995 and included a variety of test sections involving modified asphalts and/or fiber stabilizers. Based on the survey, Watson (2003) found that SMA mixture has given exceptional rut-resistant performance even though these mixtures have been used on some of the highest traffic volume routes. Rutting in excess of 0.25 in. (6 mm) was a problem for only one (8%) of the SMA projects; it was overlaid after three years due to the degree of rutting at intersections. The rut-resistant, durable SMA mixes have resulted in some states implementing SMA as a matter of standard policy [Watson, 2003].

The following conclusions are drawn in Watson [2003]

- *SMA mixture has been shown to be rut-resistant even when placed on high traffic volume facilities.*
- *Much of the observed cracking, especially load-related cracking, appeared to be more related to problems other than mix design or material properties (such as underestimating traffic volumes, or using less than the normal 20-year pavement design life) of the surface courses.*
- *Premature distress on some of the projects in this study was a result of end-of-load segregation and not necessarily a mix design problem.*
- *Several of the SMA projects are still in excellent condition after being in service for 5 and 9 years, respectively.*
- *SMA mixes may significantly reduce the propagation rate of reflective cracking*

2.3. Performance of Pavement Maintenance

Roughly, the performance of a pavement would depend on roughness and rutting and cracking in pavement. These three categories are mentioned in the present section.

2.3.1. Roughness

Roughness is a barometer for roadway evaluation related to ride-quality. ASTM defines (E867) road roughness as "the deviation of a pavement surface from true planer surface with characteristic dimensions that affect vehicle dynamics, ride quality, dynamic loads and drainage, for example, longitudinal profile, transverse profile and cross slope." Therefore, roughness affects comfortable and safe vehicle operation, vehicle operation cost and fuel consumption, as well as ride-quality.

Compared to other preventive treatments such as slurry seal, crack sealing, and chip seal, Hall et al. (2002) mentioned in their study that thin overlay treatment had significant effect on not only initial roughness reduction but also long-term roughness. For lower ride-quality pavement, chip seal also had some effect on long-term performance regarding roughness; however, slurry seals and crack seals did not show long-term roughness. In Hall et al.'s (2002) test section of thin overlay and slurry seal, a slight but statistically noticeable correlation was detected between average annual precipitation and International Roughness Index value increment [Hall et al., 2002].

Tighe et al. (2001) also had got valuable information on roughness after only eight years of observations in their Canadian Long Term Pavement Performance project. The following conclusions are drawn in Tighe et al. [2001]

- *Progression of roughness for thin overlays (30-60 mm) is higher than for medium (60-100 mm) and thick (100-185 mm) overlays.*

- *In wet, high freeze zones, thinner overlays show a higher rate of roughness progression than thicker overlays, regardless of subgrade type.*
- *In dry, high freeze zones, roughness progression for medium and thick overlays is relatively small.*
- *In wet, low-freeze zones, thinner overlays combined with a fine subgrade show the highest rate of roughness progression.*
- *Traffic, in terms of Equivalent Single Axle Loads (ESALs) seemed to have a limited effect for all the above; this was attributed largely to all the traffic essentially falling into one level and the 200,000 ESALs per year designated as the boundary between low and high traffic levels.*

2.3.2. Cracking

In general, there are four different type of cracking: longitudinal cracking, which is a parallel crack to the wheel path, transverse cracking, which is perpendicular cracks to the wheel path, block-cracking, which is a crack with rectangular shape, fatigue cracking, which are interconnected cracks after appearance of longitudinal cracks in the wheel path and similar to alligator skin.

Fatigue cracking has so far been remarkably consistent among the thin overlays in the Hall et al.'s (2002) study, Specific Pavement Studies (SPS-3) experiment, which pavements range from about two to eleven years in age. Some control sections have more than four times as much cracking as the thin overlay sections at the same sites. The chip seals and slurry seals were also exhibiting relatively less cracking than the control sections; however the crack seal treatment did not show reduction in long-term cracking at all. Furthermore, the crack seal sections showed more long-term cracking than the control sections. Hall et al. (2002) explained crack seal's drawback that "*this may not be due to any truly adverse effect of crack sealing, but rather to (1) sealing of new cracks (cracks that appeared after the initial treatment date), and/or (2) the greater visibility of sealed cracks* [Hall et al., 2002].

2.3.3. Rutting

Rutting is appearance of surface depressions in the wheel paths. Compared to other preventive treatments such as slurry seal, crack sealing, and chip seal, Hall et al. mentioned in their study that thin overlay treatment had a significant initial effect on rutting and the greatest effect on long-term rutting development. It is found that only age was significantly correlated to the rate of rutting in thin overlay sections. Average annual precipitation was the only one of the investigated factors that was found to be significantly correlated to the increment of rutting in crack seal and chip seal sections [Hall et al., 2002].

2.3.4. Long-term effectiveness of thin Hot Mix Asphalt overlay

Labi et al. (2005) presented and demonstrated a methodology for determining the long-term effectiveness of thin overlay treatments using three measures of effectiveness: maintenance treatment service life, increase in pavement condition, and area bounded by the performance curve. For each measure of treatment effectiveness, three pavement performance indicators are used in: International Roughness Index (IRI), Pavement Condition Rating (PCR), and rutting. Depending on levels of weather severity, traffic, and roadway type, it is shown that the service life of thin overlay treatments is approximately 3-13 years (when IRI is used as the performance indicator), 3-14 years (for rutting) and 3-24 years (for PCR). Labi et al.' (2005) suggest that increased severity of either weather or traffic effects may cause a drastic decline in the treatment service life; further, that the effect of increased traffic on service life reduction seems to be greater than the effect of increased weather severity, for interstate pavements on the basis of IRI. However, on the basis of rutting and PCR, the effect of increased traffic on service life reduction seems to be less than the effect of increased weather severity by a similar rate, for both interstate roadway pavements and non-interstate pavements. Furthermore, on the basis of IRI, service life of thin Hot Mix Asphalt (HMA) overlay treatment at non-interstate sections consistently exceed those of their interstate counterparts by 47-56% when IRI is used, but are at least 44% lower than their interstate counterparts when rutting and PCR are used [Labi et al., 2005].

