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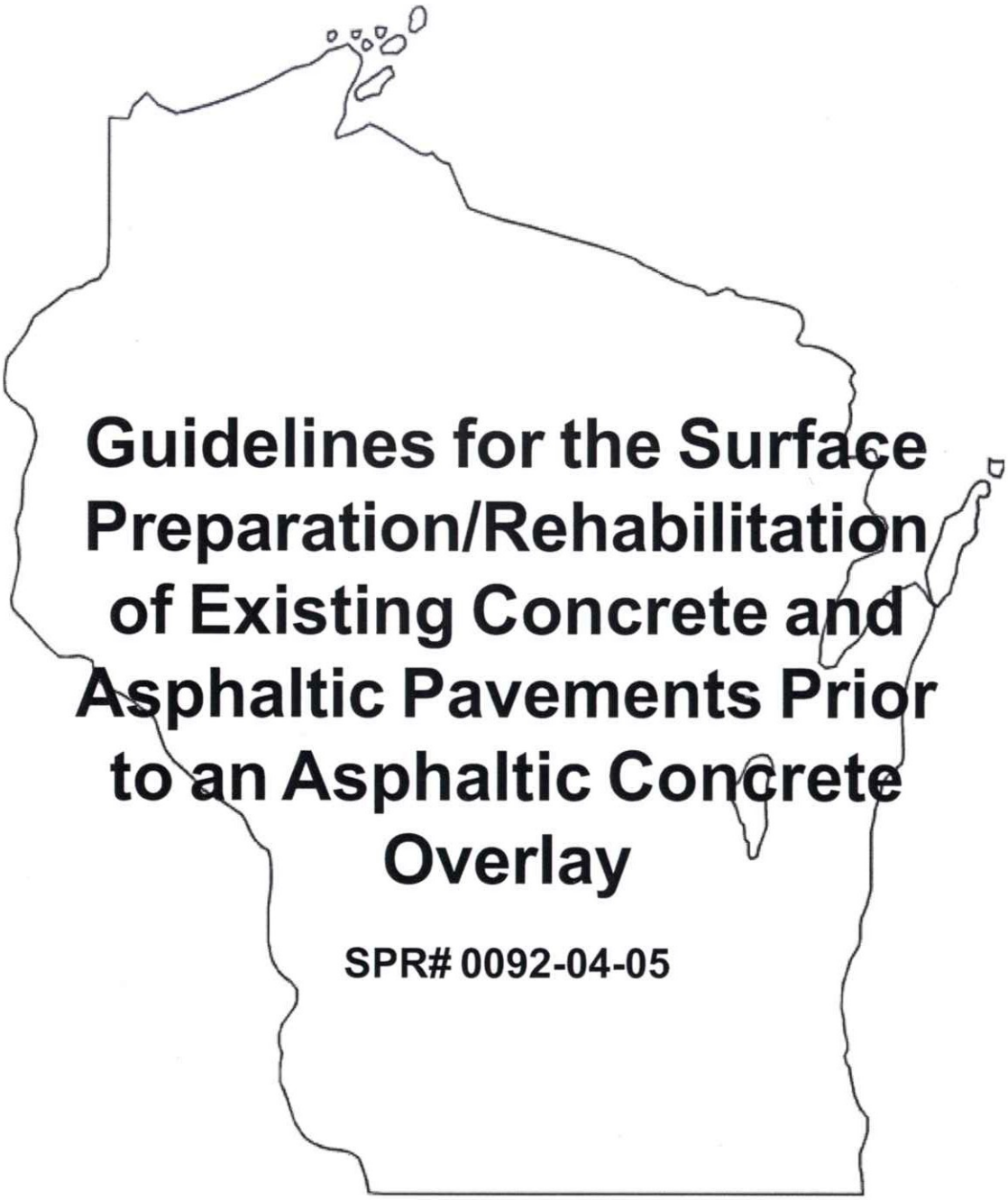

Guidelines for the Surface Preparation/Rehabilitation of Existing Concrete and Asphaltic Pavements Prior to an Asphaltic Concrete Overlay

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GUIDELINES FOR THE SURFACE PREPARATION/REHABILITATION OF EXISTING CONCRETE AND ASPHALTIC PAVEMENTS PRIOR TO AN ASPHALTIC CONCRETE OVERLAY

FINAL REPORT

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16. Abstract

A large percentage of the asphaltic paving projects performed in Wisconsin are asphaltic overlays of existing concrete or asphaltic pavements. Due to varying performance of overlay, a standard set of guidelines is needed to determine the amount of surface preparation which provides a consistency along with more accurate and stable project budgets for this type of work. Literature review of WisDOT and national practices of pre-overlay repair of existing concrete and asphaltic pavements was conducted. Previous asphalt overlay projects were reviewed and overlay performance was analyzed. In addition, three overlay projects during 2004 construction season were studied in the field.

For asphalt overlay of existing concrete pavements, it was found that overlays with doweled concrete base patching performed best, followed by non-doweled concrete base patching and then asphaltic base patching. Partial depth repair is needed to fix the medium severity transverse cracks and longitudinal/transverse distressed joints in existing concrete pavement. A minimum of three inches, practically three and half an inch, overlay thickness was found to be able to mitigate reflective cracking in overlay. All high-severity joints/cracks/patches should be repaired. The current IRI in overlay was highly correlated with initial IRI of overlay, indicating the importance of profile index. The roughness prediction model used in the NCHRP 1-37A 2002 design guide was calibrated with locally available data.

For asphalt overlay of existing asphalt pavements, block cracking in existing asphalt pavement does not adversely affect the overlay when milling is used. Existing asphalt pavement with extensive alligator cracking should be pulverized to prevent the reflection of underlying alligator cracking. Milling the existing asphalt pavement can not eliminate the reflection of transverse cracking in existing asphalt pavement. The ratio of overlay thickness to milling depth should be kept a minimum of three to prevent longitudinal cracking from re-occurring in overlay.

A set of guidelines was developed to be included in the Facility Development Manual and Construction and Material Manual.

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EXECUTIVE SUMMARY

PROJECT SUMMARY

This research study consists of reviewing performance of previous asphalt overlays over existing concrete and asphalt pavements. The best practices being used by WisDOT were identified to develop a set of guidelines to determine the amount and methods of surface preparation prior to asphalt overlay.

PROJECT BACKGROUND

A large percentage of the asphaltic paving projects performed in Wisconsin are asphaltic overlays of existing concrete or asphaltic pavements. The condition and distress of these pavements vary considerably when they are chosen for overlay, and the methods of preparing the existing surface of these pavements prior to the overlay also vary widely. This lack of consistency in the surface preparation or rehabilitation leads to large variations in the performance of these asphaltic overlays. A standard method of surface preparation would make the performance of these overlays more consistent and thus easier to determine more accurate life cycle costs. The amount of surface preparation is also determined largely in the field during construction. This leads to either increased project costs, or an understanding that the proper amount of work is not done to the existing pavement in order to maintain the project budget. A standard set of guidelines to determine the amount of surface preparation or rehabilitation prior to asphaltic overlay that would address concerns during design and construction would provide this consistency, along with more accurate and stable project budgets for this type of work.

Wisconsin Department of Transportation, through the Wisconsin Highway Research Program, sponsored this study. The contract was awarded to Bloom Consultants, LLC, with University Wisconsin-Milwaukee as a subcontractor.

PROCESS

Literature was reviewed from WisDOT and various national sources for practices of pre-overlay repair of existing concrete and asphaltic pavements. Surveys were sent to the eight WisDOT districts to identify the practices being used for WisDOT projects. Previous WisDOT asphalt overlay projects were identified and overlay performance was analyzed. In addition, three overlay projects were studied in the field during the 2004 construction season. The best practices resulting in good and consistent performance of overlay were identified.

FINDINGS

After data analysis, the best practices being used by WisDOT were identified. A set of guidelines to be used for design and construction was developed. Specifically, the findings are as follows:

Asphalt Overlay of Concrete Pavements

(1) Three base patching methods are being used for pre-overlay of existing concrete for WisDOT projects: doweled concrete, non-doweled concrete, and asphaltic base patching. It was found that overlays with doweled concrete base patching perform best, followed by non-doweled concrete base patching and asphaltic base patching.

Based on statistical analysis, from a standpoint of service life, an overlay with doweled concrete base patching lasted two years longer than that with non-doweled concrete base patching, and three years longer than that with asphaltic base patching, before another overlay is warranted. Doweled concrete base patching should be used to repair the existing concrete pavement.

(2) For those overlays which utilized partial-depth joint and crack repair to correct the medium-severity longitudinal distressed joints, no medium or severe longitudinal distressed joints occurred in overlays within about 10 years since the placement of overlay. Other overlay projects that did not utilize partial depth joint/crack repair, however, exhibited varying performance of longitudinally distressed joints. This indicates that partial depth repair should be used to fix the partial-depth (medium-severity) longitudinally distressed joints.

(3) Transverse cracking development in overlay was slowed down when partial depth repair was used to repair medium-severity distressed transverse joint and cracks, compared to that in overlay without pre-overlay partial depth repair. Therefore, partial-depth transverse joint/crack distresses should be repaired utilizing partial-depth joint/crack repair.

(4) The thickness of overlay should be a minimum of three inches, practically three and half an inch, to mitigate reflective cracking. However, beyond the three inch thickness, simply increasing thickness might not be as effective.

(5) All the high-severity joints/cracks/patches should be repaired prior to the asphalt overlay.

(6) The rutting in asphalt overlay of existing concrete pavement was insignificant.

(7) The current IRI in overlay was highly correlated with initial IRI of overlay, indicating the importance of profile index. The roughness prediction model used in the NCHRP 1-37A 2002 design guide should be, and was, calibrated with locally available data.

Asphalt Overlay of Asphalt Pavements

(1) It seems that the milling and overlay projects which had an overlay thickness of more than two inches, have not been affected by pre-overlay block cracking in existing asphalt pavements. Therefore, mill and overlay could be used to repair the existing asphalt pavement with block cracking prior to overlay.

(2) Mill and overlay can not prevent alligator cracking from reflecting in the overlay. For asphalt pavements with extensive alligator cracking, pulverization should be used.

(3) Mill and overlay is not effective in preventing underlying transverse cracking from reflecting into the overlay. Other than pulverization, no practices being used by WisDOT was found to be effective in controlling the adverse effects of pre-overlay transverse cracking.

(4) Increasing the ratio of overlay thickness to milling depth was found to be an effective way to control the longitudinal cracking development in the overlays. The ratio should be kept at a minimum of three, if longitudinal cracking is severe in existing asphalt pavement.

RECOMMENDATIONS

The set of guidelines developed can be included in the Facilities Development Manual and Construction and Material Manual. The WisDOT Pavement Surface Distress Survey Manual should be published online for designers and field engineers to access. A standard special provision (STSP) should be included in an STSP update for designer's use. Other recommendations are listed as follows:

(1) For existing concrete pavement, which has been overlaid at least once, more study is needed to identify the distresses to repair, prior to another overlay. Distresses that do not appear to be severe may be badly deteriorated beneath the existing overlay.

(2) Transverse cracking is the dominant distress in asphalt pavement in Wisconsin. Study is needed to effectively repair the existing transverse cracking in existing asphalt pavement, prior to overlay, or to mitigate the cracking from reflecting. On the other hand, a study of current Hot Mix Asphalt (HMA) mix design, and asphalt binders being used by WisDOT, is needed to reduce the susceptibility of asphalt pavement to thermal cracking.

(3) Pavement Information File (PIF) database is a good source to study the pavement performance. However, some of the weight factors are assigned incorrectly and should be corrected. The format of recording the distresses, such as the 25 percent rule and distress extent range, artificially eliminates first-hand accurate survey data and results in extra errors. At this time, the purpose of the PIF is to calculate the PDI value for pavement management and six year program planning. A simple change of format could convert the PIF into an excellent pavement performance database for future study.

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CHAPTER 1. INTRODUCTION

1.1 BACKGROUND AND PROBLEM STATEMENT

A large percentage of the asphaltic paving projects performed in Wisconsin are asphaltic overlays of existing concrete or asphaltic pavements. The condition and distress of these pavements vary considerably when they are chosen for overlay, and the methods of preparing the existing surface of these pavements prior to the overlay also vary widely. The lack of consistency in the surface preparation or rehabilitation leads to large variations in the performance of these asphaltic overlays. A standard method of surface preparation would make the performance of these overlays more consistent, and thus easier to determine more accurate life cycle costs. The amount of surface preparation is also determined largely in the field during construction. This leads to either increased project costs or an understanding that the proper amount of work is not done to the existing pavement in order to maintain the project budget. A standard set of guidelines that could determine the amount of surface preparation or rehabilitation prior to asphaltic overlay during design and construction would provide this consistency, along with more accurate and stable project budgets for this type of work.

1.2 RESEARCH OBJECTIVES

The objective of this research is to develop guidelines for the surface preparation/ rehabilitation of existing concrete and asphaltic pavements prior to an asphaltic concrete overlay that can be used during both the design and construction.

1.3 RESEARCH APPROACH

To accomplish the research objectives, the following tasks were performed:

1.3.1 Task 1: Review Wisconsin Procedure on Surface Preparation

A review of literature related to this issue was conducted to document published information and results of studies from the Wisconsin Department of Transportation (WisDOT).

The references include WisDOT Facilities Development Manual (FDM) *(1)*, Construction and Material Manual (CMM) *(2)*, Facilities Maintenance Manual *(3)*, and Standard Specifications *(4)*.

To summarize the surface preparation methods being used for WisDOT projects, survey questionnaires were sent to WisDOT districts. The feedback was used to identify the surface preparation techniques and procedures.

1.3.2 Task 2: Review National Research on Surface Preparation

The Long Term Pavement Performance (LTPP) program, sponsored by the Federal Highway Administration (FHWA) provided information for pavement performance evaluation. The performance of the pavements in Special Pavement Study (SPS) and General Pavement Study (GPS) had been previously analyzed by several researchers. The study reports were reviewed for this project.

The Asphalt Institute has been working on pavement rehabilitation strategies. It has published several manuals for pavement rehabilitation, such as "Asphalt Overlay for Highway and Street Rehabilitation," MS-17. Each state has its own pavement

rehabilitation practice and guideline. The guidelines and specifications on surface preparation of existing pavements used by some State DOTs on were reviewed.

1.3.3 Task 3: Identify Projects for Field Comparisons

1.3.3.1 Performance Evaluation of Previous Overlays

A list of asphaltic overlay projects (over both existing concrete and asphaltic pavements) from past construction was identified. The amount of surface preparation done, and the current performance of the overlays was investigated. Investigation included pavement performance data prior to and after overlay, project records documenting surface preparation of the existing pavement, project plans, and special provisions.

Asphalt Overlay over Asphaltic Pavement

The service life of an asphalt overlay over asphaltic pavement ranges between eight and fifteen years. Since the long-term performance of the overlay is of more interest in this study, projects which had been overlaid for about 4~13 years were selected. Additionally, only projects which have detailed documentation about the performance prior to overlay and the surface preparation prior to overlay were selected.

The WisDOT pavement management unit has been monitoring the performance of principal arterials, including International Roughness Index (IRI) and Pavement Distress Index (PDI). Therefore, the performance data was extracted from the WisDOT database. The pre-overlay conditions of the selected projects were summarized, in terms of distress severity and extent, and IRI. The pre-overlay repairs from as-built plan and from final pay quantities were recorded, in terms of surface repair methods and

amount. The overlay thickness and traffic loads also are two important factors affecting the overlay performance.

The current performance of overlay was analyzed, with respect to pre-overlay conditions, pre-overlay repair amount, traffic, and overlay thickness. The best pre-overlay repair practices were determined, based on the data analysis and correlation.

Asphalt Overlay Over Concrete Pavement

The major structural distresses for concrete pavement are distressed joints/cracks. The pre-overlay repairs of existing concrete pavements consist mainly of partial-depth repair and full-depth repair.

Similar to the approach for surface preparation of asphalt pavement, the current performance of overlay on existing concrete pavement was extracted from databases and was correlated with both pre-overlay conditions and pre-overlay repairs. The effects of pre-overlay repairs on the post-overlay performance were determined.

1.3.3.2 Field Study of Asphalt Overlay Projects

A list of asphaltic overlay projects for the 2004 construction season (over both existing concrete and asphaltic pavements) were identified for the purpose of performing field observations to assess the condition of the pavements prior to overlay, and record the methods used to prepare the surface prior to overlay. Detailed distress surveys and Falling Weight Deflectometer (FWD) tests were conducted to evaluate the pavement structure.

1.3.4 Task 4: Guidelines Development

Based on the information obtained, a set of guidelines used to determine the surface preparation/rehabilitation recommended prior to an asphaltic concrete overlay was developed. The proposed guideline will provide a consistent and an effective pre-overlay repair strategy. It will also aid the analysis of life cycle cost of asphalt overlay. A set of guidelines were developed and recommended for incorporation into the WisDOT's FDM for use during the design process along with the CMM for use during construction.

CHAPTER 2. LITERATURE REVIEW

The literature review was performed to identify the surface preparation methods being used in Wisconsin and other states. Questionnaire was mailed to eight WisDOT districts surveying their pre-overlay repair practices.

2.1 REVIEW OF WISCONSIN PROCEDURES ON SURFACE PREPARATION

A literature review was conducted to document published information or results of studies from Wisconsin that are related to this issue. The specifications on surface preparation prior to asphalt overly in Wisconsin were reviewed. The references reviewed include the FDM, CMM, FMM, and Standard Specifications.

It is noted that the available source for the current practices of pre-overlay repair in Wisconsin is very limited. Most of the design and construction were done based on the experiences of designers or field engineers. In the FDM, only the Concrete Pavement Rehabilitation Manual is available. The manual for asphalt pavement is not published yet.

A review of the 2003 Standard Specifications identified the current repair methods of existing asphalt pavements and concrete pavements. In summary, the repair methods for asphalt pavements are relatively clear when compared to concrete pavement repair. A list of pre-overlay repair methods for both asphalt pavements and concrete pavements are shown as follows:

2.1.1 Overlay of Existing Asphaltic Pavement

1. Item 390.0201 or 390.0203, Base Patching, Asphaltic. This item was originated for base patching of existing concrete pavement prior to asphalt overlay. It is also being used to repair localized distressed areas in existing asphalt pavements prior to overlay.
2. Item 325.0100, Pulverize and Relay. This item consists of full depth in-place pulverizing of the existing asphaltic pavement along with a portion of the underlying base and relaying of the pulverized material to construct a new base.
3. Item 325.0200, Mill and Relay. This work is comprised of partial depth in-place milling of the existing asphaltic pavement and relaying of the milled material to construct a new base.
4. Item 204.0120, Removing Asphaltic Surface, Milling. This is the most commonly used method for surface preparation of the existing asphaltic pavement prior to asphaltic overlay. It includes removing and disposing of the existing asphaltic pavement or surfacing by milling to a partial depth. This item could also be used to correct the cross slope of the existing asphaltic pavement prior to asphalt overlay. Many of the existing asphaltic pavements have a cross slope of 1.5 percent and need to be improved to 2 percent to provide a uniform asphalt paving thickness of overlay.
5. Item 211.0100, Preparation of Foundation for Asphaltic Paving. This work includes filling the potholes, and removing loose crack filler or sealers.

