Quantitative Guidelines for Use of Thin Maintenance Surfaces

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ABSTRACT

Thin maintenance surfaces (TMS) extend the service life of bituminous and asphalt cement concrete roads—a task that has challenged road and highway agencies for years. Many of these agencies are aware of TMS as a maintenance treatment; however, selection of the proper TMS to use has been difficult. Guidelines for TMS selection were needed to improve the success of TMS.

The first phase of this research project, funded by the Iowa Department of Transportation and completed in April 1999, developed qualitative selection guidelines. For example, "Slurry seal and micro-surfacing are not recommended for badly cracked pavements; however, those treatments can be used to address a small amount of light cracking." However, the definitions of "badly cracked" and "light cracking" can vary from one person to another.

Therefore, quantitative standards for the selection of TMS were needed. The second phase of this research project refined the qualitative guidelines and developed quantitative guidelines for TMS selection. These new guidelines use the pavement condition index (PCI) rating developed by the U.S. Army Corps of Engineers. To avoid confusion with another index used in Iowa that is also referred to as the PCI, the index is called the surface condition index (SCI) herein.

The allowable distress is chosen by considering an appropriate SCI value for given treatments, traffic levels, and distresses. Users are expected to use judgment and to interpolate or to extrapolate to select a TMS for a particular traffic count. Transportation maintenance managers may find these guidelines useful for pavement management systems.

Key words: pavement management—thin maintenance surfaces

Proceedings of the 2003 Mid-Continent Transportation Research Symposium, Ames, Iowa, August 2003.

INTRODUCTION

In recent years there has been a renewal of interest in preventative maintenance techniques designed to extend pavement life of and to ensure low life-cycle costs for our nation's road infrastructure network. Thin maintenance surfaces (TMS) can be an important part of a preventative maintenance program for asphaltic concrete or bituminous roads. The need to demonstrate the use of TMS in Iowa and to develop guidelines for TMS use that are specific to Iowa spawned this research project. The Iowa Department of Transportation (Iowa DOT) and the Iowa Highway Research Board sponsored the project in two phases.

Phase One of the TMS research project included the following:

1. a survey of local transportation officials to determine current practices in Iowa
2. construction and monitoring of test sections (U.S. 151 and U.S. 30 in 1997 and U.S. 69 in 1998)
3. development of interim qualitative guidelines to help transportation officials select TMS

Before developing an interim set of guidelines, the researchers reviewed the literature, examined the results of the survey of local transportation officials, reviewed test section performance, and held discussions with the research advisory committee. Transportation decision makers are guided to select thin maintenance surfaces using a step-by-step process, beginning with an assessment of the condition of the road network. The second step is to identify technically feasible treatments by using a table based on the pavement surface condition and traffic load of the candidate road. The remaining steps result in a choice between technically feasible alternatives by considering past practices, cost, durability, user preferences, neighbor preferences, and other factors that are difficult to quantify.

The interim guidelines improved upon the scattered information that previously existed. However, because the guidelines required further improvement by providing better-defined decision points and guidance on when to use various types of aggregates and binders, a second phase of research was proposed to the Iowa Highway Research Board and subsequently approved.

Phase Two of the TMS research project included the following objectives:

1. continued monitoring for previously placed test sections
2. construction and monitoring of additional test sections (U.S. 218 in 1999)
3. evaluation of design processes for seal coats and recommendation of one for statewide use
4. further investigation of TMS aggregates
5. investigation between TMS and winter maintenance activities
6. refinement of the guidelines for TMS developed in Phase One

Objective 6 of Phase Two produced a set of quantitative guidelines. The allowable quantity of each type of distress was selected by considering an appropriate surface condition index (SCI) value for given treatments, traffic levels, and distresses. After selection of the SCI level, a permissible amount of distress was back-calculated. Three levels of traffic were considered: 5,000; 2,000; and 200 AADT.

Users are expected to exercise their judgment and to interpolate or to extrapolate to investigate treatment selection for a particular traffic count. In general, treatments that are the most appropriate for particular types of distress will be recommended for pavements with relatively low SCI values (indicating larger amounts of distress). Conversely, treatments that are least appropriate for a particular type of distress will not be recommended unless the pavement has a relatively high SCI value (indicating lesser amounts of distress). The ultimate product of Phase Two was a set of quantitative guidelines for TMS selection.