When the increase in average pavement condition for the treatment life is used as the measure of effectiveness, depending on the roadway type, traffic level and weather severity, the results show that thin HMA overlay treatments show a 18-36% decrease in IRI, a 5-55% reduction in rutting, and a 1-10% increase in PCR. Labi et al. (2005) suggest that higher levels of traffic or weather severity leads to only slight effectiveness reduction of the treatment, when IRI or PCR is the performance indicator. However, when rutting is used, it seems that higher traffic level leads to bigger average rutting reductions for interstates but actually the same for non-interstates and that for severer weather at constant traffic, average rutting reduction is smaller. On the basis of rutting and PCR, however, thin overlays seem to be more effective in increasing the condition of interstate pavements compared to non-interstates [Labi et al., 2005].

CHAPTER 3

THIN OVERLAY PAVEMENT SURVEY IN DELAWARE

48 incorporated places in Delaware were surveyed to learn how these local municipalities were addressing maintenance of their roads. The survey targeted the use of hot mix asphalt overlays and the assessment of existing pavements at the local level. Using the State of Delaware Website, the database of Incorporated Places in Delaware was created. In order to collect qualified data, it was solicited by the Road Masters or Directors of Streets in local Public Works Departments. If the municipality was not large enough to support either a street or public works department, it was solicited to the Town Manager, Clerk or Mayor, with priority given in the order. Of the 48 municipalities solicited, only 17 communities participated in the survey by completing the questionnaire and returning the Survey in the SASE provided. An alphabetical listing of the communities is included in Table 3.1. The results of the survey are presented in the paragraphs below.

A copy of the survey is presented in Appendix-I. Question 1 of the Thin Overlay Pavement Survey asked if thin overlays for preventive maintenance were used in the community. These 12 questions were put forward to know the use of thin overlay in Delaware communities. First 1 to 4 questions are focused on knowing whether local communities adopt preventive pavement maintenance, use thin overlay as maintenance, or how they use thin overlay. Question 6 and 7 were focused on knowing how local communities support preventive maintenance system. Question 7 and 8 were focused on knowing local communities select mix type. Question 11 was focused on how local communities perceive pavement defect. Finally, question 12 was put forward to know what criteria local communities use. Survey answers are tabulated in table 3.1.

Approximately fifty percent of the participating local governments indicated using thin overlays for preventative pavement maintenance. Of the eight communities indicating past or current use of thin overlays:

- Two communities make use of other preventive maintenance techniques such as micro-surfacing and seal coating techniques,
- Three municipalities utilize HMA overlays over existing rigid/concrete pavements, and
- Seven of the eight communities have used HMA overlays over existing flexible pavements.

Specifically, The City of Seaford indicated that the city has used thin overlays; it has not utilized other preventive maintenance techniques since 2000, approximately 4 years ago. Additionally, the Town of South Bethany indicated that while it does not use thin overlays, it may consider the use of micro-surfacing or seal coatings in the near future.

Thin overlays over existing flexible (asphalt) pavements were used by 7 of the 8 communities. The Town of Bridgeville was the one community to indicate that thin overlays were used over rigid (concrete) pavements, but remarked that the overlays have had little success in holding up.

A typical overlays section measures 2 inches (50.8mm) thick, as reported by the seven communities utilizing thin hot mix asphalt overlays. Two of the seven communities remarked that 1.5 in. (38.1 mm) overlays have been constructed on some of their roads. All of the communities using HMA overlays subcontract the work to private paving contractors, but only three of the communities require the paving contractor to submit a mix design for the HMA to the Town or City prior to the start of the work. All the participating communities that have used some form of preventive maintenance indicated that the HMA overlays were used in areas of low traffic within the respective community; 85 percent of the surveyed communities use the HMA overlays in areas of medium traffic, and 43 percent of the communities use the HMA overlays in areas of high traffic. It is important to note that traffic classes were not defined in the survey. The participants were given the traffic class with no distinction between classes.

Question 11 of the Thin Overlays Pavement Survey inquired into the frequency of road condition surveys made in the local communities. The importance of this question was to provide some insight into how those participating perceive pavement problems, and if they had a clear understanding of the problems. The participants commented that road assessments were typically performed by the public works departments or addressed with resident requests.

- One community assesses its roads bi-annually,
- Two of the 17 communities assess their roads monthly, and
- Fourteen of the participating municipalities perform yearly road assessment.

Since accurate reports of pavement conditions are crucial to pavement management and maintenance activities, we asked whose guidelines or criteria the communities use to assess the condition of the pavement. These communities responded by stating they use DelDOT's criteria. The town of Millville currently has no municipal streets; all streets and roads are maintained by DelDOT, and therefore, are designed, constructed and maintained by DelDOT.