2.1.2 Overlay of Existing Concrete Pavement

1. Item 390.0101~390.0403, Base patching. Base patching is used for pre-overlay repair of existing concrete pavement with either concrete or asphaltic mixtures for overlaying with new pavements. This is the most commonly used item for surface preparation of existing concrete pavement prior to asphaltic concrete. FDM SDD 13C 14-2 requires doweled concrete base patching, as shown in Figure 2.1. However, a significant number of overlay projects used non-doweled concrete base patching or asphaltic base patching.
2. Item 320.0105-320.0165 Concrete Base 4 Inch - 10 Inch (SY). This item is used to replace the existing concrete pavement over twenty feet long, prior to the asphalt overlay. The instruction is given in FDM SDD 13C15-3, Concrete Base Course (Doweled).
3. Item 211.0100, Preparation of Foundation for Asphaltic Paving. This item includes removing surplus crack and joint sealing materials and unstable patches of asphaltic mixtures used to fill localized pits, depressions, or badly spalled, or disintegrated areas of the old pavement to the underlying concrete.

There are another two items which have been used for existing concrete pavement prior to asphaltic overlay: Break/crack and Seat; and Rubblization. Since these two methods involve mechanically breaking the structural integrity of the existing concrete pavement, instead of repair, they are not included in this study.

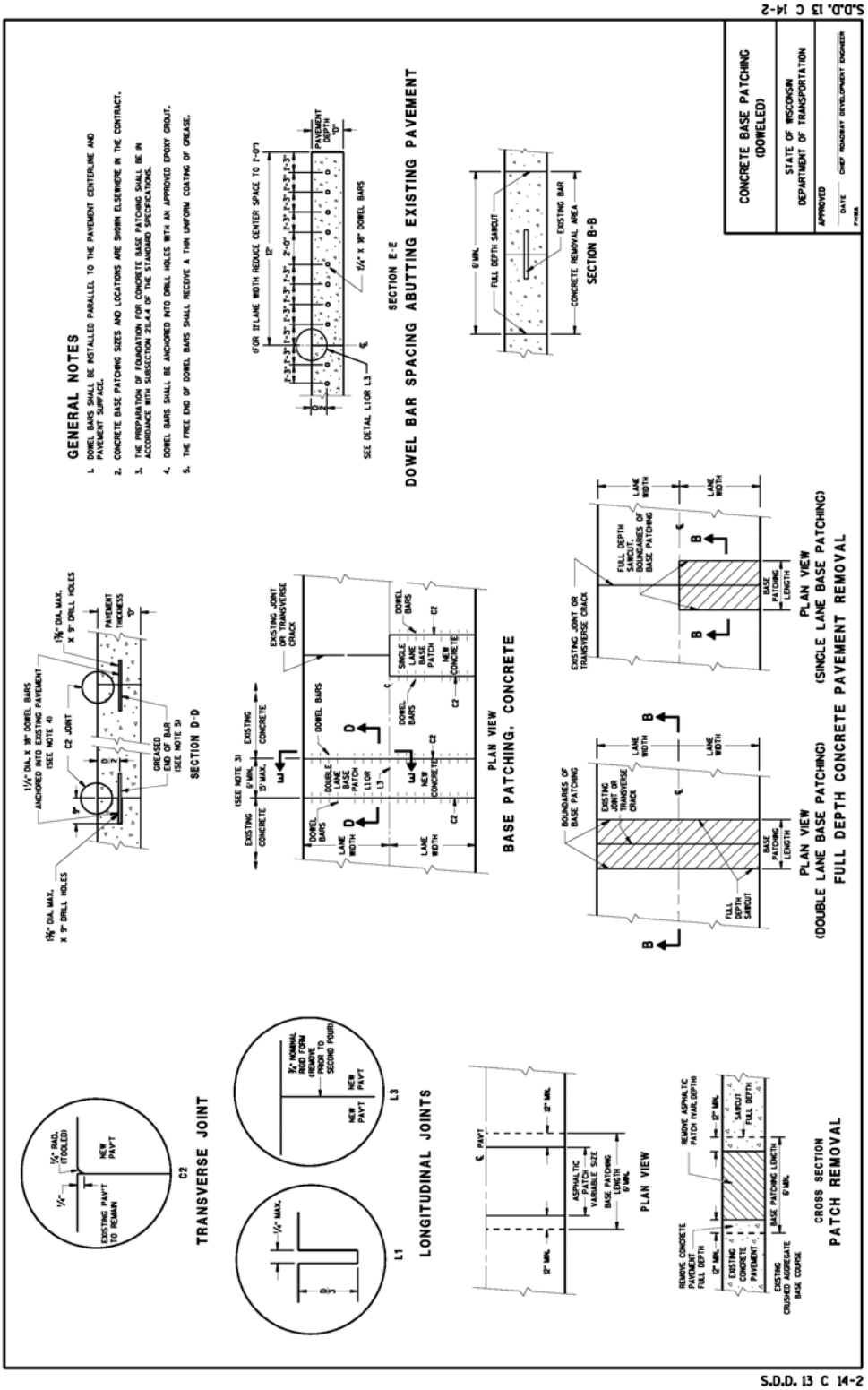

Figure 2.1 Standard Detail Drawing of Concrete Base Patching, Doweled

WisDOT Concrete Pavement Rehabilitation Manual (CPRM) was developed in 1992. The manual illustrates the distresses which warrant pre-overlay repair. Other manuals reviewed by the research team include the Pavement Surface Distress Manual (PSDM) *(5)*.

2.1.3 Questionnaire Survey of Surface Preparation in Wisconsin

WisDOT practices for pavement surface preparation before asphaltic overlays were investigated. A survey questionnaire on surface preparation techniques before asphaltic overlays was designed and mailed to pavement engineers in WisDOT's districts (8 districts). The survey responses were compiled, analyzed and presented in Tables 2.1 and 2.2. The survey questionnaire is presented in Appendix A.

Inspection of Table 2.1 indicates that there is a variation within WisDOT districts regarding the amount of distress repair of rigid pavement prior to asphaltic overlay. The amount and extent of repair also depend on the distress type and how this distress may affect the future pavement performance. For example, all surveyed districts will perform repair work ranging from 50 to 100% on patch deterioration before asphaltic overlays. This is important since placing AC overlay over deteriorated patch will lead to early pavement deterioration. In most WisDOT districts, base patching is commonly used as the surface preparation technique before AC overlay of PCC pavements.

Examination of Table 2.2 shows that WisDOT practices of pre-overlay repair of asphalt pavements vary among different districts. It should be noted that the severity of the distress affects the decision on the amount of repair work that needs to be

performed. In most WisDOT districts, surface milling is the commonly used surface preparation technique before AC overlay of AC pavements.

Table 2.1 WisDOT Districts Responses for Concrete Pavements Survey Questionnaire

Distress Type	Repair Work	Amount of Repair %			
		D3	D5	D6	D8
Slab break-up	Do nothing, full depth repair, concrete repair, patch	0	0-50	0	100
Distressed joints/cracks	Do nothing, partial depth repair, full depth repair, concrete repair	0-50	50-100	0-50	100
Patch deterioration	Do nothing, partial depth repair, full depth repair, concrete repair, mill off & replace, replace	50-100	100	50-100	100
Surface distress	Do nothing, clean & fill with HMA, concrete repair, remove unsound & patch, partial depth repair	0	50-100	0	50-100
Longitudinal joint distress	Do nothing, partial depth repair, full depth repair, clean & fill with HMA, concrete repair, edge repair	0-50	0-50	0-50	50-100
Transverse faulting	Do nothing, retrofit dowels, diamond grind, replace panel	50-100	50-100	50-100	0

*** Where D = District (e.g., D3 is WisDOT District 3)**

Table 2.2 WisDOT Districts Responses for AC Pavements Survey Questionnaire

Distress Type	Repair Work	Amount of Repair %			
		D3	D5	D6	D8
Alligator cracking	Do nothing, base patch, scratch coat, full depth mill, crack fill	0	0-50	0	0
Block cracking	Do nothing, base patch, scratch coat, full depth mill, crack fill, wedge	0	0-50	0	100
Transverse cracking	Do nothing, crack filling, remove and crack fill or patch, route and fill cracks, full depth mill	0-50	50-100	0-50	100
Longitudinal cracking	Do nothing, crack filling, broadcast filling, full depth mill, route and fill cracks	0-50	0-50	0-50	100
Flushing	Do nothing, seal coat, surface mill	0	0-50	0	0
Raveling	Do nothing, seal coat, surface mill	0	0-50	0	0
Patch deterioration	Do nothing, base patching, scratch coat, surface mill, mill off and repair, crack fill and patch, remove and replace	50-100	50-100	50-100	100
Rutting	Do nothing, scratch coat, surface mill, profile mill, rut fill, full depth mill, rut pave, fine tooth mill	50-100	50-100	50-100	100
Transverse distortion	Do nothing, scratch coat, wedge, subgrade repair, surface mill, full depth mill, fine tooth mill	0	50-100	0	100
Longitudinal distortion	Do nothing, scratch coat, mill high spots, subgrade repair, surface mill, full depth mill, fine tooth mill	0	50-100	0	100

2.2 REVIEW NATIONAL RESEARCH ON SURFACE PREPARATION

2.2.1 1993 AASHTO Guide for Design of Pavement Structures

AASHTO *Guide for Design of Pavement Structures* 1993 *(6)* addresses the pre-overlay repairs and the reflective cracking control. According to the design guide, for existing asphalt pavements, all areas of high-severity alligator cracking must be repaired; localized areas of medium-severity alligator cracking should be repaired, unless a paving fabric or other means of reflective crack control is used. For linear cracking, high-severity linear cracks should be patched; linear cracks that are open greater than 0.25 inches should be filled with a sand-asphalt mixture or other suitable crack filler. Ruts should be removed by milling or placement of a leveling course; if rutting is severe, the underlying layers should be investigated. Surface irregularities, such as depression, humps, and corrugations should be repaired.

2.2.2 Long Term Pavement Performance (LTPP)

LTPP program, a comprehensive 20-year study of in-service pavements, provides an information source for the pavement performance evaluation. Since 1987, the LTPP program began a series of rigorous long-term field experiments monitoring more than 2,400 asphalt and portland cement concrete pavement test sections across the U.S. and Canada. The specific LTPP experiments relevant to this study are SPS-5 and GPS-6B (flexible pavement rehabilitation), and SPS-6 and GPS-7B (rigid pavement rehabilitation).

In the National Cooperative Highway Research Program (NCHRP) project 20-50, Hall et al. (*7*) studied the effects of pre-overlay repair on the overlay performance,

based on LTPP data, and concluded that no significant differences in long-term cracking performance was detected between minimal versus intensive pre-overlay preparation. It is not a surprise that Hall et al. (*7*) failed to find the relationship between pre-overlay repair and overlay performance, considering variation of climate, traffic, materials, or construction methods in a national scope. However, there remains the possibility that a relationship exists between pre-overlay repair and overlay performance. It is well-known that repairing the existing distresses in the existing pavements could effectively increase the asphalt overlay life. In addition, most distresses in the overlay start at the area of distresses in the existing pavement.

2.2.3 Asphalt Institute: Asphalt Overlay for Highway and Street Rehabilitation

Chapter 7 of MS-17, “Asphalt Overlay for Highway and Street Rehabilitation” (*8*), addresses the preparation of asphalt pavements for asphalt overlays. The asphalt pavement preparation includes local repairs to fix the weakest conditions, leveling, cracking sealing, cleaning and tack coat application, crack-relief layer, and recycling.

Chapter 9 of MS-17 addresses the preparation of portland cement concrete pavements for HMA overlays. The preparation methods include joint repair, grinding, replacement, seating, sawing and sealing, and pressure relief joints, etc.

2.2.4 National Highway Institute – Techniques for Pavement Rehabilitation

In addition to describing the general methods of pre-overlay repairs, “Techniques for Pavement Rehabilitation” *(9)* introduced the concept of optimum percentage of the area repaired. For a pavement in need of repair, the cost of repair increases with the

percent of area repaired. The relationship between percent of area repaired and the life cost of the rehabilitation is a sag curve. There exists an optimum percent of area repaired so that the life-cost of the rehabilitation reaches the lowest point in the curve.

2.2.5 Other State DOTs' Practices

A literature review of other state DOT's practices was conducted based on review of publications, such as Transportation Research Records, Pavement Rehabilitation Manual, Construction Specifications, or Overlay Design Manual. Most of the publications focus on the rehabilitation of concrete pavement. Some states construction specifications or pavement rehabilitation manuals were obtained for review. These states include Minnesota *(10)*, Illinois *(11)*, Missouri *(12)*, Michigan *(13)*, Colorado *(14)*, California *(15)*, and Ohio *(16)*.

The findings in these publications included a comparison of various repair methods. According to Hall et al. *(17)*, for full-depth repair of concrete pavement in Illinois, pavements with non-doweled full-depth repair deteriorated quickly while doweled full-depth repair worked well. Wisconsin DOT also allows using asphalt concrete as full-depth repair material of concrete pavement. However, the literature review *(16, 17)* revealed that the use of asphalt concrete as repair material was not recommended. The expansion of concrete slab, due to temperature cycle, could push the asphalt concrete above the surface and cause the asphalt overlay to fail. It is also found that partial-depth repair was not working well. The distresses in the asphalt overlay were initiated at the area of underlying partial-depth repair.

Most asphalt overlays over cracked/seated pavement performed well, with some exceptions. The probable reasons for failed asphalt overlay over cracked/seated pavement are the cracking pattern, cracking machine, or seating method *(18-25).*

Undersealing is a commonly used method for concrete pavement restoration. This method involves void location identification, and sealing. Varying success with this method has been reported by Wu et al. *(26)*. WisDOT is not currently using undersealing as a standard pre-overlay repair.

Most states reported a satisfactory performance of asphalt overlay of rubblized concrete pavement. Only a few states indicated problems with rubblization, mainly due to weak subgrade *(27, 28)*. Other references reviewed are provided in the reference list *(29-40)*.

For asphalt overlay of existing asphalt pavements, the repair methods are substantially similar. The difference is the severity of the distresses to be repaired. For instance, some of the state DOT's specify repairing the crack with an opening width larger than ¼" while others use $^{3}/_{8}$" as a criterion.

For percent of area repaired, Ohio DOT *(16)* specifies a maximum 10% repair for both existing concrete pavement and asphalt pavement. This amount of repair varies among the state DOT's.

Buttlar et al. *(41)* studied the reduction of reflection cracking in the asphalt overlay using paving fabrics. It was found by Buttlar et al. *(41)* that the effectiveness of the paving fabrics to control reflection cracking is insignificant.

Tighe et al. (*42*) studied the performance of the asphalt overlay over existing asphalt pavements in Canadian Long Term Pavement Performance (C-LTPP). It was

concluded by Tighe et al. (*42*) that the thin overlay deteriorated at a higher rate than medium and thick overlay in wet-low freeze area, followed by wet-high freeze area and dry-high freeze area. Fine-grained subgrade significantly affected the performance of overlay, when compared to coarse-grained subgrade.

Harvey et al. *(43)* used a heavy vehicle simulator to study the asphalt overlay performance over existing asphalt pavement. It was found by Harvey et al. *(43)* that the asphalt overlay failed by reflection cracking, instead of fatigue cracking or rutting. The failure due to reflection cracking was verified by mapping the cracking in the existing asphalt pavements.

CHAPTER 3. PERFORMANCE REVIEW OF PREVIOUS OVERLAY PROJECTS

3.1 REVIEW PREVIOUS ASPHALTIC OVERLAY PROJECTS

The information and documents needed for the previous projects include as-built plans, construction diary, special provisions, traffic volume experienced, PDI and IRI history, and final pay quantities of items at the time of construction. The targeted asphaltic overlay age was about ten years old, ranging from 1988 to 1998. Tables 3.1, 3.2, and 3.3 show the selected projects.

Table 3.1 List of Projects of Asphalt Overlay of Existing Asphalt Pavements

Project ID	County	Highway	Overlay Year	Overlay Thickness (inches)
5964-00-60	Grant	STH 133	1994	3.5
5967-02-60	Lafayette	STH 126	1993	2
5070-00-61	Sauk	STH 154	1994	1.5
5090-02-72	Columbia/Sauk	STH 33	1995	4.5
6020-01-62	Dane/Columbia	US 51	1994	3
5155-00-60	Dane/Rock	US 14	1994	2
1701-05-72	Rock	STH 11	1995	5
6040-01-72	Columbia/Dodge	STH 33	1990	4.5
6030-01-71	Columbia	STH 22	1988	4.5
5596-03-71	Grant/Lafayette	STH 81	1989	5
3325-01-70	Walworth	STH 67	1994	3
2302-05-70	Washington	STH 167	1994	3
1330-00-70	Milwaukee	STH 83	1993	3
9180-11-71	Shawano	STH 22	1998	3
9180-11-72	Shawano	STH 22	1998	3
6230-08-71	Outagamie	STH 54	1998	2.36
6230-04-71	Outagamie	STH 54	1998	4.7
9190-08-72	Oconto	STH 32	1998	3.25
1470-06-71	Kewaunee	STH 42	1998	3
4140-08-71	Door	STH 42	1997	1.5
1498-01-71	Marinette	US 141	1997	4
1590-02-72	Marinette	US 8	1998	5.5

Table 3.2 List of Projects of Asphalt Overlay of Existing Concrete Pavements

Project ID	County	Highway	Overlay Year	Overlay Thickness (inches)
1401-03-71	Columbia	STH 16	1992	4.5
1067-01-72	Jefferson	IH 94	1995	2.5
3230-01-70	Kenosha	STH 50	1989	4.5
1430-00-70	Fond du Lac	STH 23	1994	3.5
2025-02-76	Waukesha	STH 190	1989	3
1430-00-71	Fond Du Lac	STH 23	1996	4.5
2240-08-70	Racine	STH 36	1996	3
2030-03-71	Milwaukee	US 45	1993	3
1107-03-79	Dodge	US 41	1995	3
6110-09-71	Winnebago	STH 44	1996	2
4015-09-71	Sheboygan	STH 57	1998	5

Table 3.3 List of Projects of Asphalt Overlay of Overlaid Concrete Pavements

Project ID	County	Highway	Overlay Year	Overlay Thickness (inches)
6070-00-60	Dodge	STH 68	1996	3
2350-02-70	Racine	STH 32	1994	3
1107-03-79,81	Dodge	US 41	1995	3
4015-04-70	Ozaukee	STH 57	1994	3
1103-02-74	Washington/Waukesha	US 41	1989	1.5
1100-07-73	Milwaukee	US 41	1993	3
1120-17-72	Winnebago	US 41	1996	4.25
4532-04-71	Sheboygan	STH 67	1997	2.5
1498-01-72	Marinette	US 141	1997	3
9160-5-72	Marinette	STH 64	1998	3
6070-00-60	Dodge	STH 68	1996	3

3.1.1 As-built Plan

An as-built plan contains the updated information from the original plan. A list of potential asphalt overlay projects were identified by reviewing the short descriptions of the projects in the construction maps or database, depending on the district record keeping management methods. The as-built plans of the projects in the list were retrieved and reviewed to determine if it was an asphaltic overlay over existing asphaltic or concrete pavements by examining the typical sections. Copies of some of the as-built plan sheets were made for the desired asphalt overlay projects, including title, typical sections, construction details related to surface preparation, and miscellaneous quantities. The as-built plans provided important information, such as location, existing typical section, typical finished section, and materials types.

3.1.2 Construction Diary

Initially, the construction diaries of the asphaltic overlay projects were retrieved and reviewed to obtain the surface preparation at the time of construction. It was found, however, that the construction diaries provided very limited information. An over-simplified description, mostly weather and labor count, does not help understand the surface preparation process. Therefore, it was decided not to proceed to review the construction diaries of the candidate projects.