This paper will concentrate on objective 6 of Phase Two, the development of quantitative guidelines for the selection of TMS. However, the qualitative methods developed during Phase One of the research project are described to provide background.

METHODOLOGY

The research methodology was developed in consultation with a research advisory committee. Four sets of TMS test sections were constructed and monitored over a three-year period. The surface condition index for each test section was calculated before construction. The SCI was calculated by observing the cracks in each test section and performing calculations as described in greater detail herein. After construction, observations were made to calculate the SCI at regular intervals.

The SCI results for each test section were plotted versus time. Several treatments were recorded on the same graph so as to permit visual comparisons of the performance of the various test sections. Since the test sections were placed adjacent to each other on the same route, the traffic counts and vehicle loads essentially are constant throughout the test sections. Therefore, the only difference between one test section and another would be the initial SCI and any potential differences in the condition of the subgrade below the pavement. After comparing this performance data to the amount of cracking before application of the TMS and the traffic levels, the researchers developed guidelines based upon the literature review and experience gained from test section observation.

RESULTS

Phase One Interim Qualitative Guidelines *(1)*

A fundamental knowledge of the interim qualitative guidelines resulting from Phase One is essential to understanding the development of the quantitative guidelines resulting from Phase Two. An example of a qualitative guideline follows: "Slurry seal and micro-surfacing are not recommended for badly cracked pavements; however, those treatments can be used to address a small amount of light cracking."

The Phase One interim qualitative guidelines provide a five-step TMS decision procedure:

Step 1. Collect Information on Candidate Roads

The transportation decision maker conducts a distress survey to assess the magnitude and the type of distress that the road is suffering in order to supply data for SCI calculations.

Step 2. Identify Feasible Treatments

Table 1 makes recommendations for the use of seal coats, slurry seal, and micro-surfacing *(2)*. The Phase One report provides additional guidance for selecting treatments for roads where rutting is the primary distress *(3)*. It should be noted that filling will serve as only a temporary remedy for those ruts that are caused by instability of the asphalt cement concrete or subgrade.

TABLE 1. Thin Maintenance Surfaces for Various Traffic Volumes and Distress Types

	Seal Coat	Slurry Seal	Micro-surfacing
Traffic volume:			
AADT < 2,000	Recommended	Recommended	Recommended
2,000 > AADT < 5,000	Marginal*	Marginal*	Recommended
AADT > 5,000	Not recommended	Not recommended	Recommended
Bleeding	Recommended	Recommended	Recommended
Rutting	Not recommended	Recommended	Recommended
Raveling	Recommended	Recommended	Recommended
Few tight cracks	Recommended	Recommended	Recommended
Extensive cracking	Recommended	Not recommended	Not recommended
Low friction	May improve	May improve	May improve**
Snowplow damage	Most susceptible	Moderately susceptible	Least susceptible

* There is a greater likelihood of success when used in lower-speed traffic.
** Micro-surfacing reportedly retains high friction for a longer period of time.

Step 3. Consider Other Factors

The Phase One report provides a table (see Table 2) of other factors that should be considered before making a final selection regarding seal coats, slurry seals, and micro-surfacing *(2)*. If previous investigation indicates multiple treatments are feasible, this table will indicate the preferred method.

TABLE 2. Other Factors Impacting Thin Maintenance Surface Decisions

	Seal Coat	Slurry Seal	Micro-surfacing
Past practices	Most officials prefer not to change successful past practice unless there is definite reason for a change. These reasons could be positive or negative changes in funding, neighbor complaints, user complaints, or an opportunity to use better product.		
Funding and cost	Least expensive option → less funding is required.	More expensive than seal coat and less expensive than micro-surfacing.	Most expensive option → more funding is required.
Durability	Dependent of aggregate type, binder type, and application technique.	Less durable than micro-surfacing.	More durable than slurry seal.
Turning and stopping traffic	Can be flushed by turning and stopping traffic.	Can hold turning and stopping traffic.	Best wear in turning and stopping traffic.
Dust and fly rock	Considerable dust possible during construction.*	Little dust possible during construction.	
Curing time**	Road can be opened after rolling is completed and speed should be limited to about 20 mph for 2 hours.	Road can be opened after 2 hours in warm weather and 6–12 hours in cold weather.	Road can be opened after 1 hour.
Noise and surface texture	Fairly noisy surface, open surface texture, and many loose rocks immediately after construction.	Less noise and dense surface texture (close to hot-mix surface).	
Availability of contractors	13 contractors in Iowa.	3 contractors in Iowa.	2 contractors in Iowa.
Use of local aggregates	Maximum flexibility: - Can use somewhat dusty aggregates with cutback binder. - Can use emulsion or cutbacks. - Rock chips, pea gravel, and sand may be used.	Less flexibility.	Least flexible. The binder is highly reactive (break time is affected by clay content).