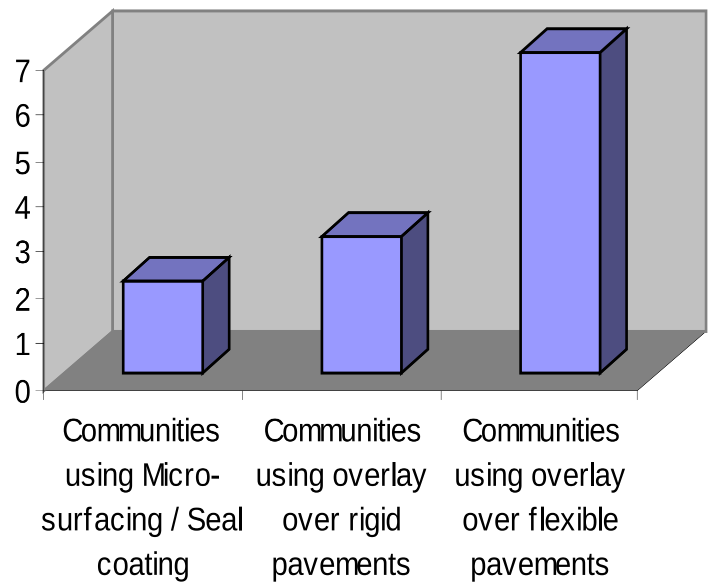

Figure 3.1. Type of Preventive Technique used by Surveyed Delaware Communities

Table 3.1. Survey Answers

	Criteria	Answered
1	Does your community use thin overlay for pavement preventive maintenance?	8 out of 17 communities
2	Does your community use micro-surfacing or seal coatings techniques for preventive maintenance?	2 out of 7 communities
3	Are thin overlay used over flexible pavement?	7 out of 8 communities
4	Are thin overlay used over rigid pavement?	1 out of 8 communities
5	What thickness of asphalt is used in the overlay?	7 out of 7 communities 7 out of 7 communities
6	Does your community require a certain mix design to be used for thin overlay?	0 out of 8 communities
7	Is the work performed by in-house crews?	1 out of 9 communities
8	Is the work is subcontracted to a private contractor, does the contractor select the mix design used for the thin overlay?	3 out of 8 communities
9	Do you require the contractor to submit a mix design prior to the start of work?	3 out of 8 communities
10	Are thin overlays used is areas of low, medium or high traffic?	4/8 :High 7/8:Medium 8/8: Low
11	How often are conditions of the roads in your community surveyed?	1/17: 2 year 14/17 :1 year 2/17 : 1 month
12	What/Whose guidelines do you use to assess the condition of the pavements?	3 out of 8 communities

Table 3.2. Tabulation of Surveyed Incorporated Places in Delaware

Community Name	**Response Received**	**Use Overlays**
Arden		
Bellefonte		
Bethany Beach	X	X
Bethel	X	
Bridgeville	X	X
Camden	X	
Cheswold		
Clayton	X	X
Dagsboro		
Delmar	X	
Dewey Beach		
Dover		
Elsmere	X	
Farmington		
Felton		
Fenwick Island		
Frankford		
Frederica		
Georgetown		
Greenwood		
Harrington	X	
Hartly		
Henlopen Acres	X	X
Kenton		
Laurel		
Lewes	X	X
Magnolia		
Middletown	X	X
Milford		
Millsboro		
Millville	X	
Milton		
Newark		
New Castle	X	
Newport		
Odessa		
Ocean View		
Rehoboth Beach	X	X
Seaford	X	X
Selbyville	X	
Smyrna		
South Bethany	X	
Townsend		
Viola		
Wilmington		
Wyoming		

CHAPTER 4

DISCUSSION SURVEY RESULTS

From the response to the survey (17 of 48 completed survey), it can be gathered that although the local communities are responsible for 11 percent of Delaware's roads, the communities do not use or support pavement preventive maintenance programs, with the exception of one community. The town of Bethany Beach has adopted a new strategy towards their road repairs. The town hired an independent consulting engineer, who generated a Pavement Management Report. Now, the town evaluates the pavement yearly, following the recommendation of the report. Additionally, the Town of Bethel, which does utilize HMA overlays, merely, repaves all the town streets every ten years at 2-inch thickness.

Two key findings of this survey, even with 35 percent of those surveyed responding are 1) generally, the communities do not require a certain mix design to be used for their HMA overlays, and 2) only three communities responded that pavement conditions are assessed using DelDOT's distress identification criteria. Since accurate distress reports are essential to the selection and implementation of preventive techniques, inquiry into DelDOT's distress identification manual was made. *DelDOT's Road Design Manual Section 9.7.6.1*: Pavement Selection: type of Overlay and Their Functions states that overlays require a fairly detailed analysis, which involve initial construction and pavement information, pavement distress survey, existing layer properties, future traffic analysis, existing pavement subgrade properties, overlay design properties, determining effective structural capacity, future overlay structural capacity, desired remaining service-life, and required overlay thickness.

However, DelDOT does not have their own Pavement Distress Survey, but has adopted the AASHTO's criteria. A possible solution to educating the local governments on preventive technique would be an acceptance of a state developed Pavement Distress Identification Manual. The manual would be used as a baseline for identifying and quantifying distresses on municipal streets. The majority of the local governments solicited indicated that while they do not use HMA overlays for preventive maintenance, they are currently exploring and researching them, so the adoption of such a toll may prove beneficial for the local governments.

The Distress Identification Manual Developed under the Strategic Highway Research Program as part of the Long Term Pavement Performance (LTPP) program. The manual through the use of drawings, text and color photographs is used to identify pavement distress, rate the severity and propose possible causes of the observed distress. A common language is used so that the person writing the report and the persons reading the report have the same accurate understanding of the problem. The benefits of such a manual on the local government scale would be an accurate recording of pavement distress types and rating (severity) over time regardless of the person preparing the report; therefore the report is not subjective.

Therefore, funds can be used more effectively for maintenance, and educated decisions can be made regarding the type of technique to be used.

CHAPTER 5

QUANTITATIVE GUIDELINES

The ultimate aim of maintenance program is to provides engineering and economic analysis tools required by decision makers in making effective selections in terms of cost, good quality, user satisfaction, etc.; however, most of preventive maintenance guidelines or existing pavement condition rate tables are expressed by qualitative evaluation of existing pavement like table 5.1. Qualitative guidelines cannot but depend on the rater's or the field engineer's subjective point of view. Therefore, the importance of quantitative guideline is critical. As a matter of course, education or workshop could increase the accuracy of pavement evaluation, however, if there are reliable quantitative guidelines for evaluators, not only budget but also timesaving will be possible.