3.1.3 Special Provisions

At the time of construction of the overlay projects, some of the surface preparation methods, which are standard procedures today, had not been established

and, thus not included in the standard specification or standard detailed drawing. The surface preparations at that time were specified in the special provisions for bidding and construction. Therefore, the highway proposals were retrieved to reveal what was specified to repair the surface prior to overlay, if any.

3.1.4 Traffic

The traffic volume experienced by the overlay has to be considered. The plan and traffic book provided Average Daily Traffic (ADT) at the time of design and ADT by the end of the overlay life.

3.1.5 Final Quantities

The as-built plans contain a list of estimates of quantities for pay items and miscellaneous quantities. A review of the as-built plans found that they were not updated to reflect quantities after construction. It is not unusual that there is a discrepancy between plan quantity and final pay quantity. Actually, one of the objectives of this research project was to solve the problem of discrepancy between design and field. With the assistance of the WisDOT Bureau of Construction, Construction Engineering Unit, the final pay quantities of the candidate projects were retrieved. The unit prices were also included in the final estimate, which may provide a basis for economic analysis of various repair methods.

3.1.6 PDI and IRI

The WisDOT Pavement Information Files (PIF) database was obtained for this research project, including the PDI and IRI history. State Trunk Highway (STH) and Interstate Highways (IH) were surveyed by the WisDOT pavement unit every other year to obtain PDI and IRI, following the WisDOT *Pavement Distress Survey Manual (5)*. Unlike other distresses which are surveyed manually, IRI and the average rut depth were measured by an automated video profiler PSI-24LG. In the manual, the extent and severity of the distresses are classified. Every one-tenth mile segment is surveyed within about one mile section. It is noted that the PDI and IRI data are recorded in the term of extent and severity which represents a range. For example, an extent of “one” for block cracking means that about 10-24 percent of the area of the survey segment is affected. The exact extent remains unknown. WisDOT has a weight factor matrix for each combination of severity and extent. These coefficients are used to represent the effect of a specific distress in calculating PDI. If a distress does not exist in a pavement, a value of one is given for that distress, for the purpose of PDI computation. When the extent or severity level becomes higher, a smaller value is given, indicating a deterioration of the pavement condition. An observation of these coefficients indicates that most of the coefficients are reasonably representative of the distresses surveyed, except for Continuous Reinforced Concrete Pavement (CRCP) pavement deterioration and Jointed Reinforced Concrete Pavment (JRCP) or Jointed Plain Concrete Pavement (JPCP) slab breakup. For instance, a pavement deterioration of "0, 0, 0, A" has a weight factor of 0.47 while "0, 0, 2, 8" has a "0.36". "0, 0, 0, A" means 100% of pavement

segment is affected by a pavement distress of level 3, which should have the lower weight factor than that of “0, 0, 2, 8”. It is also learned that the extent of some of the distresses are modified from 2003 on. This does not affect this research project, since the latest PDI and IRI used in this study are up to 2002. The PDI and IRI survey mentioned in this project is still based on the 1993 WisDOT Pavement Distresses Survey Manual. In this study, several major distresses, such as transverse cracking or rutting, needed to be analyzed individually. Therefore, a set of distress indices were given for each individual distress using the following equation:

$$\text{Distress Indicator} = 100 \times (1 - \text{individual distress weight factor}) \tag{3.1}$$

It could be seen that the above equation is analogous to PDI expression when only one type of distress exists. For an individual distress, a higher value of the distress indicator means that a more severe distress is present.

3.2 DATA ANALYSIS

The data collected through the above procedures were analyzed statistically. The correlation among the variables was investigated to find the factors influencing the performance of asphalt overlay.

3.2.1 Asphalt Overlay of Existing Concrete Pavement

Statistical analysis was performed to identify the effects of pre-overlay repair amounts and methods on overlay performance.

3.2.1.1 Effect of Base Patching Materials and Methods

Review of previous overlay projects indicates that three base patching methods were used for WisDOT projects: asphaltic base patching; non-doweled concrete base patching; and doweled concrete base patching. It was found that overlays using doweled concrete base patching had the best performance, in terms of the average transverse cracking (reflective cracking) development rate. The distress development rate was based on the progression of the distress indicator over the overlay service years. The distress indicator was calculated using the WisDOT distress weight factors in *Pavement Distress Survey Manual (5)*, as shown in Equation 3.1. Overlays using the other two methods deteriorated quickly compared to overlays using base patching with concrete, doweled. The effect of base patching methods on overlay performance is illustrated in Figure 3.1.

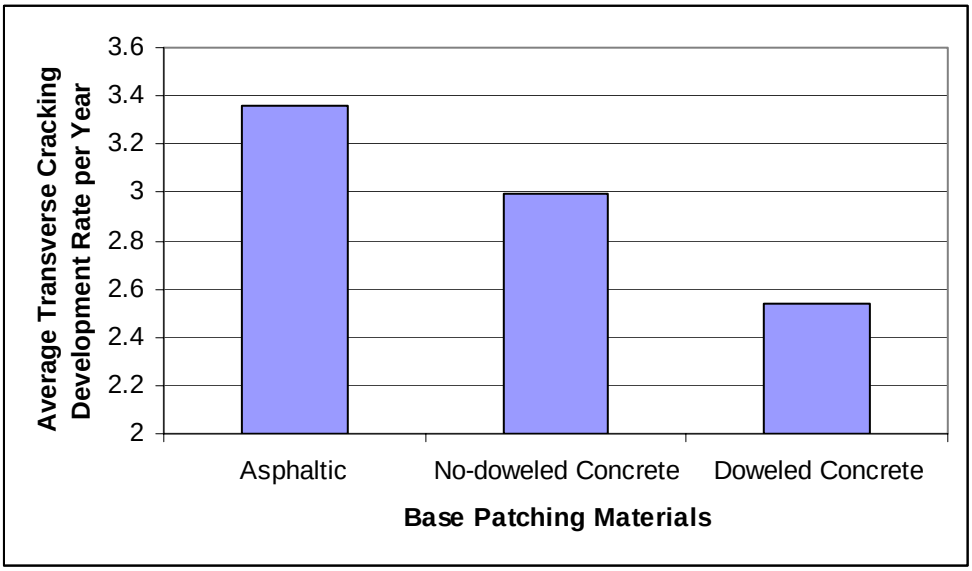

Figure 3.1 Effect of Base Patching Methods on Transverse Cracking Development Rate

The average transverse cracking development rates of asphalt overlays with doweled concrete, non-doweled, and asphaltic base patching are 2.54, 2.99, and 3.36,

respectively. A t-test was performed to evaluate the difference of the development rates for three repair methods. It was found that the differences of average transverse cracking development rates among the three methods were statistically significant, as shown in Table 3.4. Therefore, the existing concrete pavement should be repaired using doweled concrete base patching. For instance, a distress indicator of 27.3 corresponds three high-severity transverse cracks per station occurred in an overlay or 9 percent repair of the project area when another rehabilitation project is warranted and a standard base patching width of six feet is used. It takes about 11, 9, and 8 years to reach the distress indicator of 27.3 when doweled concrete, non-doweled concrete, and asphaltic base patching are used, respectively. Therefore, the overlay life could be extended for 2~3 years with doweled concrete base patching when compared to the other two repair methods.

Table 3.4 t-test of Transverse Cracking Developement Rates

t-Test: Two-Sample Assuming Unequal Variances						
	HMA vs. Doweled Concrete		**Non-doweled vs. Doweled Concrete**		**HMA vs. Non-doweled Concrete**	
	HMA	Doweled Concrete	Non-doweled Concrete	Doweled Concrete	HMA	Non-doweled Concrete
Mean	3.35	2.54	2.99	2.54	3.36	2.99
Variance	3.10	1.11	2.90	1.11	3.10	2.90
Observations	43	36	13	36	43	13
Hypothesized Mean Difference	0.81		0.45		0.37	
df	70		15		20	
t Stat	-0.011		0.0068		-0.013	
P(T<=t) one-tail	0.495		0.497		0.495	
t Critical one-tail	1.667		1.753		1.725	
P(T<=t) two-tail	0.991		0.995		0.990	
t Critical two-tail	1.994		2.131		2.086	

Even though doweled concrete base patching resulted in better performance of overlay when compared to non-doweled concrete base patching or asphaltic base patching, there has been a controversy over whether using doweled concrete base

patching is cost-effective. Doweled concrete base patching is more expensive than non-doweled concrete base patching or asphaltic base patching. A simplified example was made to demonstrate the cost analysis of using different repair methods. It is to be noted that this is not a life cycle cost analysis, since the real service life of an overlay is to be determined. For instance, an existing concrete pavement one mile long and twenty four feet wide (two lanes) was overlaid after pre-overlay base patching. A nine percent base patching of existing concrete pavement, 1267.2 square yards (S.Y.), was needed. The unit prices for doweled concrete, non-doweled concrete, asphaltic base patching were obtained from the Estimator program being used by WisDOT which includes bidding items price history. Table 3.5 shows the price breakdown of using three repair methods for one mile of concrete pavement. For a one mile concrete pavement overlay project, the cost of using doweled concrete base patching is $22,046 and $26,558 higher than non-doweled concrete and asphaltic base patching, respectively. However, when doweled concrete base patching is used, the overlay life is two years longer than non-doweled concrete base patching and three years longer than asphaltic base patching. The extra cost resulting from doweled concrete base patching is insignificant when compared to the total cost of one mile overlay project which is generally more than half a million dollars by reviewing previous project bidding.

Table 3.5 Price Breakdown of Three Base Patching Repair Methods

		Doweled Concrete	**Non-doweled Concrete**	**Asphaltic**
Base Patching	S.Y.	1267.2	1267.2	1267.2
	Unit Price	$26.4	$26.4	$22.84
Dowel Bar	Each	2534		
	Unit Price	$8.7		
Total		**$55,500**	**$33,454**	**$28,942**

3.2.1.2 Effect of Partial Depth Repair on Longitudinal Distressed Joints

Partial depth repair could be used to repair the partial-depth distressed joint/cracks prior to asphalt overlay. It was found that partial depth joint/crack repair is an effective way to suppress the re-occurrence of longitudinally distressed joints in overlay. Partial depth joint/crack repair consists of milling off the deteriorated material (either concrete or old asphaltic materials) at an angle of approximately 45 degrees along the joint and replacing it with asphaltic materials. Sometimes this method is also called “joint/crack cleaning” or “joint and crack repair”. For those overlay projects which utilized this method, no medium or severe longitudinal distress occurred within about 10 years after the placement of overlay, as shown in Figure 3.2. However, after ten years of service, the longitudinal distressed joints deteriorated rapidly. This seems to be related to the nature of partial depth repair, which is a functional repair, instead of a structural repair like full depth base patching.

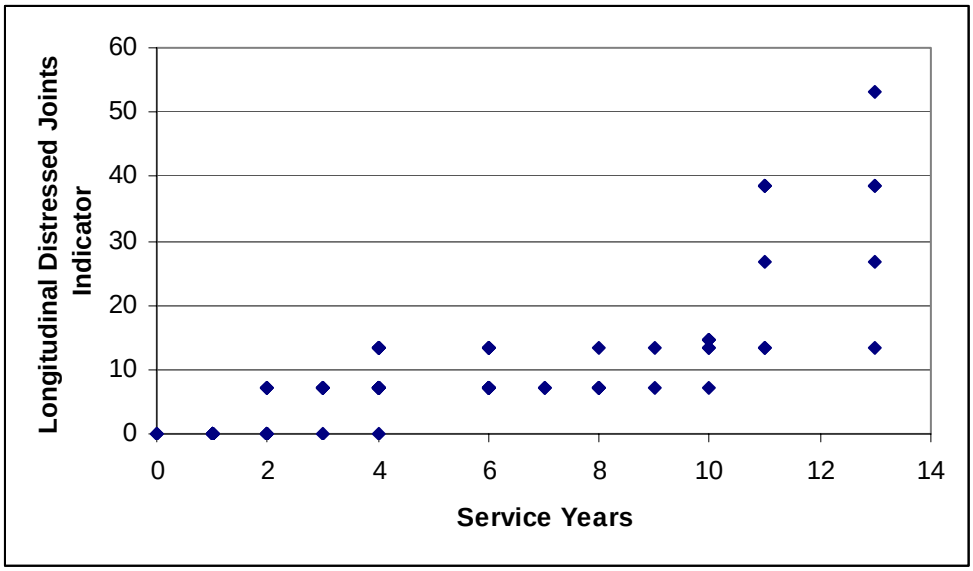

Figure 3.2 Effect of “Partial-depth Joint/Crack Repair” on Longitudinal Distressed Joints

Other overlay projects which did utilize partial depth joint/crack repair, however, exhibited varying performance of longitudinally distressed joints, as shown in Figure 3.3. This indicates that partial depth repair should be used to repair the partial-depth (medium-severity) longitudinally distressed joints. Considering this item is not a standard bid item yet, a sample of Standard Special Provision (STSP) and construction detail drawing are shown in Appendix B to be included in Special Provision and plan, respectively. A review of the overlay projects also indicates that high-severity longitudinally distressed joints in existing concrete pavements rarely happened.

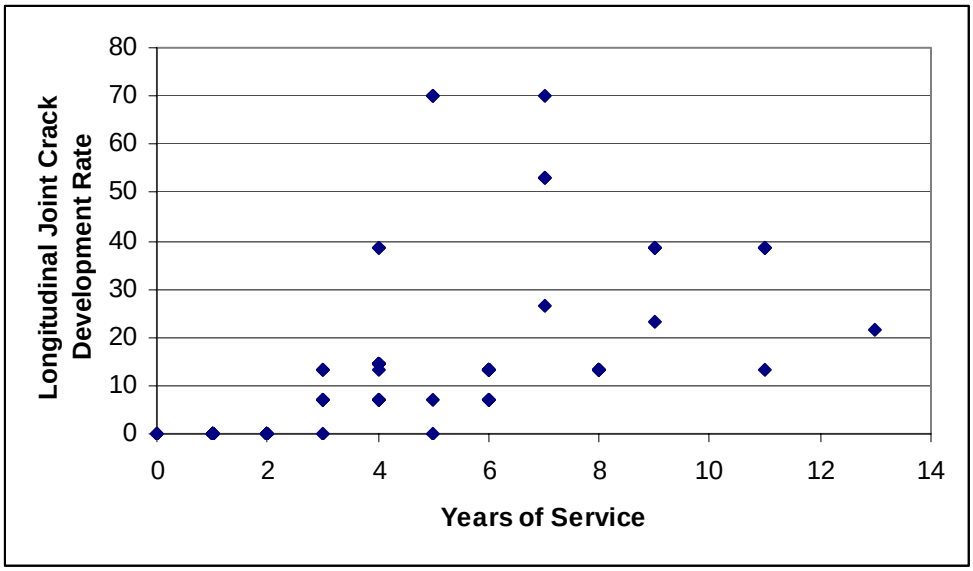

Figure 3.3 Longitudinal Joint Crack Development Rate of Overlay without Partial-depth Joint/Crack Repair

3.2.1.3 Effect of Partial Depth Repair on Transverse Cracking in Overlay

Partial-depth repair was also used to repair partial-depth distressed joints/cracks with loose deteriorated materials prior to an asphalt overlay. Since the full-depth base patching method affects the performance of transverse cracking the most, the effects of partial depth repair of partial-depth distressed joint/cracks were studied based on the overlay projects using same full-depth base patching method. Overlays with doweled

concrete base patching were selected. Transverse cracking developed slowly in overlays with partial depth repair as shown in Figure 3.4, compared to overlays without partial depth repair as shown in Figure 3.5. It is also noted that the data for overlay without partial depth repair are scattered to some degree, indicating varying performance of overlays. Therefore, partial-depth transverse joint/crack distresses should be repaired using a partial-depth joint/crack repair.

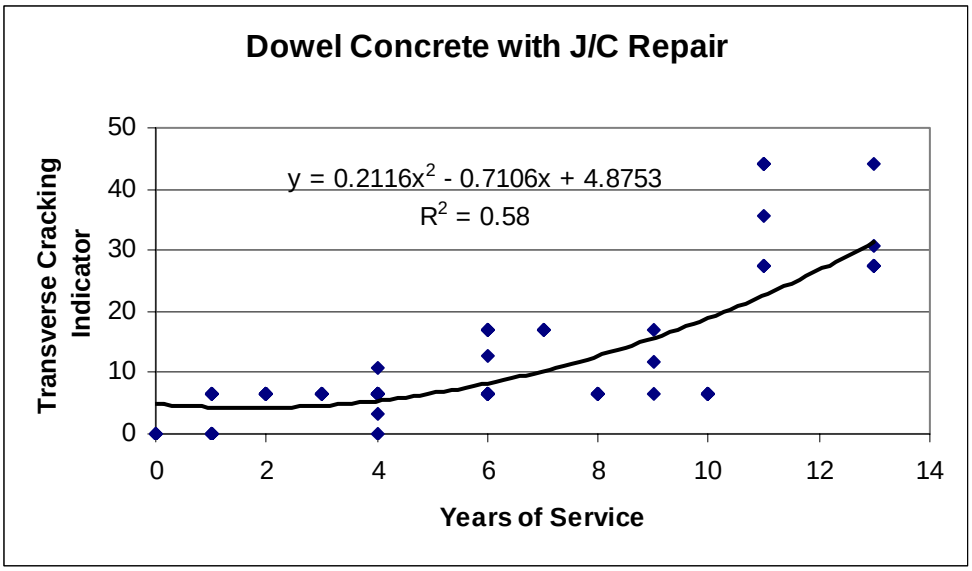

Figure 3.4 Transverse Cracking Development with Partial Depth Repair

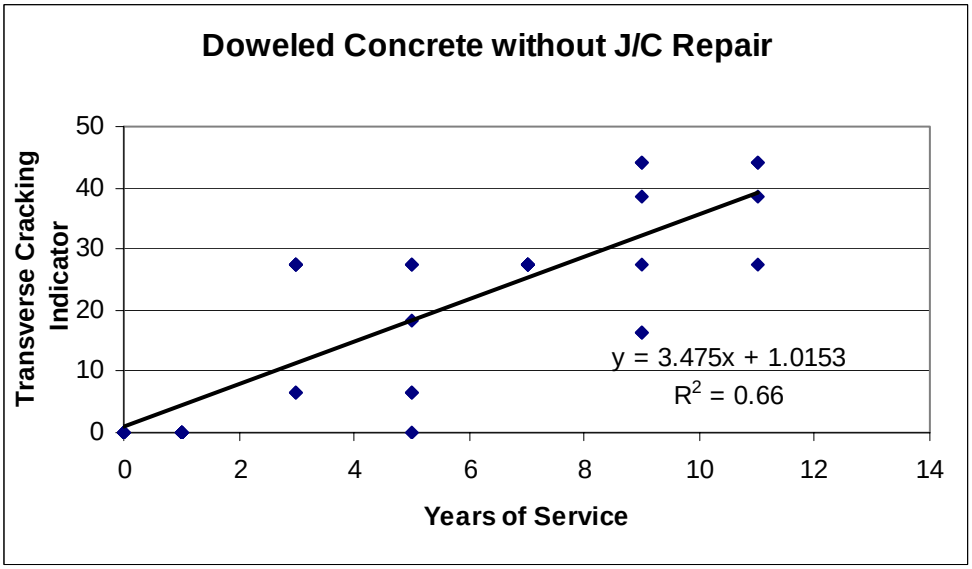

Figure 3.5 Transverse Cracking Development without Partial Depth Repair

3.2.1.4 Effect of Overlay Thickness on Transverse Cracking in Overlay

The effect of the overlay thickness was studied in terms of transverse cracking. Figure 3.6 shows the relationship between the overlay thickness and the transverse cracking development rate. This shows that with the increase of overlay thickness, the transverse cracking development rate decreases. It is believed that when the overlay thickness increases, it takes longer for the reflective cracking to reflect through the overlay and appear on the surface of the overlay.