* Dust is mitigated by using washed, hard, or pre-coated aggregate.
** Federal Highway Administration.

Step 4. Consider Timing

The construction of TMS must be properly timed. Most experts suggest applying TMS to a road seven to ten years after initial construction. Geoffroy *(4)* surveyed 60 transportation agencies regarding TMS life expectancy and reported that the expected lifespan of the treatment is five to ten years.

Transportation officials with successful TMS programs usually apply the first surface treatment when fine aggregate begins to ravel from the road surface. Raveling often occurs seven to twelve years after construction. Roads consisting of several layers of seal coat may require maintenance more often because less pavement structure is available to support loads.

Step 5. Consider Cost

As costs will vary from one area to another, users must research this locally.

Phase Two Quantitative Guidelines *(5)*

While the Phase One qualitative guidelines were an improvement, quantitative guidelines were desirable to limit the variation in application between users. The main objective of this phase of the project was to develop a framework for guidelines that are more quantitative. The framework is based on the surface condition index (pavement condition index) as described by Shahin *(6)* and the primary author's experience accumulated while executing both phases of this research project. The resulting guidelines are more quantitative than the ones developed in Phase One, but could be improved with further research.

The allowable quantity of each type of distress was selected by considering an appropriate SCI value for given treatments, traffic levels, and distresses. After the SCI level was chosen, a permissible amount of distress was back-calculated. Three levels of traffic were considered:

- **5,000 AADT:** Typical of a high-volume, two-lane, rural primary highway that may be a candidate for conversion into a four-lane highway
- **2,000 AADT:** Transition point from a high-volume primary rural highway to a low-volume primary rural highway
- **200 AADT:** Transition point between paved and graveled rural roads

Users will be expected to exercise their judgment and interpolate or extrapolate to investigate treatment selection for a particular traffic count as they follow the guidelines.

The guideline for cracks serves as an example (see Table 3).

TABLE 3. SCI Values for Maintenance Activity Types

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

TMS normally will be used for preventive maintenance, so the expectation is that the SCI value will range from 50 to 75 at the time of treatment.

Guidelines based upon cracking and traffic are described in Table 4 for four surface treatments and various crack lengths on a 24-foot-wide by 100-foot-long section of roadway. Crack lengths range from 300 to 1,500 feet in increments of 150 feet, except for a final 300-foot increment. SCI and deduct values were calculated as described by Shahin *(6)*, with the assumption that light longitudinal and transverse (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 feet (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, but the author did not offer any further explanation. All cracks (except alligator cracks) are converted into an equivalent length of light cracking. Table 4 suggests adjustments to measured crack lengths for repairs and utility patches.

TABLE 4. Thin Maintenance Surface Guidelines Based on Amount of Cracking and Annual Average Daily Traffic

Feet of Cracking*	300	450	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 (1/4 inches)		5,000		2,000		200		
Seal coat (1/2 inches)			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. High-intensity cracks require patching before treatment is placed. Therefore, one foot of high-intensity crack equals two feet of light-intensity crack. Consider utility cuts and patches as 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.

The lower bound on the amount of cracking distress that would be addressed by thin maintenance surfaces was established by the consideration of the use of slurry seal or micro-surfacing. These techniques do not address cracking as well as other techniques, so the required SCI is set somewhat above the usual preventive range at 80 for high-volume primary roads (AADT = 5,000). If light L&T cracking is the only distress, the maximum allowable percent of distress is 12.5 percent for a deduct value of 20. For a 100-foot section of road 24 feet wide (2,400 ft^2), the maximum allowable feet of length of cracking is 12.5 percent of 2,400 ft^2, or 300 feet (see Figure 1). A road with four transverse joints in 100 feet, 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 feet of crack. In the first author's experience, this represents a reasonable amount of cracking to be addressed by micro-surfacing on a high-volume road.