Table 5.1. Pavement Condition Rating [Chong, G. J., Phang, W.A. and Wrong, G.A., 1989]

PCR Range	Pavement Condition
0-20	Pavement is in poor to very poor condition with extensive severe cracking, alligator and dishing. Rideability is poor and the surface is very rough and uneven
20-30	Pavement is in poor condition with moderate alligatoring and extensive severe cracking and dishing. Rideability is poor and the surface is very rough and uneven
30-40	Pavement is in poor to fair condition with frequent moderate alligatoring and extensive moderate cracking and dishing. Rideability is poor to fair and surface is moderately rough and uneven
40-50	Pavement is in poor to fair condition with frequent moderate cracking and dishing, an intermittent moderate alligatoring. Rideability is poor to fair and surface is moderately rough and uneven
50-65	Pavement is in fair condition with intermittent moderate and frequent slight cracking, and with intermittent slight to moderate alligatoring and dishing. Rideability is fair and surface is slightly rough and uneven
65-75	Pavement is in fairly good condition with slight cracking, slight or very slight dishing and a few of slight alligatoring Rideability is fairly good with intermittent rough and uneven
75-90	Pavement is in good condition with frequent very slight or slight cracking. Rideability is good with a few slightly rough and uneven
90-100	Pavement is in excellent condition with few cracks. Rideabilty is excellent with few areas of slight distortion

Source: Manual for condition rating of flexible pavement

5.1. Iowa DOT's Quantitative Guidelines

The objective of this section 5.1. is to briefly cover how other state DOTs use quantitative guidelines. Iowa DOT's quantitative guideline research was adopted for this, since they gathered all valuable information in a study that consisted of two phases from 1997 to 2003. Thin maintenance surfaces: phase one report [1999] and thin maintenance surfaces phase two report [2003] would be helpful to know more about their achievement.

According to Surface Condition Index (SCI) value for given treatments, traffic levels, and distresses, the allowable quantity of distresses are selected. After selecting the SCI value level, a amount of permissive distress was back calculated. Jahren et al. (2003) differentiate following three levels of traffic.

- *5,000 AADT. – High Volume*

This traffic level was considered because it is typical of a high volume, two- lane, rural primary highway that may be a candidate for conversion into a four-lane (interstate) highway.

- *2,000 AADT. –Medium Volume*

This traffic level was considered because it represents a transition from a high volume primary rural highway to a low volume primary rural highway.

- *200 AADT. –Low Volume*

This traffic level was considered because it represents a transition between rural roads that are usually paved to ones that are usually graveled.

Note: Those three levels of traffic are considered by Jahren et al. and Iowa DOT; therefore, based on the DOT agencies' subjectivity, the standard value of Annual Average Daily Traffic (AADT) Volume may be different.

The guidelines of Iowa DOT were developed with the expectation that the guideline users will use their judgment to investigate treatment decision for particular traffic counts. Generally, treatments, which are the most appropriate for given shape and depth of distress, will be recommended at lower SCI values than treatments that are less applicable. The guideline for cracks serves as an example. At first, notice that the SCI value for routine maintenance ranges from 60 to 95, for preventive maintenance from 50 to 75, for rehabilitation from 25 to 60, and for reconstruction from 0 to 60 (Table 5.2.). It is anticipated thin maintenance surface (TMS) will be applied for preventive maintenance; therefore, the SCI value will range from 50 to 75 at the time of preventive treatment. Likewise, other pavement maintenance treatment selection will follow the steps mentioned above [Jahren et al., 2003].

Table 5.2. SCI Values for Maintenance Activity Types [Jahren, C. T., Nixon, W. A. and Bergeson, K. L., 2003]

Maintenance Activity	SCI Value	Deduct Value
Routine	60-95	5-40
Preventive	50-75	25-50
Rehabilitation	25-60	40-75
Rebuilding	0-40	60-100

Source: Thin Maintenance Surfaces: Phase Two Report with Guidelines for Winter Maintenance on Thin Maintenance Surfaces

Table 5.3. was developed for four different surface treatments (micro-surfacing, 0.25 in./6.35 mm seal coat, 0.5 in./12.7 mm seal coat, and double seal coat) and various lengths of crack on a 24 ft. (7.3 m) wide by 100 ft (30.4m) long section of

roadway. By the increment of 150 ft. (45.7m), lengths of crack were differentiated in range from 300 to 1,500 ft. (91.4 to 457.2 m), except for a last 300 ft. (91.4m) increment. SCI and deduct values were calculated as described by Shahin (1994), with the assumption that light longitudinal and transversal (L&T) cracking was the only distress present. Note that Shahin's method does not provide SCI calculations for L&T crack lengths that exceed 720 ft./219.4m (30 percent distress). It may be that distress densities that exceed this amount are considered block cracking or some other type of distress in this method; no further explanation was found [Jahren et al., 2003].

Table 5.3. Thin Maintenance Surface Guidelines Based on Amount of Cracking and Annual Average Daily Traffic [Jahren, C. T., Nixon, W. A. and Bergeson, K. L., 2003]

	Daily Traffic							
Feet of Cracking	300	400	600	750	900	1,050	1,200	1,500
SCI Basis	80	78	73	71	***	***	***	***
Deduct Basis	20	22	27	29	***	***	***	***
	AADT							
Micro/ Slurry	5,000		2,000		200			
Seal Coat (0.25 in.)		5,000		2,000		200		
Seal Coat (0.5 in.)			5,000		2,000		200	
Double Seal Coat				5,000		2,000		200

Note: Based on 100 feet of road 24 feet wide.
* Medium intensity cracks require joint sealing or slurry strip repair before surface treatment is placed. Likely long-term result is two closely spaced light intensity cracks. Therefore, consider 1 foot of medium intensity crack equal to 2 feet of light intensity crack. High intensity cracks require patching before treatment is placed. The likely long-term result is two closely spaced light intensity cracks. Therefore, consider 1 foot of high intensity crack equal to 2 feet of light intensity crack. Utility cuts and patches are considered low intensity cracks around the perimeter of the repairs.
** Based on light L&T cracking.
*** SCI basis and deduct are not given for more than 750 feet of light L&T crack.

Source: Thin Maintenance Surfaces: Phase Two Report with Guidelines for Winter Maintenance on Thin Maintenance Surfaces

All cracks (except alligator cracks) are converted into an equivalent length of light cracking for the purposes of these guidelines. Medium and heavy intensity cracks are considered to be equivalent to light density cracks at twice the length of the original crack. Assuming that both types of cracks will be repaired before the maintenance treatment is applied: medium intensity cracks with joint sealant and high intensity cracks with patches. The likely result in both cases is two light intensity parallel cracks, one on each side of the repair. The boundary of any patches or utility cuts is also considered to be the origin of a light intensity crack [Jahren et al., 2003].