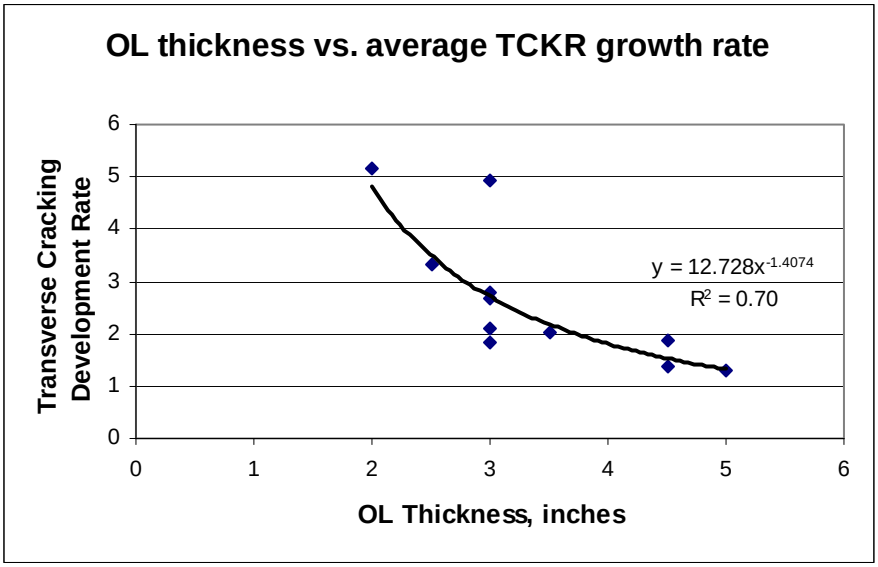

Figure 3.6 Overlay Thickness vs. Transverse Cracking Development Rate

Additionally, when overlay thickness is less than three inches, the relationship curve in Figure 3.6 is steep. A slight increase of the overlay thickness could effectively reduce the transverse cracking development rate. Therefore, it is suggested that the overlay thickness should not be less than three inches, to control the reflective cracking. It is understood that the overlay thickness is based on pavement design. However, the overlay thickness resulting from pavement design depends greatly on the evaluation of the conditions of the existing concrete pavement. The evaluation of existing concrete

pavement conditions has been empirical. Specifying a minimum overlay thickness of three inches may be beneficial to the overlay performance. Practically, three inches exceed the maximum thickness for one lift in accordance with WisDOT standard specifications. In general, the minimum thickness for two lifts is three and half inches. It is noted that, however, beyond the three inches thickness the relationship curve between the overlay thickness and the transverse cracking development rate tends to be flat, indicating that simply increasing the thickness might not be as effective.

3.2.1.5 Effects of Amount of Repair on Transverse Cracking in Overlay

The amount of repair, especially for full-depth base patching, greatly affects the overlay performance. Base patching is an item that often overruns in the field. Sometimes, to maintain the budget, the proper amount of repair was not done. The relationship between overlay performance and amount of repair was studied.

The actual amount of repair in the field, in terms of number of repaired distressed joints/cracks/patches per station, was obtained for some of the overlay projects. The number of existing high severity distressed joints/cracks/patches per station in the existing concrete pavement prior to asphalt overlay was obtained from the PIF database. The number of unrepaired joints/cracks/patches per station is the number of existing high-severity joints/cracks/patches minus the number of repaired distressed joints/cracks/patches. Figure 3.7 shows the relationship between the amount of unrepaired high severity joints/cracks/patches and the transverse cracking development rate.

It can be seen that with the increase of the number of unrepaired joints/cracks/patches, the transverse cracking development rate increases accordingly, indicating the importance of repairing all the high-severity distressed joints/cracks/patches.

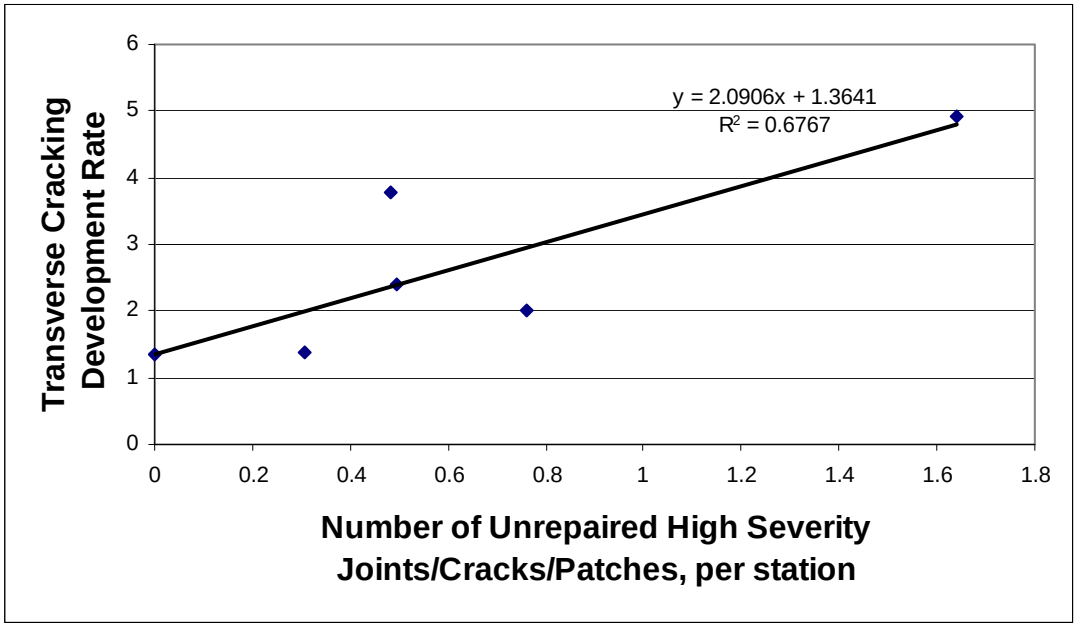

Figure 3.7 Number of Unrepaired Joints/Cracks/Patches vs. Transverse Cracking Development Rate

A multiple linear regression analysis was performed to investigate the effects of the amount of unrepaired high severity joints/cracks/patches, accumulated Equivalent Single Axle Load (ESAL), and the overlay thickness on transverse cracking development rate. It was found that the relationships between transverse cracking development rate and number of unrepaired high severity joints/cracks/patches as well as overlay thickness are statistically significant. However, the relationship between the transverse cracking development and the accumulated ESALs is not statistically significant.

3.2.1.6 Rutting in Asphalt Overlay of Existing Concrete Pavement

Figure 3.8 shows the current rut depths in asphalt overlays of existing concrete pavements in this study. Most of the rut depths in asphalt overlays of existing asphalt pavement were less than 0.1 inches, with an average of 0.07 inches, after a service period of 4 ~ 13 years. This even holds true for those sections with high traffic volume and a long service period. Therefore, rutting in an asphalt overlay of existing concrete pavement was insignificant, regardless of the mix type (MV or HV). This observation agrees well with the finding by Hall et al. *(7)* The rutting may be from compaction of mix by traffic. It was reported that the rutting in an asphalt overlay of concrete pavements occurred and developed within the first two years after the overlay. The minimal rutting in asphalt overlay of concrete pavement indicated that the asphaltic materials used in the overlays have been resistant to rutting.

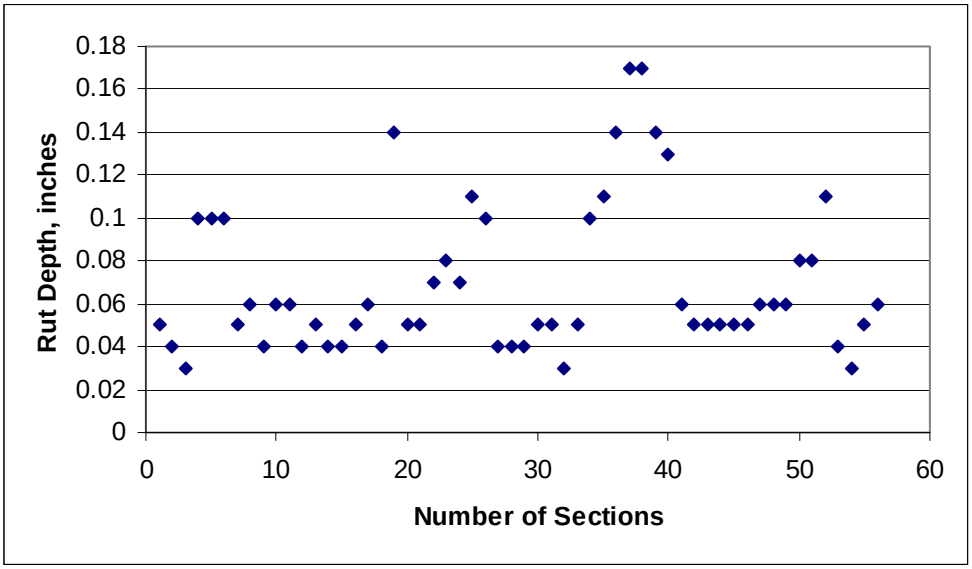

Figure 3.8 Rut Depth in Asphalt Overlay of Concrete Pavements

3.2.1.7 Roughness of Asphalt Overlay of Existing Concrete Pavement

The roughness of an asphalt overlay could be affected by many factors, such as pre-overlay roughness, pre-overlay repair, and distresses. IRI is a measurement of the roughness of pavement, as a functional performance. In this study, the effects of pre-overlay IRI and initial IRI of overlay on current roughness were investigated. Figure 3.9 shows the relationship between pre-overlay IRI and current IRI. It should be noted that the standard unit for IRI is m/km. No correlation was found between the pre-overlay IRI and the current IRI.

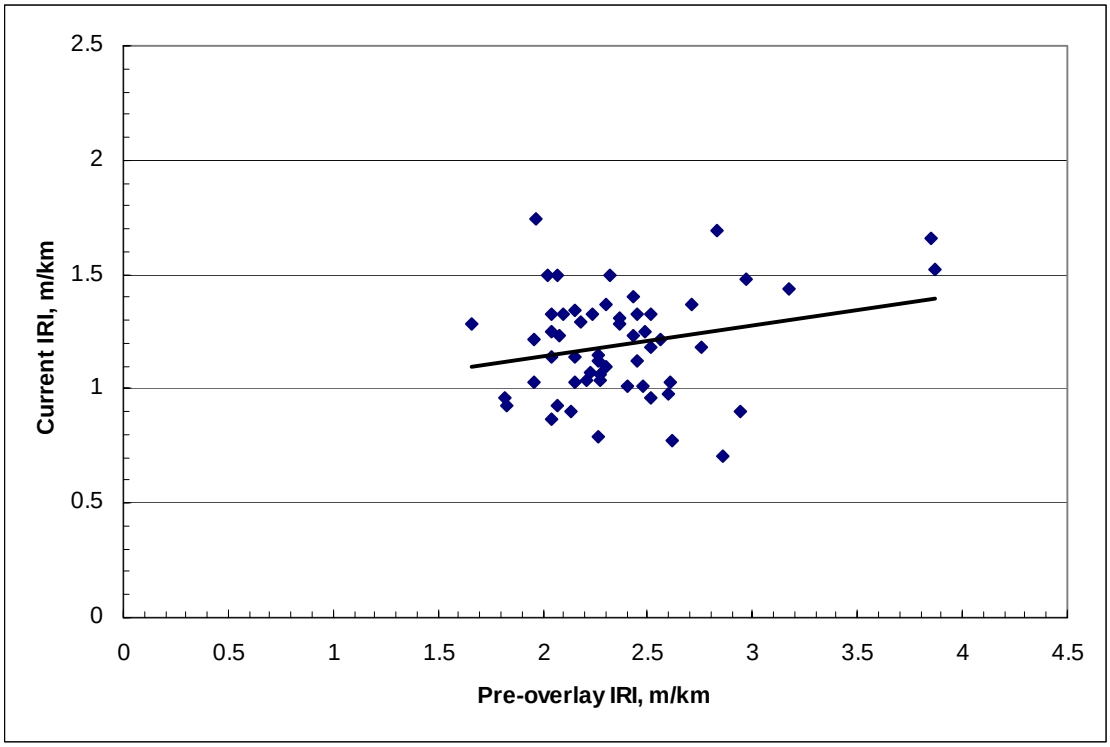

Figure 3.9 Pre-overlay IRI versus Current IRI in Asphalt Overlay of Concrete Pavements

It is presumed that the initial IRI right after placement of overlay is affected by the construction and pre-overlay IRI. The correlation between pre-overlay IRI and initial IRI, however, was found to be insignificant. This is probably because modern asphalt paving

equipments could correct the roughness of existing concrete pavement. The pre-overlay repair could also improve the roughness of existing pavement prior to overlay. This finding, however, was in contrast to the observation by Hall et al. *(7)* in which initial IRI after placement of overlay was found to increase with the increase of pre-overlay IRI.

The relationship between initial IRI of overlay and current IRI was investigated. Figure 3.10 indicates that initial IRI had a significant correlation with current IRI. With the increase of initial IRI, current IRI increased as well. Therefore, the profile index in an asphalt overlay of concrete pavement is a critical factor influencing the future performance of an asphalt overlay of existing concrete pavement.

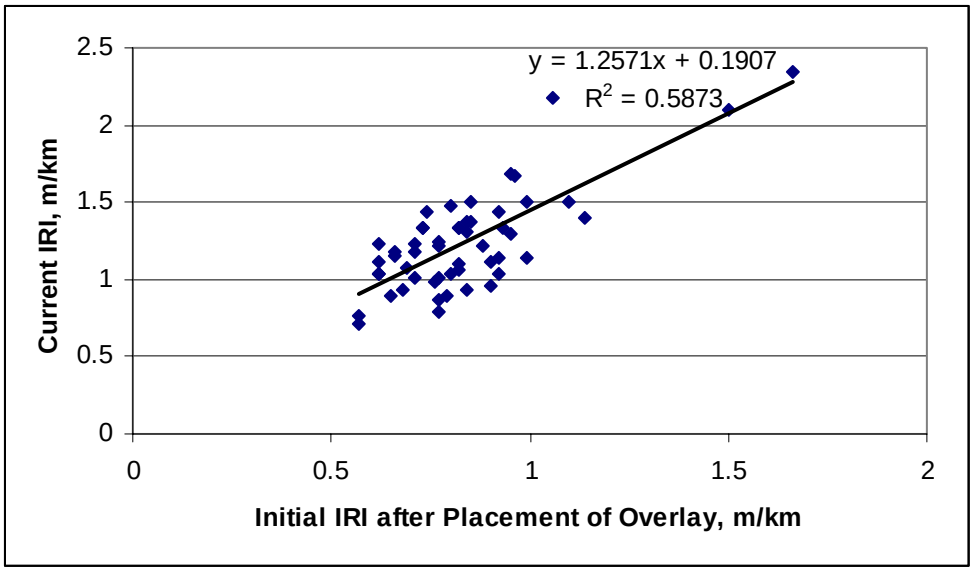

Figure 3.10 Initial IRI versus Current IRI in Asphalt Overlay of Concrete Pavements

3.2.1.8 Local Calibration of Roughness Prediction Model for Asphalt Overlay of Concrete Pavement in NCHRP 1-37A 2002 Pavement Design Guide

In the recently released NCHRP 1-37A 2002 design guide *(44)*, one advancement is the adoption of distress prediction models to predict the future performance of pavements. These models were developed based on regression of data

obtained from LTPP. The distress prediction models in an asphalt overlay of existing asphaltic and concrete pavements are provided. For roughness in asphalt overlay of rigid pavement, the roughness prediction model is presented as follows:

$$\mathrm{IRI} = \mathrm{IRI}_0 + 0.0082627(\mathrm{t}) + 0.0221832(\mathrm{RD}) + 1.33041\left(\frac{1}{(TC_S)_{MH}}\right) \quad (3.2)$$

Where:

IRI_0 =Initial IRI at the time of HMA overlay placement, m/km,

t =Time after overlay placement (measured in years),

$(TC_s)_{MH}$=Average spacing of medium and high severity transverse cracks, m,

RD =Average rut depth, mm.

Considering the variation of materials, construction, and climate in LTPP, it is imperative that the above distress prediction model be calibrated locally. In Equation 3.2, initial IRI, service years, and rut depth are available from the WisDOT PIF database. However, the transverse cracking survey method used by WisDOT is different from that in LTPP. According to *WisDOT Pavement Surface Distress Manual (5)*, the severity of transverse cracking is categorized as follows:

0 = None,

1 = less than ½" in width,

2 = greater than ½" in width,

3 = band cracking (multiple cracks in close proximity resulting in a narrow band of cracks) with or without dislodgement. A transverse crack is banded if the pavement area affected is within one foot of the crack.

The severities of "2" and "3" are considered as "medium" and "high", respectively. During a WisDOT distress survey, sealed and adequately filled cracks were rated as

severity level 1 unless it was clearly visible that the cracks are severity level "2" or "3". Crack sealing disguised the appearance of transverse cracks. However, the conditions of transverse cracks were not improved and thus, the severity remains the same after sealing, or worse under traffic. To evaluate the severity of the transverse cracks, the worst case in the history of distresses was brought forward and used in the data analysis. For instance, if the database indicated that a severity of transverse cracks was “3” in 1998 and “1” in 2002 due to crack sealing, a severity of “3” will be used for 2002 for the purpose of calibration.

The extent of transverse cracking was determined from the average number of transverse cracks per 100 feet in the survey segment. A transverse crack should be 6 feet in length to be counted. According to the WisDOT *Pavement Surface Distress Manual (5)*, the extent of transverse cracking was categorized as follows:

0 = None,

1 = 1 to 5 cracks per 100 feet,

2 = 6 to 10 cracks per 100 feet,

3 = greater than 10 cracks per 100 feet.

It is noted that the number of cracks was recorded as a range in the PIF database, instead of an exact count. Therefore, the average of number of cracks was used in the analysis. For the extent of “3”, 10 cracks were used, which happened only once in the selected sections. Even though using the average number of cracks may bring extra errors, the pattern of the extent of cracks was similar to an exact count. A nonlinear regression was performed to obtain the coefficients in Equation 3.2. The

results of regression indicated that the following roughness prediction model should be used in Wisconsin:

$$\mathrm{IRI} = \mathrm{IRI}_0 + 0.0131(\mathrm{t}) + 0.1621(\mathrm{RD}) + 0.4782\left(\frac{1}{(TC_S)_{MH}}\right) \tag{3.3}$$

The measured and regressed IRIs using Equation 3.3 are shown in Figure 3.11. The coefficient for rut depth in Equation 3.3 is significantly greater than that in Equation 3.2. This could be ascribed to the data source used to develop the model. LTPP used controlled experimental test sections to develop the prediction model. However, such data from experimental sections are not available for WisDOT. Secondly, as stated in the 2002 design guide, the IRI model was developed in a limited number of LTPP sections and may have serious deficiencies *(44)*. In addition, the distress survey methods are different between WisDOT and LTPP. The prediction model resulting from LTPP could not be directly applicable and has to be calibrated with the local data generated from past practices of state agencies.