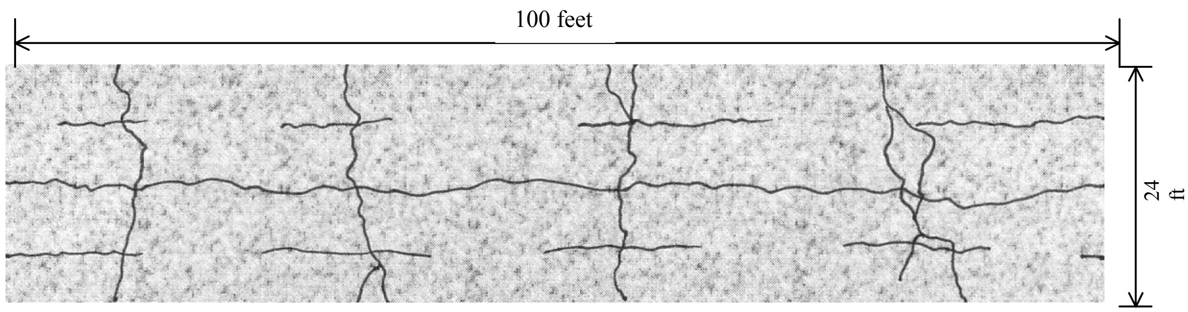
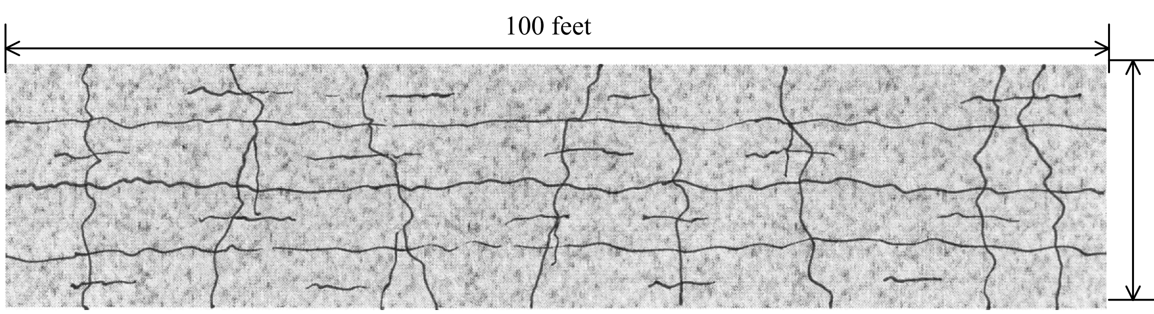


FIGURE 1. 2,400 ft^2 Section of Roadway with about 300 Feet of Cracking

If length of crack doubles, micro-surfacing would only be recommended if traffic is 2,000 or less AADT (see Table 4). This yields a SCI value of 73, inside the preventive range. Six hundred feet of crack could occur in a 100-foot section of 24-foot-wide road if there are eight transverse cracks, the centerline and both mid-lanes were cracked, and 25 percent of the wheel paths are cracked (see Figure 2). The start of wheel path cracks, as illustrated in Figure 2, may suggest incipient fatigue failure; however, at 2,000 AADT it is possible that the pavement may retain sufficient structural strength to last the life of the maintenance treatment (about seven years). However, TMS will do little to mitigate fatigue failure. Note that for 600 feet of light-intensity cracks on a higher volume road (5,000 AADT), 1/2-inch seal coat would be suggested, if the agency had a policy of seal coating such high-volume roads.



1 longitudinal joint	100 feet
2 mid-lane	200 feet
25% of 4 wheel paths	100 feet
8 foot × 24 foot transverse	192 feet
Miscellaneous	8 feet
Total	600 feet

FIGURE 2. 2,400 ft^2 Section of Roadway with about 600 Feet of Cracking (with calculations)

To establish an upper bound for the amount of cracking distress that could be addressed with TMS, the researchers considered a 3-foot by 3-foot crack pattern similar to block cracking, and a double seal coat was identified as a satisfactory treatment for roads with 200 or less AADT. This selection was made on the basis of anecdotal evidence that the first author collected where a road with a similar crack pattern was successfully treated in this way. It is important to note that the cracks cannot "work" up and down under load, and the road may not meet the usual standards for ride and appearance. However, the treatment might preserve a road with very light traffic.