The possible use of slurry seal or micro-surfacing was considered to establish a lower bound on the amount of cracking distress that would be addressed by TMS. Since these techniques do not address cracking like other techniques, the required SCI is set above the general preventive range at 80 (preventive range is 50–75) for high volume roads (AADT = 5,000). If light L&T cracking is the only distress in pavement, the maximum permissive percentage of distress is 12.5 percent for a deduct value of 20. For a 24 ft. wide 100 ft. road section (2,400 ft^2/222.9m^2), the maximum permissive feet of length of crack is 12.5 percent of 2,400 ft^2, or 300 ft. A road with four transverse joints in 100 ft. (30.4 m), a completely cracked longitudinal joint at the centerline of road, and a partial (50 percent) crack in each mid- lane would yield slightly less than 300 ft. (91.44 m) of crack. In the Jahren's experience, Jahren et al mentioned that this represents a reasonable amount of cracking to be addressed by micro-surfacing on a high volume road [Jahren et al., 2003].

Table 5.3. shows that if length of crack doubles, micro-surfacing would only be recommended if traffic is 2,000 or less AADT. This calculates to a SCI value of 73, which is inside the preventive range. Six hundred feet of crack could occur in a 100 ft. (30.4 m) section of 24 ft. (7.3 m) wide road, if there are eight transverse cracks, the centerline and both mid-lanes were cracked and 25% of the wheel paths are cracked. Although the start of wheel path cracks may suggest initial fatigue failure, at 2,000 AADT, it is possible that the pavement may maintain sufficient structural strength to the last of the life of the maintenance treatment that is about seven years. Note that caution should be used when applying TMS to pavements that may be suffering from fatigue failure, because TMS do not mitigate enough this failure. 0.5 in. (12.7mm) seal coat would be recommended for 600 ft. (182.8m) of light intensity cracks on a higher volume road (5,000 AADT), if the agency had a policy of seal coating such high volume roads [Jahren et al., 2003].

To establish an upper bound, for the amount of cracking distress that could be addressed with TMS, a 3ft. by 3ft. (0.9m) crack pattern that is similar to block cracking was considered and a double seal coat was selected as a treatment for roads with 200 or less AADT. This was selected on the basis of anecdotal evidence of previous phase (Thin Maintenance Surfaces: Phase one report) of Thin Maintenance Surfaces (phase two report with guidelines for winter Maintenance on thin Maintenance surfaces) that was collected where a road with a similar crack pattern was successfully treated in this way. Note that the cracks could not be cracks that “work” under load and that the road may not meet the usual standards for ride and appearance. However, the treatment might successfully retain a road with such light traffic [Jahren et al., 2003].

Guidelines were also developed to address alligator cracking with TMS. Alligator cracking usually indicates that the pavement is experiencing a fatigue failure. Again, since TMS does very little to address fatigue problems, the strong possibility exists that the pavement will experience continued structural failure and an investment in preventive maintenance would be wasted. However, a TMS may reduce the amount of moisture entering the base and subgrade through the pavement, thus stiffening the subgrade and reducing pavement stress, which would provide modest benefit. Also, the principal investigator has anecdotal evidence that low volume roads, especially urban residential streets can also be candidates for thin maintenance surfaces, if they have light alligator cracking due to small deflection fatigue (the pavement may fail in fatigue after it has lost flexibility with age and has experienced many small fatigue cycles) [Jahren et al., 2003].

Table 5.4. was developed to provide a guideline for using TMS for addressing alligator cracking distress. Thin maintenance surfaces are not recommended for a pavement that is experiencing medium or heavy intensity alligator cracking; any such areas that exist should be patched before the TMS is applied. Table 5.2. indicates that zero percent distress is allowed for medium and heavy intensity cracking and for roads with traffic volumes of 5,000 AADT. The SCI requirement for micro-surfacing and 2,000 AADT was set at 75, which is the upper limit of the usual range for preventive maintenance. Thus the maximum allowable alligator cracked area

would be 5 percent. This was chosen because micro-surfacing/slurry seal is not a preferred treatment for addressing cracking distress [Jahren et al., 2003].

Based on Jahren's judgment, the required SCI for 2,000 AADT and

- 0.25 in. seal coat is 70
- 0.5 in. seal coat is 65
- Double seal coat is 60

The required SCI for 200 AADT is 10 points less for each treatment.

Table 5.4. Thin Maintenance Surface Guidelines Based on Amount of Alligator Cracking and Annual Average Daily Traffic [Jahren, C. T., Nixon, W. A. and Bergeson, K. L., 2003].

	Micro / Slurry			Seal Coat (1/4 inches)		
AADT	5,000	2,000	200	5,000	2,000	200
SCI basis	*	75	65	*	70	60
Deduct basis	*	25	35	*	40	50
Light cracking **	*	5%	12%	*	8%	1%
Medium cracking	*	***	***	*	***	***
Heavy cracking	*	***	***	*	***	***
	Seal Coat (1/2 inches)			Double Seal Coat		
AADT	5,000	2,000	200	5,000	2,000	200
SCI basis	*	65	55	*	60	50
Deduct basis	*	35	55	*	40	50
Light cracking **	*	12%	22%	*	18%	40%
Medium cracking	*	***	***	*	***	***
Heavy cracking	*	***	***	*	***	***

Note: Based on 100 feet of road 24 feet wide.
* TMS are not recommended to address any alligator cracking on roadways with 5,000 or greater AADT.
** Applies to alligator cracking caused by fatigue due to advanced age combined with moderate deflection on firm subgrade. Do not use TMS for fatigue cause by severe deflections on soft subgrade.
*** TMS not recommended for medium or heavy alligator cracking.