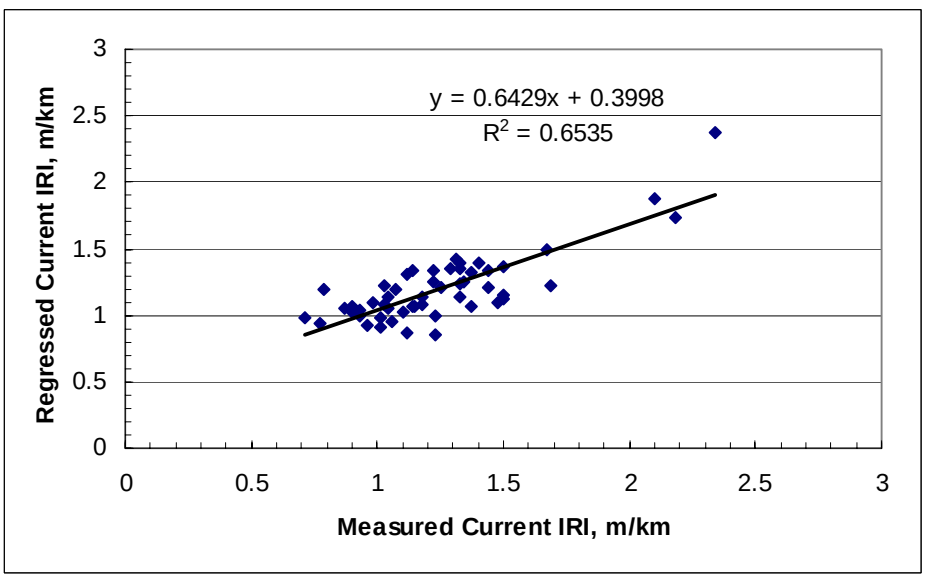

Figure 3.11 Measured IRI versus Regressed IRI in Asphalt Overlay of Concrete Pavements

3.2.2 Asphalt Overlay of Existing Asphalt Pavement

The performance of asphalt overlays on existing asphaltic pavements was reviewed. For the asphalt overlays of asphaltic pavements projects, the surface preparation methods consist of milling and pulverization. These two types of overlay projects were reviewed separately.

3.2.2.1 Block Cracking

Among thirteen milling and overlay projects, eight of the existing asphalt pavements had extensive block cracking prior to overlay. Within four years, only one of these eight overlay projects exhibited block cracking. This overlay has a minimum thickness of two inches among all the overlays. For the rest of the overlays, the service years range from four to ten years and overlay thicknesses range from two and half inches to four inches. None of them exhibited block cracking up to 2002, including one with two and half inches thickness and nine years of service. Since only one overlay of existing asphalt pavement with block cracking exhibited re-occurring block cracking, a correlation between pre-overlay block cracking and current block cracking performance can not be obtained. It seems the milling and overlay projects which have an overlay thickness of more than two inches have not been affected by pre-overlay block cracking in existing asphalt pavements. Therefore, milling and overlay could be used for asphalt pavement with block cracking.

Among nine pulverization and overlay projects, three overlays exhibited block cracking. An examination of the three projects indicated that two overlays used 100% recycled asphalt pavement (RAP) and that the third overlay was placed on a twice

pulverized asphalt pavement. The two RAP overlays exhibited block cracking after seven and nine years of service, respectively. The third overlay exhibited block cracking after seven years. The rest of the overlays have not shown any block cracking to date, after 4~14 years of service. The performance of an overlay in a pulverization and overlay project is not affected by the conditions of existing asphalt pavements, but by the overlay itself, the underlying base, or subgrade.

3.2.2.2 Alligator Cracking

Among the thirteen milling and overlay projects, only two overlays exhibited alligator cracking after three years of service. These two overlays were placed over existing asphalt pavements with alligator cracking. There was no alligator cracking in the existing pavements for the rest of the overlay projects up to 2002. Figure 3.12 shows the effects of pre-overlay alligator cracking on overlay performance.

Figure 3.12 demonstrates that milling can not prevent alligator cracking from reflecting in the overlay. This finding agrees with that by Harvey et al. *(43)*. For asphalt pavements with alligator cracking, pulverization should be used.

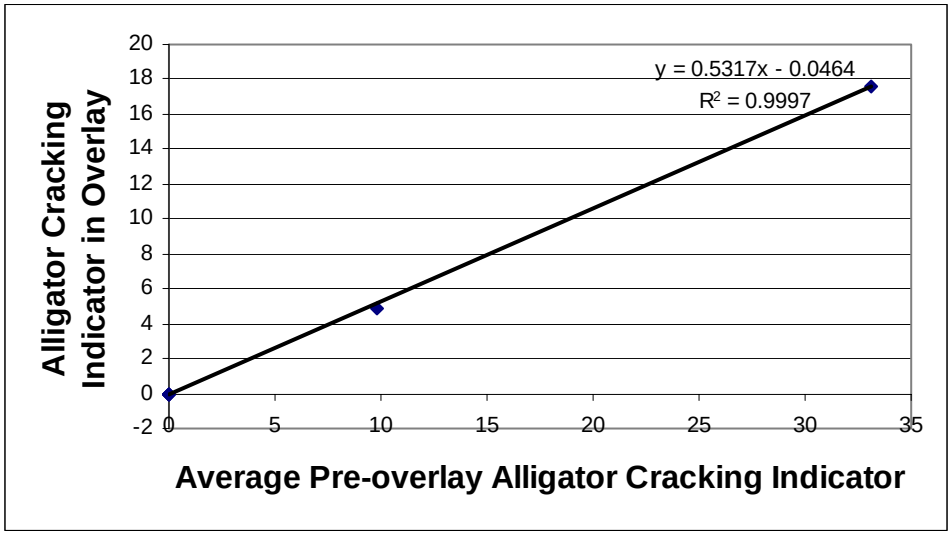

Figure 3.12 Effects of Pre-overlay Alligator Cracking

Similar to the findings regarding block cracking, among the nine pulverization projects, only three overlays exhibited alligator cracking. The three overlays are those which also exhibited block cracking, which used 100% RAP or twice pulverized base course. The remaining overlays have not shown any alligator cracking to date whether the existing pavements had alligator cracking or not. Thus, pulverization should be used when the existing asphalt pavements have extensive alligator cracking.

3.2.2.3 Transverse Cracking

Unlike block/alligator cracking, overlays exhibited a diverse degree of transverse cracking. The average transverse cracking development rate in overlays with milling is 2.22, compared to 0.67 for overlay with pulverization. This difference was tested by a t-test and was statistically significant. In an overlay with pulverization, the transverse cracking is a thermal cracking which starts on the surface of the overlay. This thermal cracking equally applies to the overlays with milling. Since overlays with milling

exhibited more transverse cracking than overlays after pulverization, it is believed that extra transverse cracking resulted from the reflection of transverse cracking in the existing asphalt pavement. This indicates that milling is not effective in preventing underlying transverse cracking from reflecting into the overlay.

No correlation was found between the transverse cracking development rate and other factors, such as milling depth, pre-overlay conditions, and overlay thickness. It indicates that other than pulverization, no practices were effective in controlling reflection of transverse cracking in existing asphalt pavement. Another study done by Minnesota DOT *(45)* also concluded that transverse cracking reflected through the overlay and the attempt to control the reflection using patching was not successful.

3.2.2.4 Longitudinal Cracking

The effects of surface preparation on longitudinal cracking in overlays were investigated. It was found that when the ratio of the overlay thickness to the milling depth increases, the longitudinal cracking development rate decreases, as shown in Figure 3.13. The ratio of overlay thickness to milling depth could be up to 8. This is because some overlay projects only milled the very top of the existing asphalt pavement surface. Increasing the ratio of overlay thickness to milling depth is an effective way to mitigate the longitudinal cracking development in the overlays.

Figure 3.13 shows that when the ratio of overlay thickness to milling depth increases from one to three, the longitudinal cracking development rate drops sharply. It seems that a ratio of three is a critical threshold. Therefore, it is suggested that the ratio of overlay thickness to milling depth be a minimum of three. When the ratio is more than

three, the relationship curve in Figure 3.13 tends to be flat, indicating that simply increasing the ratio is not as effective.

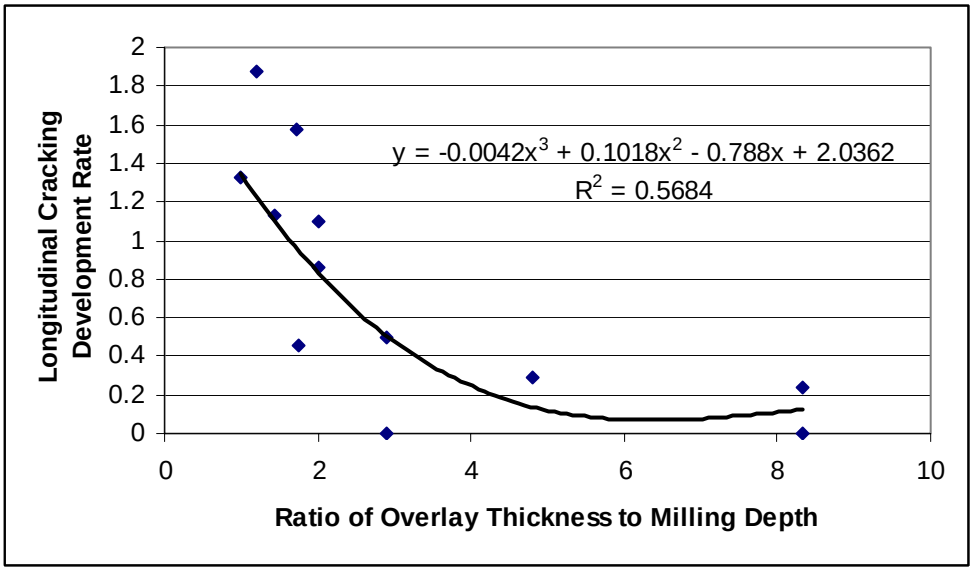

Figure 3.13 Effect of Ratio of Overlay Thickness to Milling Depth on Longitudinal Cracking

CHAPTER 4. FIELD STUDY

Three asphaltic overlay projects were selected for the field study during 2004 construction season: (1) Project #6040-00-63, STH 33, Portage, Columbia County, (2) Project #2290-08-70, STH 38, Mount Pleasant, Racine County and (3) Project #1410-05-70, STH 33, Newburg, Washington County. The AC overlays in these projects were constructed over AC or PCC pavements. Initial and comprehensive distress surveys were conducted on selected sections along these projects. In addition, Falling Weight Deflectometer (FWD) testing was conducted to evaluate the existing conditions of the pavements. Description of fieldwork conducted on these projects is given below.

4.1 STH 33 – PORTAGE, COLUMBIA COUNTY

This project was located on STH 33 that runs through the City of Portage in Columbia County. The project consisted of placing asphaltic overlay on top of asphaltic pavement for a length of about 7.62 miles. The existing pavement structure consisted of 8″ of asphalt pavement surface layer on top of 10″ of gravel/crushed stone base course. Overlays were performed at this site both 2 and 10 years ago. The recent overlay had problems in tack coat and is the main reason for severe delamination distresses.

4.1.1 Detailed Distress Survey Before Surface Preparation

A detailed distress survey was conducted to quantify distresses in this project. Three 100 ft sections were identified for this purpose. Details of the distress surveys for each section are described below.

4.1.1.1 Section 1

This 100 ft section starts at a “Narrow Bridge” sign and is located at the beginning of the project limit. The section was selected along the 2-lane AC pavement. The lane width is 12 ft on both westbound and eastbound lanes with a 3 ft shoulder on both sides.

The pavement surface was very rough with raveling and potholes in many areas. A low severity rutting was observed along a curved superelevated section of the pavement. The common type of distress found was delamination with high density. There were also thermal cracks across both lanes at regular intervals ranging in distance from 25 to 50 ft. Figure 4.1 depicts pictures of distresses observed on section 1. The results of the detailed distress survey on section 1 are presented in Figure 4.2.

(a) Delamination (2.5’×2’) (b) Moderate Thermal Cracking

Figure 4.1 Pictures of Distresses in Section 1, STH 33, Portage

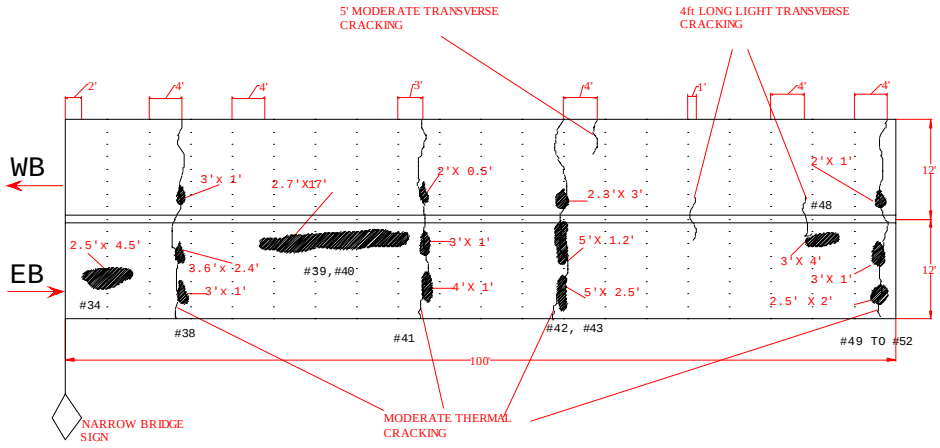

Figure 4.2 Detailed Distress Survey before Asphaltic Overlay for Section 1, STH 33, Portage

4.1.1.2 Section 2

This section was severely delaminated with distresses stretching along the whole length of the section. There were low severity transverse cracks, which were present on the centerline and shoulder section of the pavement, as shown in Figure 4.3. Medium to low severity thermal cracks were observed, which extended across both lanes. The results of the detailed distress survey on section 2 are depicted in Figure 4.4.

4.1.1.3 Section 3

There was high severity rutting (0.5″) along the curved section of the highway. Delamination of high severity/density was observed only on the westbound lane. Hairline transverse cracks were recognized on the eastbound lane with minor transverse cracks on the centerline and shoulder section of the highway. Figure 4.5

depicts pictures of distresses of section 3. Details of the distress survey of section 3 are illustrated in Figure 4.6.

(a) Minor transverse cracks across the center line

(b) Severe delamination along the wheel path

Figure 4.3 Pictures Showing Distresses in Section 2, STH 33, Portage

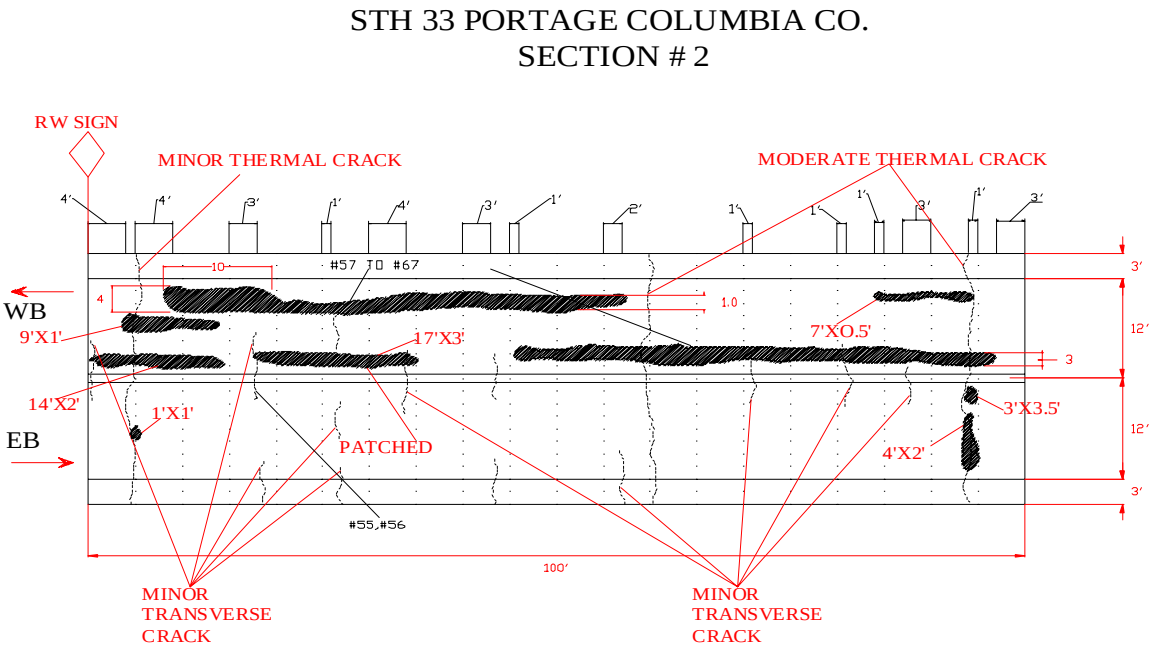

Figure 4.4 Detailed Distress Survey before Asphaltic Overlay for Section 2, STH 33, Portage

(a) Severe delamination (b) Closer view showing the severity of the distress

Figure 4.5 Pictures Showing Distresses in Section 3, STH 33, Portage

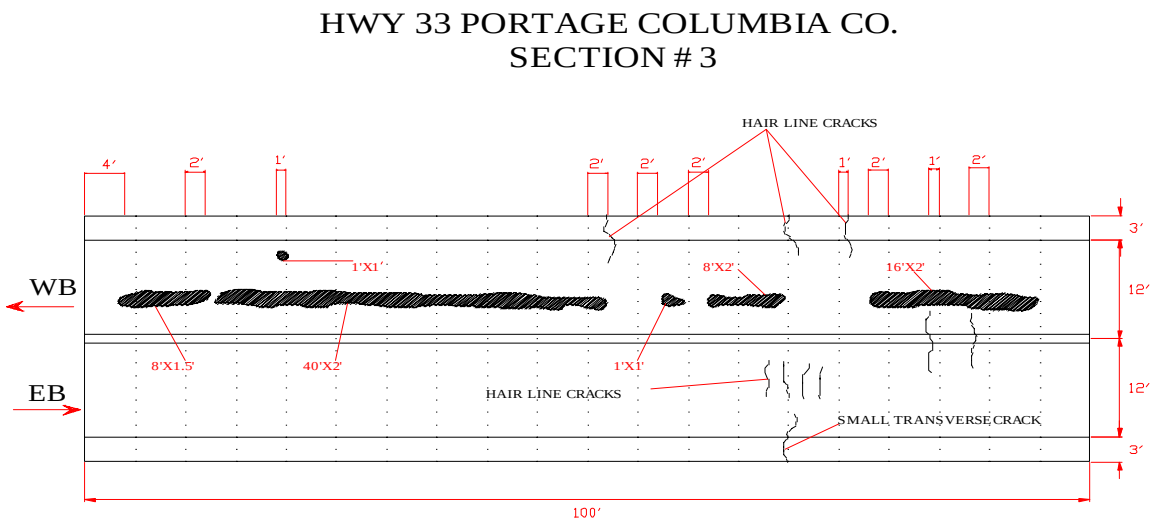

Figure 4.6 Detailed Distress Survey before Asphaltic Overlay for Section 3, STH 33, Portage

4.1.2 Surface Preparation for Asphaltic Overlay

For this project, the surface preparation consisted of milling the pavement surface to a depth ranging from 1″ to 1.75″, depending on the location and distress level. After milling, the surface was cleaned by air blowing and sweeping to get ready for the new asphalt layer. Figure 4.7 shows pictures of surface milling and the milling machine used.