Although alligator cracking frequently indicates a fatigue failure, guidelines were developed to address this condition with TMS. As stated previously, TMS do very little to address fatigue problems; however, TMS may reduce the amount of moisture entering the base and subgrade through the pavement, thereby 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 be candidates for TMS, if they have light alligator cracking due to small deflection fatigue. For a low-volume road, the thin maintenance surface may be sufficient "glue" to hold the alligator blocks in place, to reduce crack width, and to prevent spalling for a period of time, thereby extending the life of the pavement.

Guidelines for using TMS to address light intensity alligator cracking distress are given in Table 5. Zero percent distress is allowed for medium- and heavy-intensity cracking 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. Therefore, the maximum allowable alligator cracked area would be 5 percent. This level was chosen because micro-surfacing/slurry seal is not a preferred treatment for addressing cracking distress. The required SCI for 2,000 AADT and 1/4-inch seal coat, 1/2-inch seal coat, and double seal coat are 70, 65, and 60, respectively, based on the primary author's judgment. For each treatment, compared to the requirement for 2,000 AADT, the SCI requirement is 10 points less for 200 AADT.

TABLE 5. Thin Maintenance Surface Guidelines Based on Amount of Alligator Cracking and Annual Average Daily Traffic

	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%
	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%

Note: Based on 100 feet of road 24 feet wide.
* TMS are not recommended for 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.
Note: TMS are not recommended for medium or heavy alligator cracking.

Guidelines were refined to address bleeding as well (see Table 6). Independent guidelines for slurry seal and micro-surfacing were generated. The minimum SCI requirement for 5,000 AADT and micro-surfacing was set at 80; while 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 decrease the quantity of binder in the mix design to compensate for bleeding from the substrate. For seal coat, an SCI requirement of 60 was selected because the amount of binder can be adjusted downward to compensate for bleeding. The SCI of 60 is near the middle of the preventive maintenance range (see Table 3). If a seal coat is used, the chances of success can be increased by using one-size aggregate that will allow excess void space to accommodate additional oil from the bleeding surface.

TABLE 6. Thin Maintenance Surface Guidelines Based on Amount of Bleeding and Annual Average Daily Traffic (based on 100 feet of road 24 feet wide)

	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%	15%	25%	25%**	40%**	60%**

* 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).

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This research project has demonstrated that it is possible to develop quantitative guidelines for use in the selection of TMS using the concept of the surface condition index. It should be noted that the results of this study are empirical in nature. By back-calculating an acceptable level of distress after selecting an SCI, the user will be guided to a specific TMS.

The guidelines were developed based on observations from four sets of test sections placed over three years, as well as a literature review, anecdotal evidence from conversations with government and industry employees, and observations by the authors.

Recommendations

Transportation decision makers should try both the qualitative and the quantitative guidelines. For many users, the qualitative guidelines may be adequate. These users are expected to use their experience and judgment when applying the guidelines. For others, the quantitative guidelines may be more appropriate. These users may be required to use interpolation or extrapolation at times. This system provides a definitive TMS selection such that all users should come to a standardized conclusion.

The quantitative guidelines may lend themselves to integration into a computerized pavement management system. Users may wish to compare the results from these guidelines to other systems that may already be in use. The guidelines should be further refined as more experience is collected.

ACKNOWLEDGMENTS

The research team would like to thank the Iowa Highway Research Board for sponsoring Phase Two of the Thin Maintenance Surfaces project (TR-435). Phase One of the project was funded by the Iowa Department of Transportation through its research agreement with the Center for Transportation Research and Education, Iowa State University.

The research project advisory committee included the following members:

- Iowa DOT Office of Construction: Dave Jensen, P.E., and later Jeff Schmitt, P.E.
- Iowa DOT Office of Maintenance: John Selmer, P.E., and Francis Todey, P.E.
- Iowa DOT Office of Materials: John Heggen, P.E., and later Mike Heitzman, P.E.
- Carroll County: David Paulson, P.E.
- Kossuth County: Richard Scheik, P.E., L.S.
- City of Carroll: Randy Krauel, P.E.
- City of Newton: Neil Guess, P.E.
- Fort Dodge Asphalt: William Dunshee
- Koch Materials, Inc.: Bill Ballou (Dan Staebell, alternate)
- Sta-Bilt Construction Co.: Richard Burchett

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