Source: Thin Maintenance Surfaces: Phase Two Report with Guidelines for Winter Maintenance on Thin Maintenance Surfaces

Jahren et al. also mentioned bleeding guidelines (Table 5.5.). Separate guidelines were developed for slurry seal and micro-surfacing. The minimum SCI requirement for 5,000 AADT and micro-surfacing was set at 80, on the other hand for the same traffic and seal coat, the SCI was set at 60. As traffic decreases, 10 point increments are allowed between each category. The SCI requirement was set high for micro-surfacing and slurry seal because it is difficult to change the mix design to use less binder to compensate for bleeding from the substrate. For seal coat, a SCI requirement of 60 was selected because the amount of binder can be adjusted downward to counterbalance for bleeding. The 60 SCI value is close to the middle of the preventive maintenance range (Table 5.2.). If seal coat is used, the successful possibility may be increased by use of same-size aggregates that will allow excess void space to accommodate additional oil from the bleeding surface. Obviously, larger sized aggregates will provide more void space for excess oil [Jahren et al., 2003].

Table 5.5. Thin Maintenance Surface Guidelines Based on Amount of Bleeding and Annual Average Daily Traffic [Jahren, C. T., Nixon, W. A. and Bergeson, K. L., 2003]

Daily Traffic

	Micro / Slurry			Seal Coat		
AADT	5,000	2,000	200	5,000	2,000	200
SCI basis	80	70	60	60	50	40
Deduct basis	20	30	40	40	50	60
Light bleeding	100%	100%	100%	100%	100%	100%
Medium Bleeding	23%	55%	100%	100%**	100%**	100%**
Heavy bleeding	8%	12%	25%	25%**	40%**	60%**

Note: Based on 100 feet of road 24 feet wide.
* Consider using clean, one-size cover aggregate to provide more void space for excess oil and reducing binder application rate (especially for medium to heavy bleeding).
** Consider using 1/2-inch cover aggregate (more void space for excess oil).

Source: Thin Maintenance Surfaces: Phase Two Report with Guidelines for Winter Maintenance on Thin Maintenance Surfaces

5.2. Framework for Treatment Selection

Pavement treatments that are applied after initial construction are employed to either preserve or extend the life of an existing pavement. There are many indicators used by DOT agencies as a basis for identifying an appropriate preventive maintenance to address a given condition of pavement distress. Decision tree is the most popular tool and depends on certain criteria that is set forth by agency having past experience for treatments selection. Hicks et al. (1999) mentioned the general type of data that are considered on the development of decision tree include:

- Pavement surface type and construction history
- An indication of functional classification and/or traffic level
- At least one type of condition index
- More specific information about the type of distress
- Environmental conditions in which the treatment is to be used.

Many DOT agencies have developed decision tools for selecting the appropriate maintenance strategies for given pavements. A decision tree presented in this paper can be used for Delaware Department of Transportation as well as Delaware local communities without their own guidelines.

5.2.1. Subsurface Condition Evaluation

For the preventive maintenance material selection, cracking width and length, rut depth, and traffic volume could be measured by numerical assessment; however, these evaluations are also limited to the evaluation of roadway surface. For the more precise evaluation of existing pavement condition it is crucial not only to evaluate the condition of surface but also evaluate structural condition or deficiency of subsurface for cost effectiveness of network level. Of course it is the best way to estimate the condition of subsurface through sample extraction; however, destructive testing is not cost and time effective. Therefore non-destructive testing is considered for characterizing the structural condition of existing pavement. As a non-destructive measuring technology, Ground Penetrating Radar (GPR), which was developed for military application such as tunnels and buried mine detection in 1974, operates by purse of transmitting electromagnetic energy from transmitting antenna to testing pavement and then the energy is reflected back to the receiving antenna with time gap and amplitude which is related to material characteristic of pavement layers.

5.2.2. Decision Tree

Decision guidelines or decision trees, which are made up of quantitative value of deterioration or condition, for selecting preventive maintenances already have been presented by other researches, however, most of the decision trees are made up on the basis of qualitative pavement condition or under the simple quantitave value. Figure 5.1. is made on the basis of "Selecting a Preventive Maintenance Treatment for Flexible Pavements" (Hicks et al., 1999) and "Thin Maintenance Surfaces" (Jahren et al., 2003); also other DOT's decision trees and decision matrices are referred to reduce the possible errors. The basic assumptions of this decision tree are follows:

- All structural deterioration of existing pavement is not exist or structurally acceptable
- The level of roadways is interstate highway
- Presented AADT adopted Hicks et al.'s (1999) guideline for Foundation for Pavement Preservation. - (may be different from each DOT’s guidelines)