(a) Picture showing 1 ¾" milling

(b) Machine used for milling

Figure 4.7 Surface Milling Before Asphaltic Overlay, STH 33, Portage

4.1.3 Distress Survey After Milling

Survey of the three sections was conducted after pavement surface milling. It was noticed that the minor transverse cracks, which were present in the middle of the pavement and the shoulder area of the pavement, were more prominent after milling. Transverse thermal cracks of moderate severity were noted in the middle section after the milling process. Figure 4.8 depicts pictures of transverse and thermal cracks after surface milling.

(a) Transverse thermal cracks after milling

(b) Cracks more prominent after milling

Figure 4.8 Pictures of Cracks After Milling, STH 33, Portage

4.1.4 AC Overlay

After surface milling, tack coat was applied and a 1.75″ E-3 mix asphaltic overlay was constructed at the top of the pavement surface. Type E-3 hot asphaltic mixes are designed to support a traffic load of 1-3 million ESAL during the pavement service life.

4.1.5 Survey After Overlay Construction

Four months after overlay construction; a windshield survey of the pavement condition was conducted. The quality of the ride was considered good, based on subjective evaluation. No minor or major distresses were observed. Figure 4.9 depicts a picture of the highway pavement after overlay construction.

Figure 4.9 Pavement Surface after Overlay Construction, STH 33, Portage

4.2 STH 38 - MOUNT PLEASANT, RACINE COUNTY

The project site of STH 38 was located in Mount Pleasant, Racine County. The project was 1.3 miles long and started at station 28+50 (Taurus Drive) and ended at Rapid Drive. The existing pavement was jointed plain concrete pavement (JPCP). The highway has 2 northbound (NB) and 2 southbound (SB) lanes separated by a depressed median. This highway had an Average Daily Traffic count of 18,400 in 2002.

The percentage of trucks using the highway is 6.2. For the field study, three 100 ft sections were selected for detailed distress survey.

4.2.1 Detailed Distress Survey Before Surface Preparation

A detailed distress survey was conducted to quantify distresses in this project. Three 100 ft sections were identified for this purpose. Details of distress surveys for each section are described below.

4.2.1.1 Section 1

Section 1 was selected in the northbound direction over two lanes and starts at station 66+00 near Chapel Street and ends at 67+00. The shoulder width is 3.5 ft toward the inner lane, and 3.0 ft toward the outer lane. Both lanes are 12 ft wide. The existing pavement structure was JPCP with 9″ PCC slab, 6″ of gravel or crushed stone base course layer and 6″ granular subbase course.

There were transverse cracks on this section and major spalling was observed along the longitudinal joints as shown in Figure 4.10. Transverse cracks were also spalled with a spalling width of 2 ft. Two full depth old patches of about 5 ft in width were observed in this section. These patches have some moderate deterioration as shown in Figure 4.11. Details of the distress survey of section 1 are depicted in Figure 4.12.

(a) Spalled transverse crack (High severity)

(b) Spalled longitudinal joint (high severity)

Figure 4.10 Spalling of Longitudinal and Transverse Joints in Section 1, STH 38, Racine County

Figure 4.11 Old patch 5 ft Wide with Moderate Deterioration, STH 38, Racine County

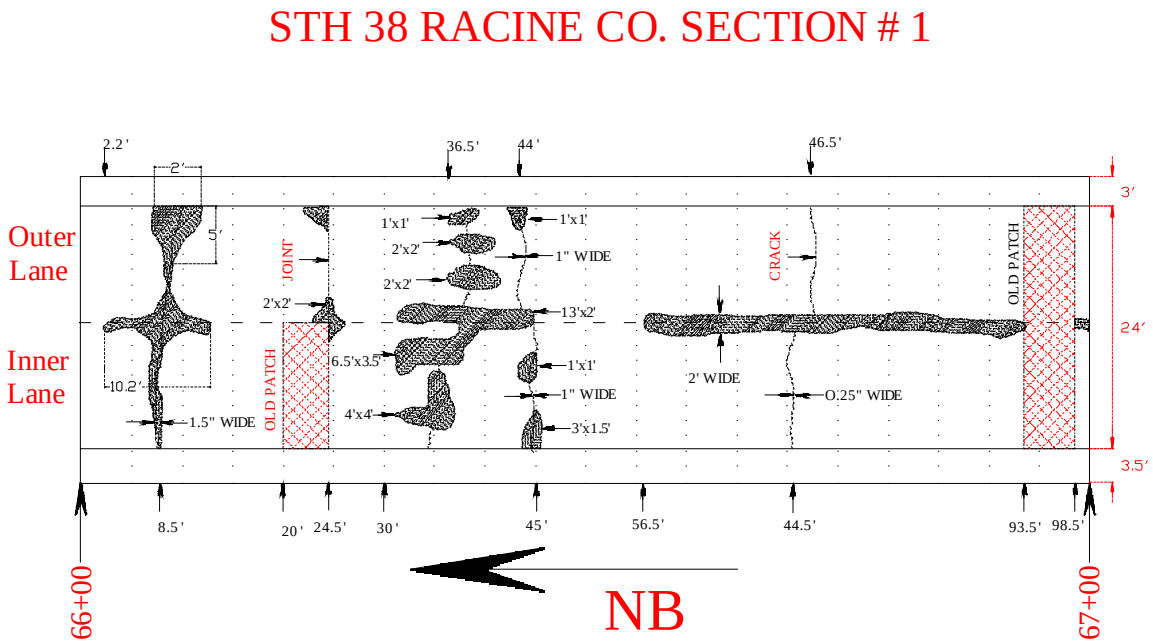

Figure 4.12 Detailed Distress Survey before Asphaltic Overlay for Section 1, STH 38, Racine County

4.2.1.2 Section 2

This section was selected on the southbound (SB) direction and starts at station 66+00 and ends at 67+00.

This section suffered from severe spalling on longitudinal joints. At certain places the spalling was approximately 1 ft wide. There were transverse cracks that spalled ½ to 1 inch in width, as shown in Figure 4.13. Full depth old patches were also present in the section, with about 5 ft of width as shown in Figure 4.14. There were some hairline cracks present in this section. Figure 4.15 depicts the results of the distress survey conducted on section 2.

Figure 4.13 Spalled Transverse Crack (High Severity), STH 38, Racine County

Figure 4.14 Old Patch and Longitudinal Joint Spalling, STH 38, Racine County

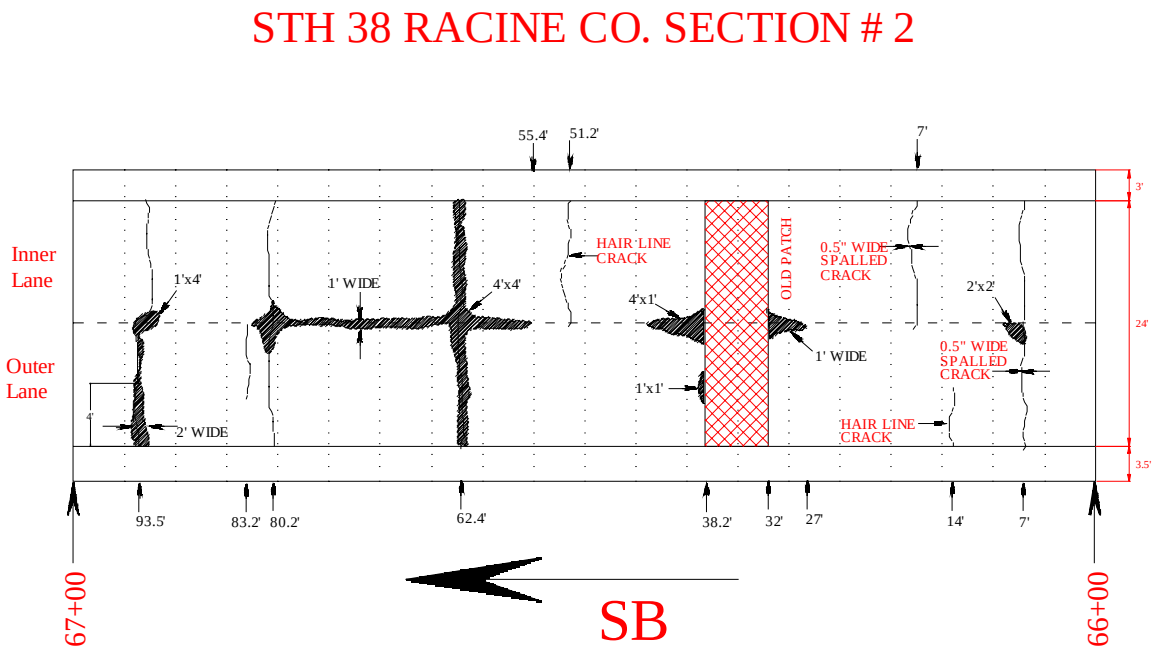

Figure 4.15 Detailed Distress Survey before Asphaltic Overlay for Section 2, STH 38, Racine County

4.2.1.3 Section 3

This section was selected on the southbound direction and starts at station 75+00 and ends at 76+00. The pavement structure was the same as that of sections 1 and 2.

This section was characterized by severe spalling of the longitudinal and transverse joints, ranging from 2 ft to 4 ft in width as shown in Figure 4.16. There was one full depth patch present in this section, which was about 6 ft wide and spanned over both lanes. Transverse cracks were also present and spalled severely with spalling width ranging from 2 inches to 1 ft. Figure 4.17 depicts details of the distress survey of section 3.

(a) Longitudinal joint spalling (high severity)

(b) Transverse crack 2″ wide

Figure 4.16 Distresses in Section 3, STH 38, Racine County

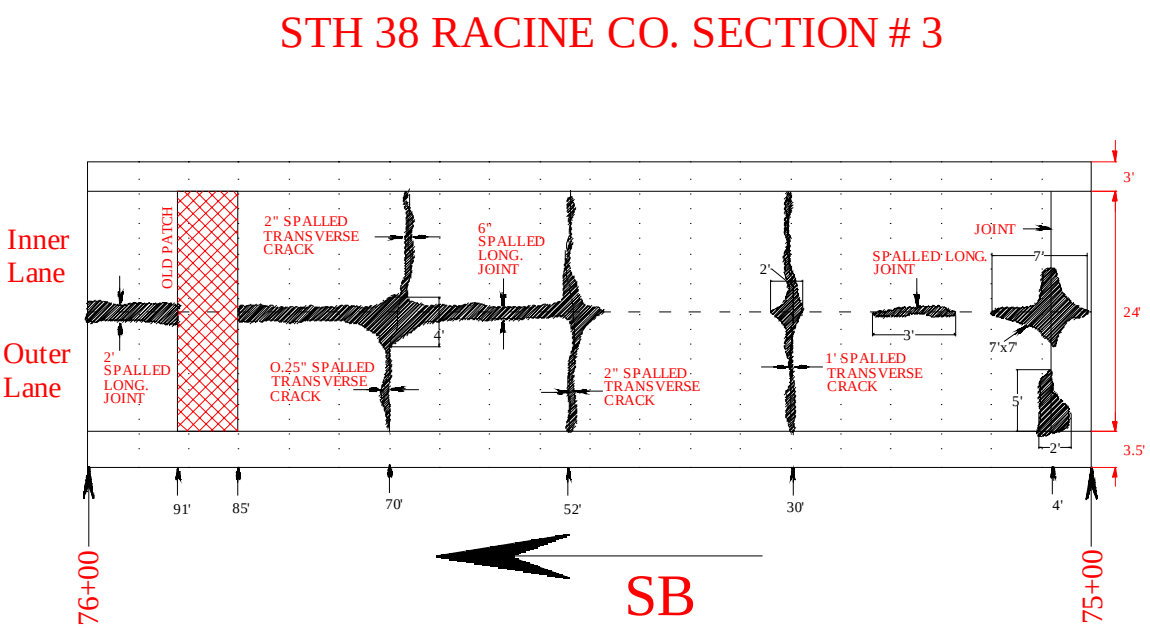

Figure 4.17 Detailed Distress Survey before Asphaltic Overlay for Section 3, STH 38, Racine County

4.2.2 Surface Preparation for Asphaltic Overlay

For this project, surface preparation consisted of full depth repair (base patching) for the severely deteriorated spalled crack areas. The distress area was identified and then the concrete slab was cut by the conventional wet sawcutting technique. The distressed area was rubblized and cleaned, and the base course was compacted. Holes were drilled in the surrounding slabs in the transverse direction to allow dowel bar placement. Then concrete was poured and the patch was left to cure. Figure 4.18 shows pictures of the full depth repair process. Some of the longitudinal and transverse cracks with less deterioration were treated by placing AC patches.

(a) Full depth saw cut (b) Full depth pavement repair

Figure 4.18 Base Patching at STH 38, Racine County

4.2.3 Falling Weight Deflectometer Testing

FWD testing was conducted on STH 38 for evaluation of the existing conditions of the pavement. The FWD testing was conducted by WisDOT using the KUAB FWD shown in Figure 4.19. Testing was done at three different locations in each test section. The points selected were in the middle of the slab for the deflection basin and on the approach slab near a joint and crack to determine the load transfer efficiency. A total of

9 points were taken on the 3 sections. At each point, two sets of loading values were applied with three drops for each loading value. FWD testing was done using 9,000 and 12,500 lb load values.

(a) KUAB FWD machine

(b) Segmented base plate (11.82″ dia.) placed near the joint.

Figure 4.19 FWD Testing Using KUAB at STH 38, Racine County

4.2.4 Distress Survey after Surface Preparation

A detailed survey was conducted to identify the amount of surface preparation work conducted on the three selected sections. Figures 4.20-4.22 depict the results of the survey and show the type of surface preparation work conducted. In order to quantify the repair work conducted, measurements were made in these three sections. Table 4.1 presents a summary of the amount of repair work conducted on these sections.

REPAIR ON SECTION # 1

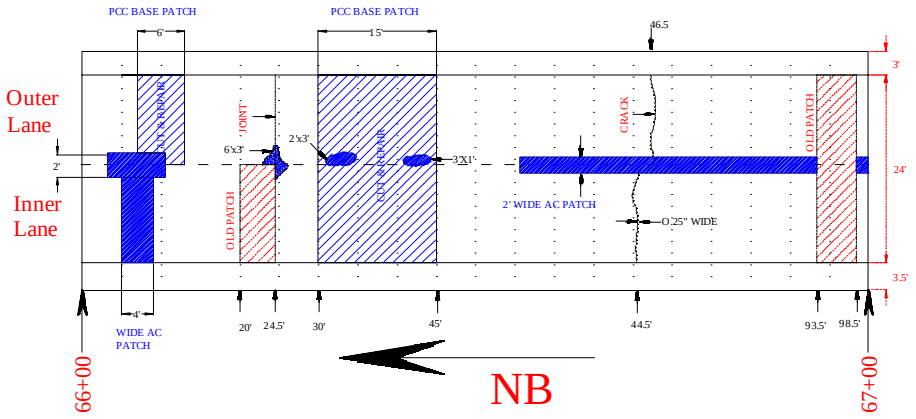

Figure 4.20 Repairs Done on Section # 1, STH 38, Racine County

REPAIR ON SECTION # 2

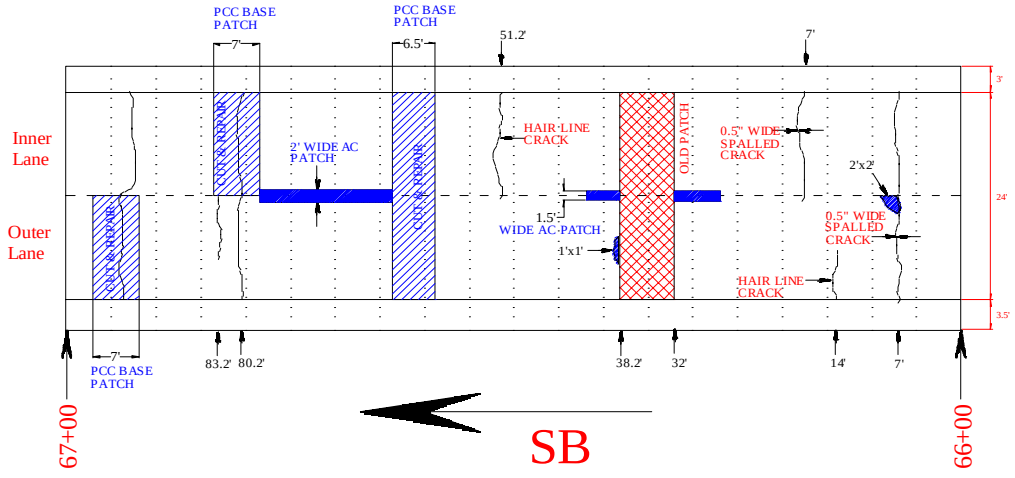

Figure 4.21 Repairs Done on Section # 2, STH 38, Racine County

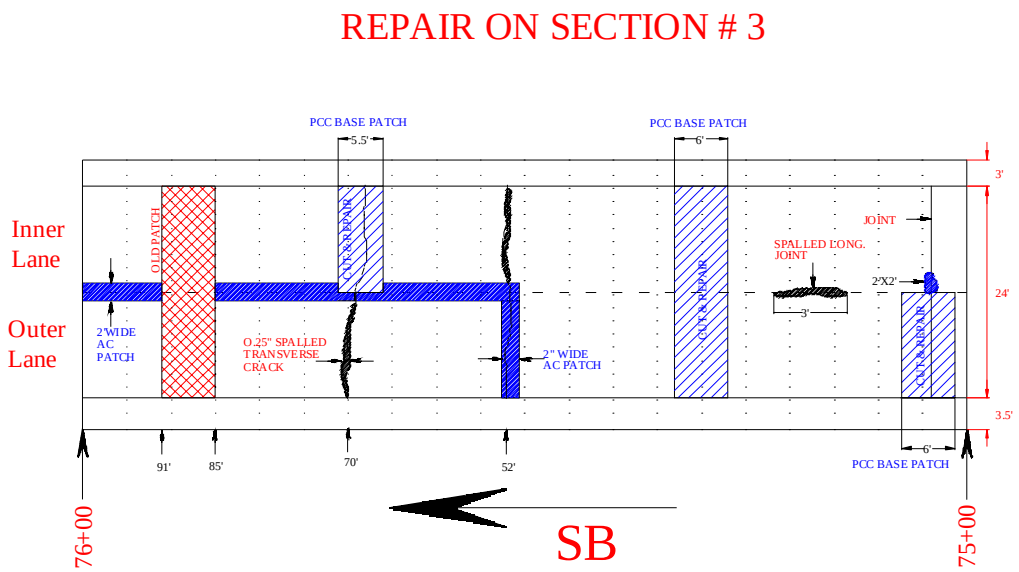

Figure 4.22 Repairs Done on Section # 3, STH 38, Racine County

Table 4.1 Amount of Repair Done on Sections 1, 2 & 3, STH 38, Racine County

Sections	Pavement Distress	Quantity	Quantity of Repair	% Repair
Sec 1 – NB	Crack Spalling	235 ft^2	432 ft^2 PCC	100
	Transverse Crack	84 ft	36 ft	43
	Joint Deterioration	121ft^2	138 ft^2 AC	100
	Patch Deterioration	0	0	
Sec 2 – SB	Crack Spalling	73 ft^2	324 ft^2 PCC	100
	Transverse Crack	144 ft	48 ft	33
	Joint Deterioration	37 ft^2	71.2 ft^2 AC	100
	Patch Deterioration	0	0	
Sec 3 – SB	Crack Spalling	35 ft^2	210 ft^2 PCC, 24 ft^2 AC	100
	Transverse Crack	72 ft	24 ft	33
	Joint Deterioration	145 ft^2	88 ft^2 AC, 72 ft^2 PCC	100
	Patch Deterioration	0	0	

4.2.5 AC Overlay

After surface preparation work was completed, a variable (5.5″ at centerline to 4″ at outer edge) E-10 type asphaltic overlay was constructed at the pavement surface.

4.2.6 Survey After Overlay Construction

Three months after the AC overlay construction was completed, a windshield survey was performed. No major distresses were found. The ride quality of the highway was considered to be good.

4.3 STH 33 – NEWBURG, WASHINGTON COUNTY

This project was located in Washington County on STH 33 and is 3.249 miles long. The project started at station 199+51.86, which was near Popular Road and ended at station 372+00 at the Ozaukee County line. The lane width is 12 ft and shoulder width is 3 ft on both sides of the highway. The type of pavement at this project was AC pavement with 5″ of AC surface on top of 6.5″ of crushed aggregate base course. STH 33 is a two lane divided highway that runs in an east-west direction. The ADT for 2003 was 8,700 with 7.1% trucks.

4.3.1 Detailed Distress Survey before Surface Preparation

A detailed distress survey was conducted to quantify distresses in this project. Three 100 ft sections were identified for this purpose. Details of distress surveys for each section are described below.

4.3.1.1 Section 1

The 100 ft section started at station 297+00 and ended at 296+00. On this section, there were many interconnected transverse and longitudinal cracks (block cracking) that are spalled in many places. The width of the cracks ranged from ¼ to ½ inch. Severe thermal cracks were also observed at this section. Figure 4.23 depicts pictures of the cracks observed at section 1. The results of the detailed distress survey are presented in Figure 4.24.

(a) Interconnected cracks (b) Severe transverse crack with spalling on the right side

Figure 4.23 Distresses in Section 1, STH 33, Washington County

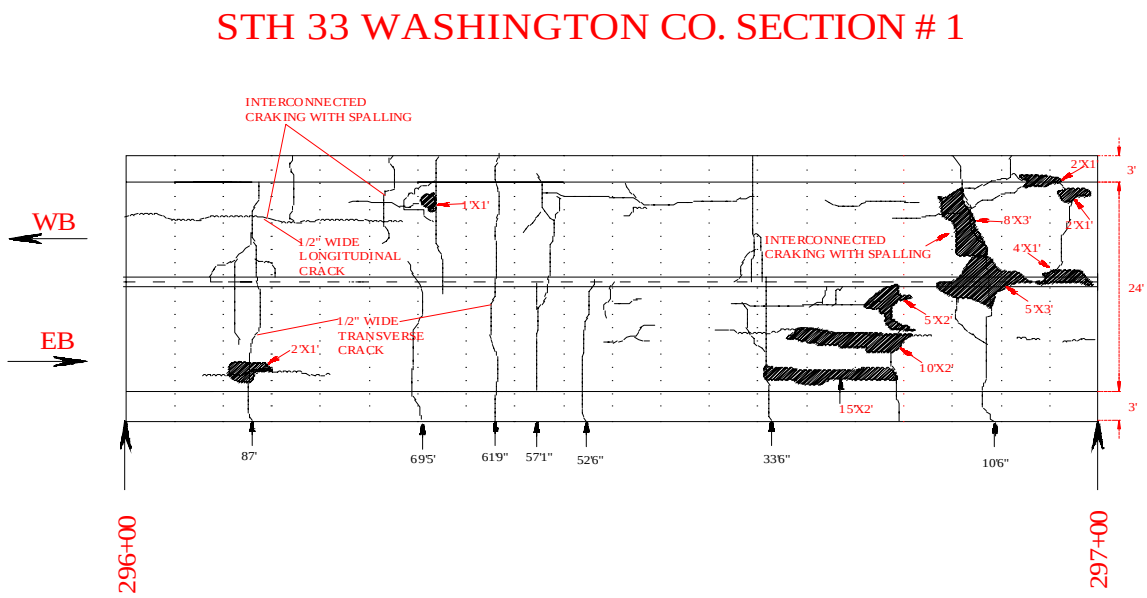

Figure 4.24 Detailed Distress Survey before Asphaltic Overlay for Section 1, STH 33, Washington County

4.3.1.2 Section 2

This section starts at station 328+00 and ends at station 327+00. On this section, severe thermal cracks of about ¼ to ½ inch in width were observed. There were many interconnected transverse and longitudinal cracks. Figure 4.25 shows pictures of distresses observed at this test section. The results of the detailed distress survey for this section are presented in Figure 4.26.

(a) ½ ″ thermal cracking with interconnected cracks

(b) High density of interconnected cracks

Figure 4.25 Distresses in Section 2, STH 33, Washington County

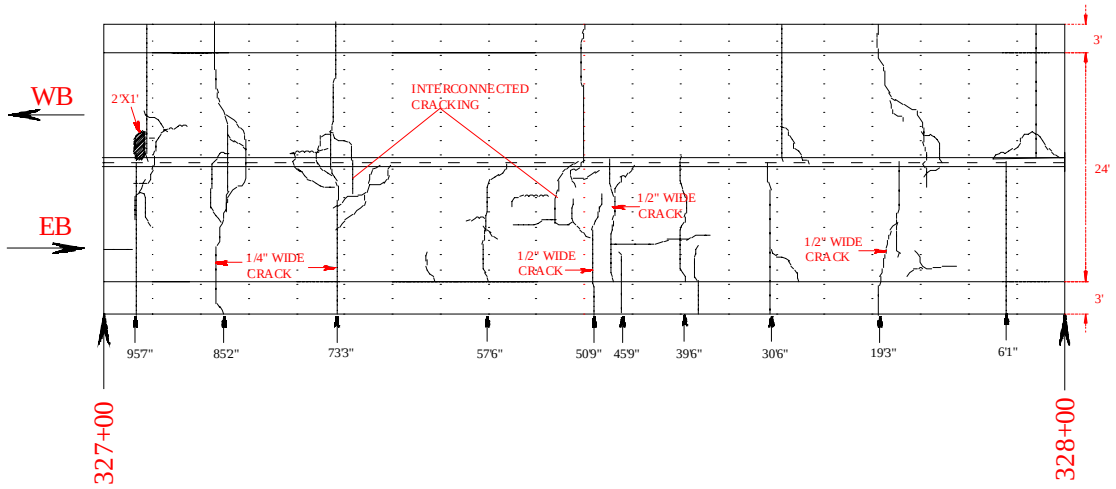

Figure 4.26 Detailed Distress Survey before Asphaltic Overlay for Section 2, STH 33, Washington County

4.3.1.3 Section 3

This section started at station 318+00 and ended at 317+00 and was taken across both lanes of the highway. The existing pavement for this section consisted of 5" recycled bituminous surface and 10" crushed aggregate base course.

A major spalling was observed towards the end of the section. There were severe thermal cracks of about ¼ to ½ inch in width. Several hairline cracks were observed in the section. The cracks are interconnected at many places. Figure 4.27 shows pictures of cracks observed at this test section. Figure 4.28 shows the details of the distress survey conducted on section 3.

(a) Spalled interconnected cracks

(b) Thermal crack

Figure 4.27 Distresses in Section 3, STH 33, Washington County

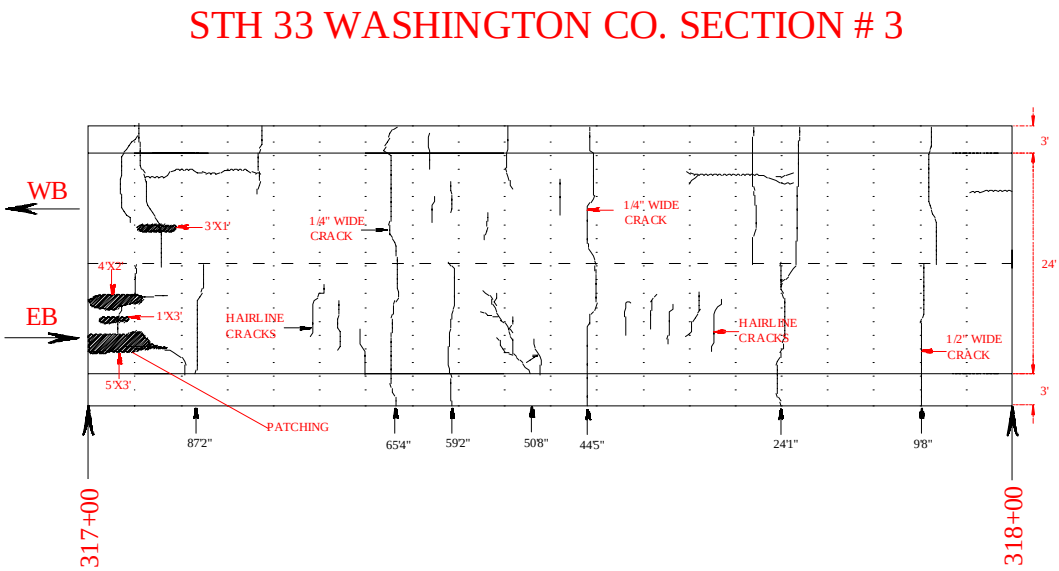

Figure 4.28 Detailed Distress Survey before Asphaltic Overlay for Section 3, STH 33, Washington County

4.3.2 Surface Preparation for Asphaltic Overlay

For this project, surface preparation consisted of 5″ of base patching for the severely deteriorated crack areas followed by milling 1.5″ of the existing pavement surface. The sections were marked where the distresses were severe. The marked sections were base patched by removing 5" of the pavement and then filled with fresh asphalt. The base patches ranged from 10 to 50 ft in length. Figure 4.29 shows the

process of base patching using asphalt. After the base patching, the whole project length was milled by removing 1.5" of the surface asphalt.

(a) Base patch 50′ long and 5″ deep

(b) Compacting the new asphalt base patch

Figure 4.29 Base Patching, STH 33, Washington County

4.3.3 Falling Weight Deflectometer Testing

FWD testing was conducted on STH 33 for evaluation of the existing conditions of the pavement. The testing was conducted by WisDOT using the KUAB FWD. The testing was done using 9,000 and 12,500 lb loading with 3 drops at each point. The location of FWD testing is shown in Figure 4.30. In general, the intervals of the test points were set to 20 ft within the test section and to 100 ft outside the test section.

FWD TESTING

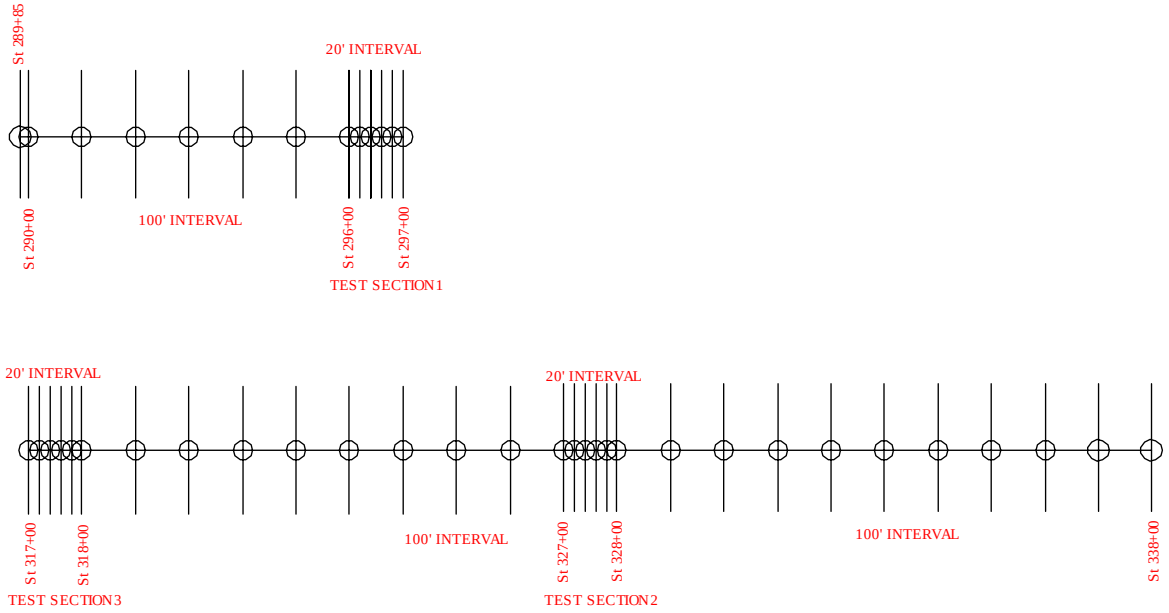

Figure 4.30 FWD Testing Interval, STH 33, Washington County

4.3.4 Distress Survey after Surface Preparation

A detailed survey was conducted to identify the amount of surface preparation work conducted on the three selected sections. Figures 4.31-33 depict the results of the survey and show the type of surface preparation work conducted with milling and patching. Table 4.2 presents a summary of the amount of repair work conducted on these three sections.

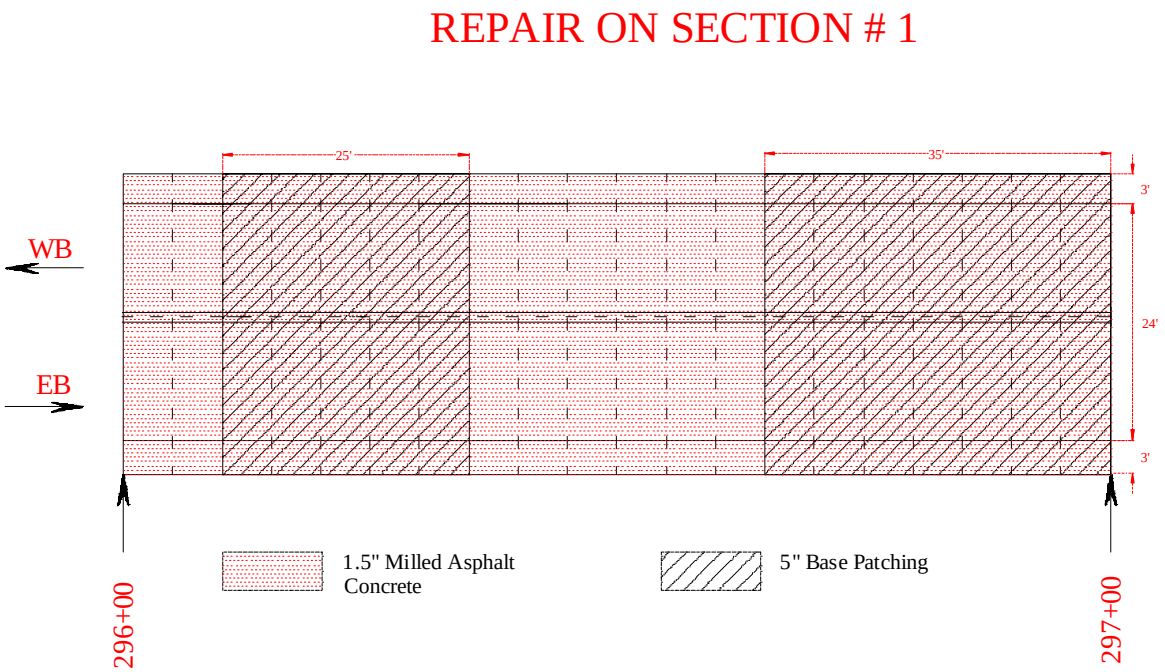

Figure 4.31 Repairs Done on Section # 1, STH 33, Washington County

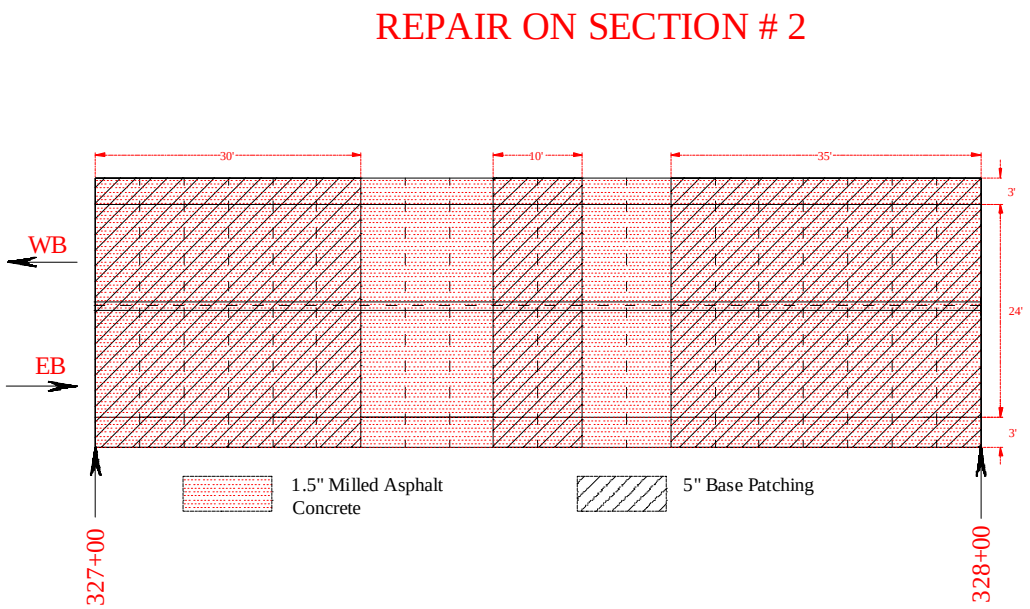

Figure 4.32 Repairs Done on Section # 2, STH 33, Washington County

REPAIR ON SECTION # 3

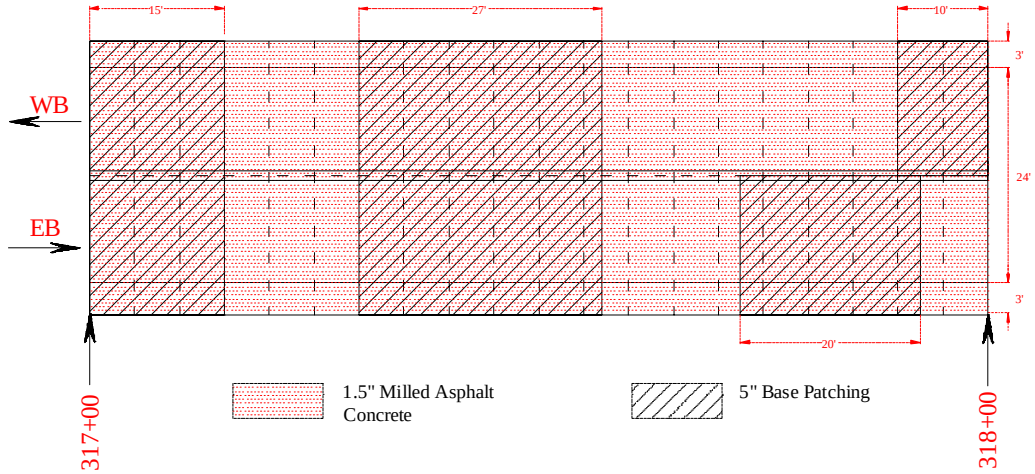

Figure 4.33 Repairs Done on Section # 3, STH 33, Washington County

Table 4.2 Amount of Repair Done on Sections 1, 2 & 3, STH 33, Washington County

Sections	Pavement Distress	Quantity	Quantity of Repair	% Repair
Sec 1 – NB	Alligator Cracking	408 ft^2	408 ft^2 (AC)	100
	Longitudinal/Transverse Cracking	370 ft	220 ft (AC)	60
	Polished Aggregates	400 ft^2	240 ft^2 (AC)	60
Sec 2 – SB	Block Cracking	360 ft^2	120 ft^2 (AC)	33
	Longitudinal/Transverse Cracking	245 ft	195 ft (AC)	80
	Polished Aggregates	400 ft^2	300 ft^2 (AC)	75
Sec 3 – SB	Block Cracking	144 ft^2	144 ft^2 (AC)	100
	Longitudinal/Transverse Cracking	235 ft	200 ft (AC)	67
	Polished Aggregates	400 ft^2	230 ft^2 (AC)	57
	Patch/Patch Deterioration	23 ft^2	23 ft^2 (AC)	100

4.3.5 AC Overlay

After surface preparation work was completed, a 4″ type E-3 asphaltic overlay was constructed on top of the pavement surface.