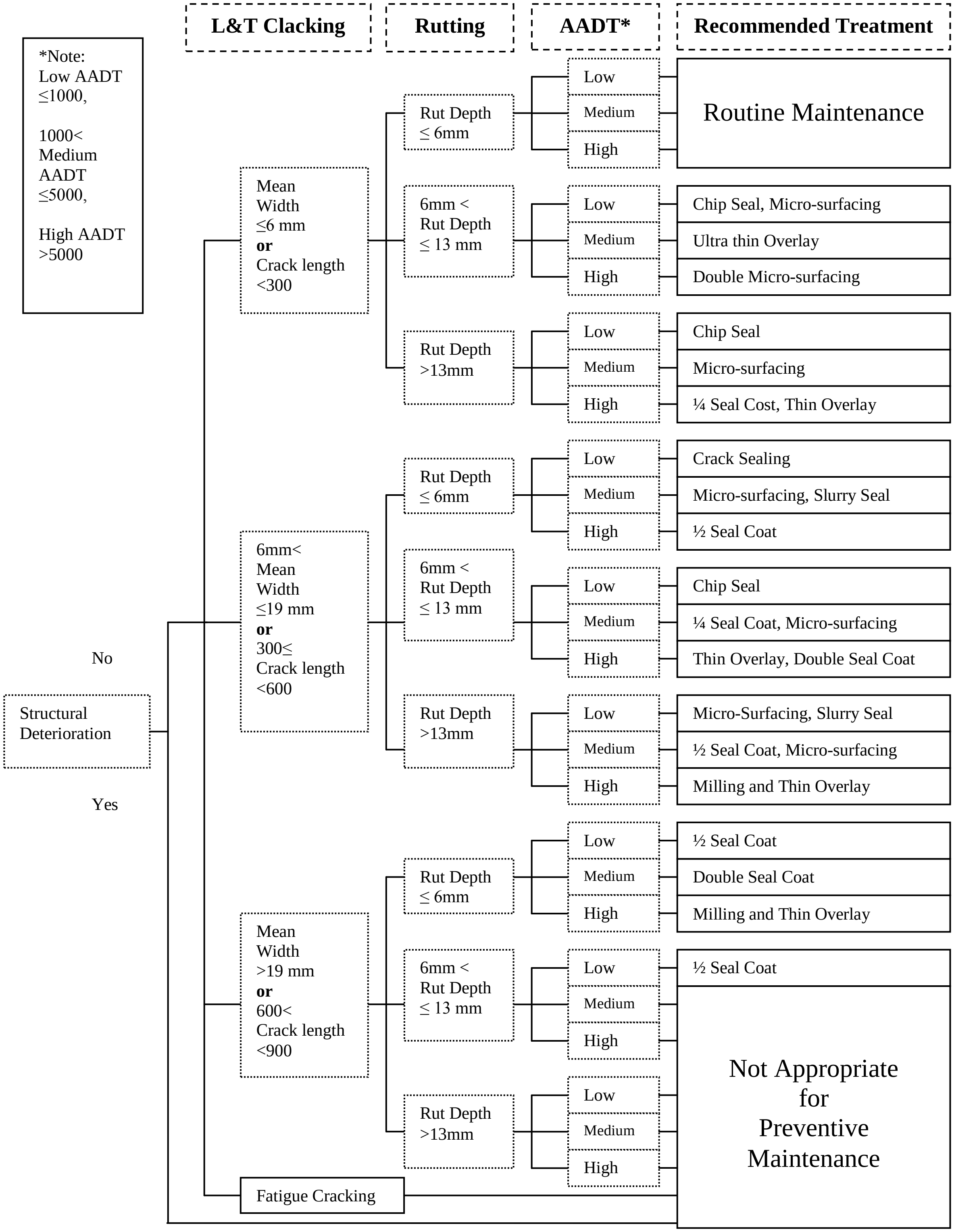

Figure 5.1. Decision Tree for Preventive Maintenance Selection

This simplified decision tree is made under the condition of longitudinal and transverse cracking, rutting, and AADT; however, there are other factors influencing the selection of treatments. Therefore, all possible factors should be opened to decision step.

To minimize possible errors for appropriate preventive maintenance selection, feedback step and considering other factors step are shown in Figure 5.2. Possible factors are presented in Table 5.6; however, the decision maker should keep in mind that other factors can influence the selection of maintenance treatments such as funding level, weather condition and so forth.

This decision support system should be used as a supplementary guide since there are many aspects that the decision maker must consider before the final decision such as climate, truck factor, distance of material provider and so forth.

Table 5.6. Comparison Table for Preventive Maintenance

	Chip Seal/Seal Coat	**Slurry Seal/ Micro-surfacing**	**Thin Overlay**
Turning & Stopping traffic	Can be flushed	Durable	Durable
Curing Time	20mph for 2 hour	After 1-12 hour	-
Noise	Fairly Noisy (Loose aggregates)	Less noisy than Chip Seal	Least noisy
Snowplow Damage	More durable than Slurry Seal	Less Susceptible	Susceptible
Existing Condition	Least affected	Only on sound condition	Less influenced than slurry/micro-surfacing
Expected life	4-8 year	4-12 year	8-15 year

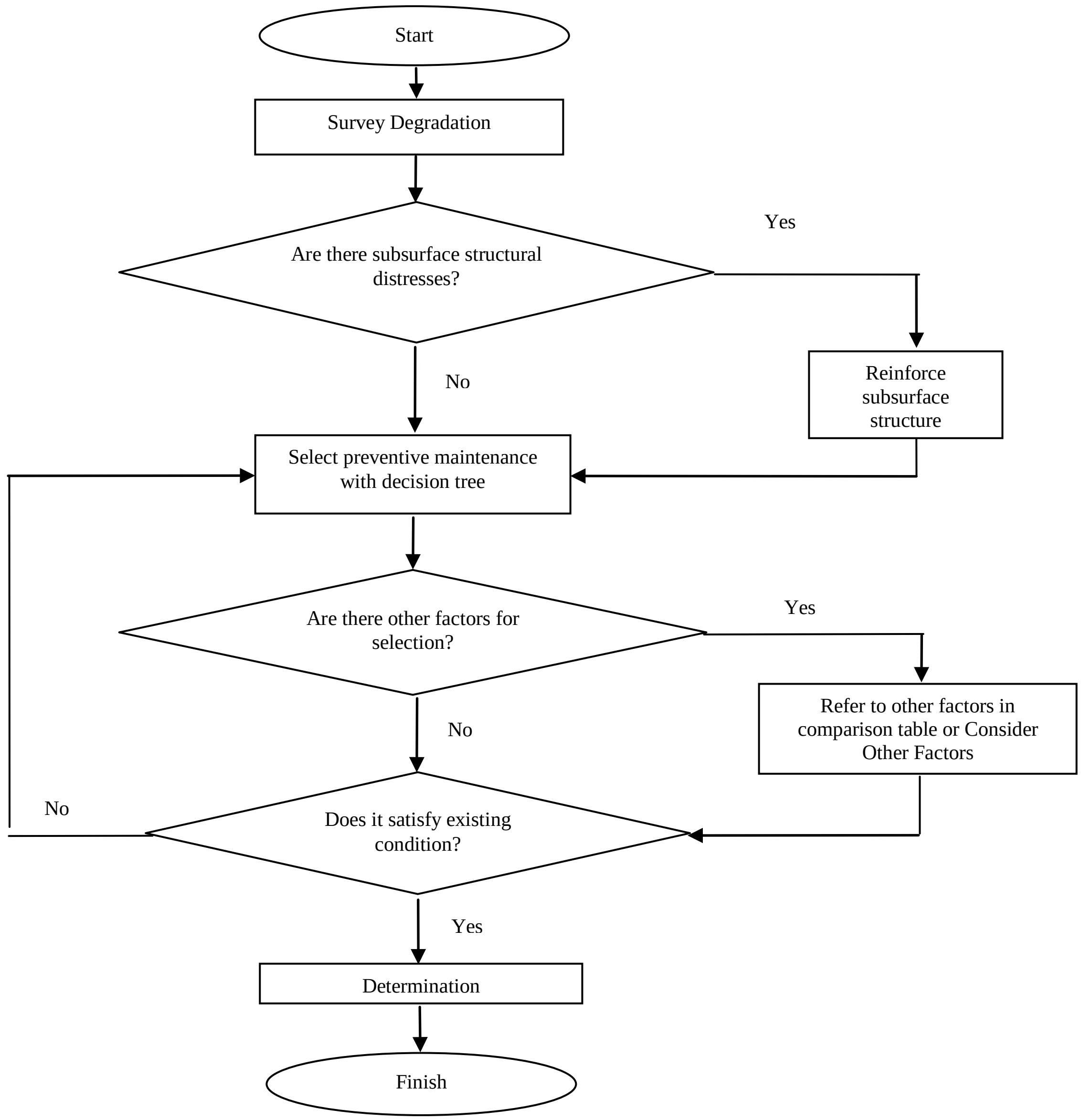

Figure 5.2. Preventive Maintenance Selection Flow Chart

CHAPTER 6
CONCLUDING REMARKS

Survey results about guideline or manual usage in Delaware local communities suggest that they do not use systematic maintenance guidelines for local communities. The benefits of such guidelines to the local government include a correct pavement maintenance assessment and evaluation; therefore, funds can be used more effectively for maintenance, and educated decisions can be made regarding the type of technique to be used. Through literature reviews and case studies and surveys, overlays may be the most versatile and effective maintenance treatment, but it does not necessarily mean it will be cost-effective.

- It appears that most small communities in Delaware do not have an established engineering procedure for thin overlay assessment and evaluation. Furthermore, it appears that DelDOT has not developed guidelines for the communities for thin overlay maintenance procedure, including evaluation, design, and construction.
- Many case studies insist that thin maintenance surfaces are one of the cost effective strategies that can improve the overall condition and performance of roadways at low cost. When thin maintenance surfaces such as thin overlay, seal coat, and slurry seal are properly applied, they can improve pavement performance. For successful application critical some factors should be satisfied

such as material selection and mix rate, technical expertise, design, curing period, and also favorable weather conditions; otherwise, pavement performance and condition might not improve considerably. Thus, prudent decisions should be made on initial concept selection step, and also quality control should follow after construction.

- The study concluded that thin maintenance surfaces reduce possible degradation rate; however, it does not necessarily mean they will always improve roadway condition and performance. Improper maintenance application on sound pavement may waste funding, and also improper thin maintenance surfaces may result in degradation of performance such as loss of skid resistance by fog seal, accident on high speed roadway caused by loss of aggregates by chip seal, and excessive traffic delay caused by lane closure. Quantitative value evaluation of existing pavement can reduce these possible errors.

APPENDIX - I

SAMPLE OF QUESTIONNAIRE

Thin Overlay Survey

Please complete the survey below. You may choose to refer to specific project when answering the questionnaire. If so, please provide the project information in the General Information Table below. Alternatively, you may choose to answer the questions on a general basis.

General Information

Agency Name:	
Project Name:	
Project Manager:	
Facilitator:	
Review Date:	

	Criteria	Yes/No	Comments
1	Does your community use thin overlay for pavement preventive maintenance?	Yes No	
2	Does your community use micro-surfacing or seal coatings techniques for preventive maintenance?	Yes No	
3	Are thin overlay used over flexible (asphaltic) pavement?	Yes No	
4	Are thin overlay used over rigid (concrete) pavement?	Yes No	
5	What thickness of asphalt is used in the overlay?	1.5-inch Other	
6	Does your community require a certain mix design to be used for thin overlay?	Yes No	
7	Is the work performed by in-house crews?	Yes No	
8	Is the work is subcontracted to a private contractor, does the contractor select the mix design used for the thin overlay?	Yes No	
9	Do you require the contractor to submit a mix design prior to the start of work?	Yes No	

Pavement Survey Questionnaire (Continue)

10	Are thin overlays used is areas of low, medium or high traffic?	Low Medium High	
11	How often are conditions of the roads in your community surveyed?	Monthly Yearly Other	
12	What/Whose guidelines do you use to assess the condition of the pavements?		

General Observations:

Comments:

After you have entered the necessary information to complete this questionnaire, please return it in the self-addressed stamped envelope provided. Thank you for your time!

APPENDIX - II

Town of Newport – Y 2003: Decision Trees

Asphalt Concrete

Pavement Distress types

Alligator Cracking

		Extent		
		Low	Medium	High
Severity	Low	11	11	15
	Medium	13	16	17/18*
	High	13	17/18*	18

* - Depends upon Subgrade/ Traffic Levels

Transverse/Block Cracking

		Extent		
		Low	Medium	High
Severity	Low	11	11	15
	Medium	12	16	17
	High	12	17	17

Longitudinal Cracking

Extent		
Low	Medium	High
12	12	12

Patching/Potholes

Extent		
Low	Medium	High
13	16	18

Roughness/Rutting

Extent		
Low	Medium	High
11	17*	18

*-Rutfill

Surface Defects

Extent		
Low	Medium	High
11	15	16

Repair Categories:

11-None
12-Cack Seal
13-Patching
14-Defer Preventive (Micro)
15-Preventive (Micro)
16-Defer Rehab
17-Rehab (overlay)
18-Rebuild

Note: Defer- repair required in the next 1-3 years (used in RSMS for budgeting purposes)

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