4.3.6 Survey after Overlay Construction

Two months after the AC overlay construction was completed, a windshield survey was performed. No distresses was found. The ride quality of the highway was considered to be good.

4.4 FALLING WEIGHT DEFLECTOMETER TESTING RESULTS

FWD testing was conducted on STH 38, Mount Pleasant; and STH 33, Newburg using KUAB FWD machine. The NDT data from FWD was analyzed to find structural number (SN) (Figure 4.34), effective pavement modulus (Figure 4.35), and subgrade modulus of STH 33 (Figure 4.36) for STH 33. For STH 38, the parameters included the PCC elastic modulus and modulus of subgrade reaction (k-value), PCC modulus of rupture, and load transfer efficiency (LTE) across joints and cracks (Figure 4.37).

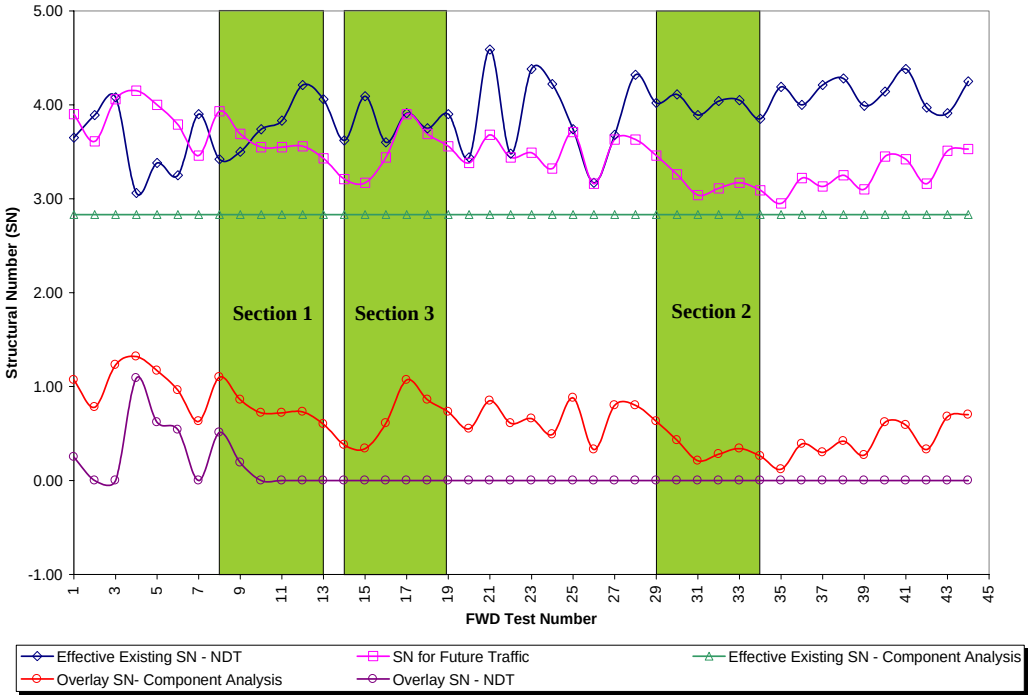

Figure 4.34 Structural Number Variation with Distance, STH 33, Washington County

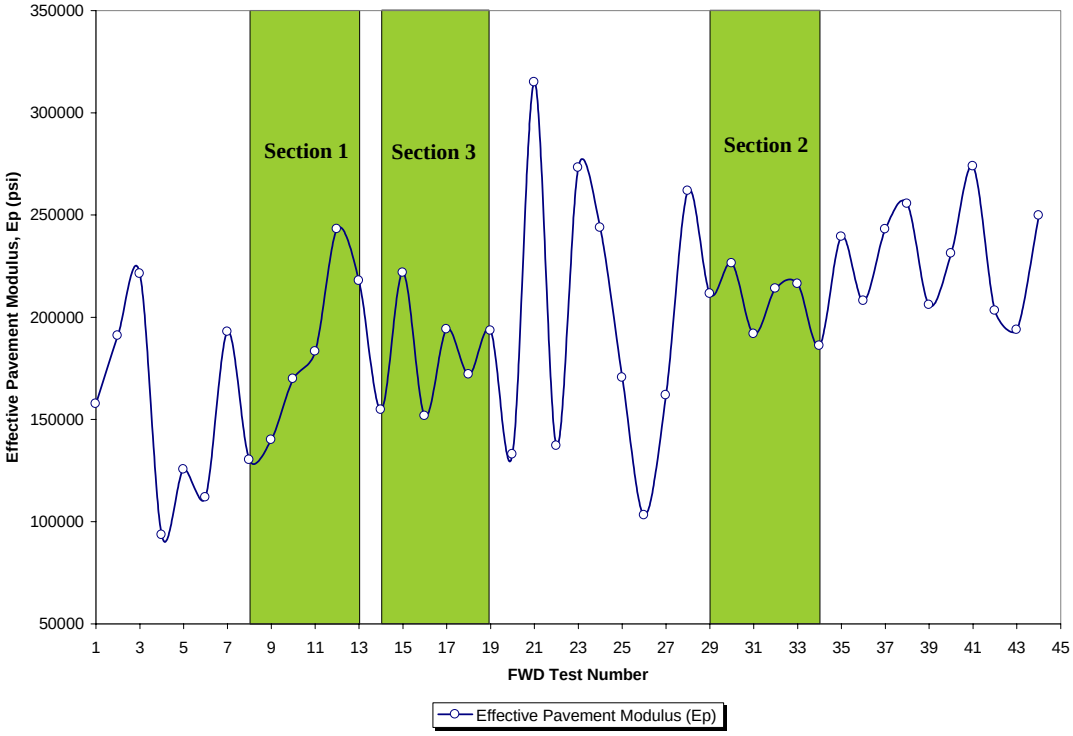

Figure 4.35 Effective Pavement Modulus Variation with Distance, STH 33, Washington County

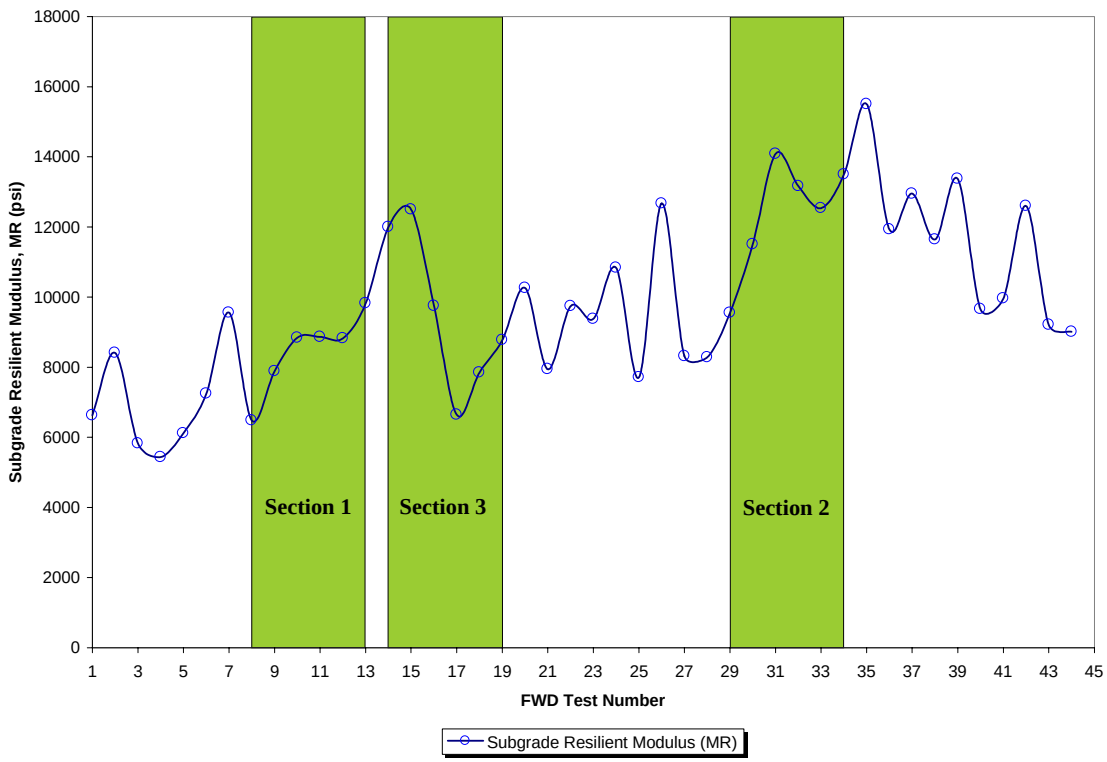

Figure 4.36 Subgrade Resilient Modulus Variation with Distance, STH 33, Washington County

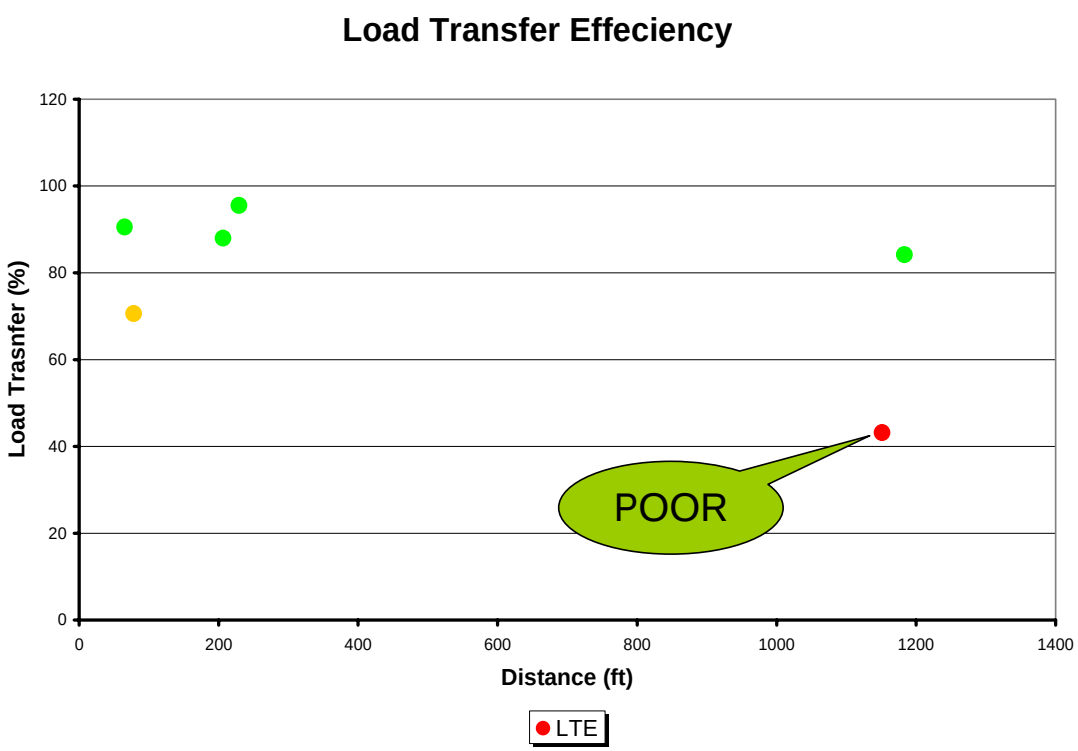

Figure 4.37 Load Transfer Efficiency for PCC pavement, STH 38, Racine County

Pavement deflections represent an overall “system response” of the pavement structure and subgrade soil to an applied load. When a load is applied at the surface, all layers deflect, creating strains and stresses in each layer. The effects of the “strength” of a pavement structure on deflection profile reflect the structural capacity of the pavement and relative stiffness between the pavement structure and subgrade. These relationships are used to backcalculate the PCC elastic modulus and modulus of subgrade reaction.

4.4.1 STH 38, Mount Pleasant, Racine County

FWD testing was conducted at each test section of this highway and the results were analyzed. The program DARWin 3.1 (1998, AASHTOware) was used to evaluate the structural capacity of the pavement from the FWD test data. The pavement input data are summarized in Table 4.3 and the results of the analysis are presented in Table 4.4. Inspection of the FWD test results showed that the PCC elastic modulus varied between 2.49×10^6 psi and 2.97×10^6 psi, the coefficient of subgrade reaction ranged from 119 to 150 psi/in and PCC modulus of rupture ranged from 597 to 618 psi.

Load transfer efficiency can be determined by placing deflection sensors across the joint or crack. Each side of the joint should be tested for Load Transfer Efficiency (LTE) and the lowest value should be used. It is recommended that load transfer testing be conducted at temperatures below 21 ºC (70 ºF). The following guidelines are used to define different levels of LTE:

- Good: greater than 75 percent.
- Fair: 50 percent to 75 percent.

- Poor: less than 50 percent.

$$LTE = \frac{D_1}{D_0} \times 100 \qquad \text{Equation (4.1)}$$

Where,

D_1 is the deflection on unloaded side.

D_0 is the deflection on loaded side.

The deflection load transfer across the joints ranged between 80 to 99.6 %, on average.

Based on the results of FWD testing, an average of 7.37″ of AC overlay was required. It should be noted that FWD was conducted during one day, which does not reflect the seasonal variations of the pavement materials such as coefficient of subgrade reaction.

The WisDOT District 2 procedure for surface preparation of this PCC pavement consisted of full depth repair (base patching) and AC patching of slightly distressed areas. Inspection of the data indicated that 100% of spalled cracks and deteriorated joints were repaired before constructing the AC overlay. The repair amount for the transverse cracks varied between 33 and 43%. This was due to the presence of some low-severity transverse cracks that did not require repair.

WisDOT constructed a 4 to 5 ½ inch AC overlay for rehabilitation of this project. It should be noted that FWD did not take into consideration the amount of surface repair before the overlay. This may be the reason for the higher estimated overlay thickness. Another reason is that the number of FWD tests may not be representative of the pavement condition along the project length.

Table 4.3 DARWin 3.1 (1998) Input Data for STH 38, Racine County

Existing PCC thickness	= 9 in
Future 18Kips ESALs	= 2,730,200
Initial serviceability	= 4.5
Terminal serviceability	= 2
Reliability level	= 95%
Overall standard deviation	= 0.39
Load transfer factor	= 3.2 (for deflection load transfer > 70%)
Overall drainage coefficient, C_d	= 1.3
Durability adjustment factor	= 0.9
Fatigue damage adjustment factor	= 0.95

Table 4.4 FWD Back-calculations Results for STH 38, Racine County

	FWD Back-calculation Results	Sec 1	Sec 2	Sec 3
FWD Testing Condition Survey Method	Pavement thickness for future traffic (in)	7.35	7.48	7.29
	Effective existing thickness (in)	4.33	4.33	4.33
	Overlay thickness (in)	5.59	5.79	5.49
	PCC modulus of rupture (psi)	597	600	618
	PCC elastic modulus (psi)	2,492,813	2,574,096	2,976,367
	Static k-value (psi/in)	147	118.5	150.5
	Dynamic k-value (psi/in)	294	237	301
	Deflection load transfer %	80.02	90.91	99.63

4.4.2 STH 33, Newburg, Washington County

Inspection of the investigated test sections indicated that the main pavement distress was interconnected cracks (block cracking and alligator cracking). The data

collected from the detailed distress survey were used to calculate the PDI according to WisDOT definitions, which ranged from 38 to 46.6. This analysis confirmed the investigated pavement eligibility for AC overlay according to the distress survey evaluation.

Due to the poor condition of the pavement at certain areas, it was necessary to determine the structural number of the existing pavement by FWD testing. FWD tests were done at regular intervals. The data was analyzed using DARWin 3.1 (1998) with input data shown in Table 4.5 and calculations were made for structural number (SN), effective pavement modulus (E_P) and subgrade resilient modulus (M_R) as shown in Table 4.6. From SN calculations, it was determined that the required overlay structural number is zero. This indicates that the existing pavement has the required structural capacity for carrying the traffic loading. As the pavement suffered from severe thermal cracking, the areas with severity were patched by removing 5″ of pavement and using asphaltic concrete as a filling material. The pavement surface was then milled for 1.5″ followed by an asphaltic overlay of 4″. This was done in order to improve the ride quality of the pavement and remove any surface distress. The pavement was competent from a structural capacity point of view, and the existing type and level of distress required only functional overlay to improve the ride quality of the pavement.

Table 4.5 DARWin 3.1 (1998) Input Data for STH 33, Washington County

Total pavement thickness	= 16.5in
Existing AC thickness	= 5 in
Resilient modulus correction factor	= 0.33
Base type	= Granular
Future 18 Kips ESALs	= 2,321,400
Initial serviceability	= 4.5
Terminal serviceability	= 2
Reliability level	= 95%
Overall standard deviation	= 0.39
Milling thickness	= 1.5

Table 4.6 FWD Back-calculation Results for STH 33, Washington County

Test No.	Station (ft)	Structural Number for Future Traffic (SN)	Effective Existing Structural Number		Overlay Structural Number		Effective Pavement Modulus E_P (psi)	Subgrade Resilient Modulus (M_R) (psi)
			Component Analysis	Non-Destructive Testing	Component Analysis	Non-Destructive Testing		
1	289.85	3.90	2.83	3.65	1.07	0.25	157,607	6,630
2	290	3.61	2.83	3.89	0.78	0.00	190,906	8,409
3	291	4.06	2.83	4.08	1.23	0.00	221,240	5,825
4	292	4.15	2.83	3.06	1.32	1.09	93,506	5,436
5	293	4.00	2.83	3.38	1.17	0.62	125,528	6,117
6	294	3.79	2.83	3.25	0.96	0.54	111,892	7,245
7	295	3.46	2.83	3.90	0.63	0.00	192,881	9,556
8	296	3.93	2.83	3.42	1.10	0.51	130,226	6,487
9	296.2	3.69	2.83	3.50	0.86	0.19	139,966	7,885
10	296.4	3.55	2.83	3.74	0.72	0.00	169,760	8,840
11	296.6	3.55	2.83	3.83	0.72	0.00	183,200	8,863
12	296.8	3.56	2.83	4.21	0.73	0.00	243,066	8,823
13	297	3.43	2.83	4.06	0.60	0.00	217,802	9,820
14	317.01	3.21	2.83	3.62	0.38	0.00	154,690	11,994
15	317.21	3.17	2.83	4.09	0.34	0.00	221,770	1,2504
16	317.4	3.44	2.83	3.60	0.61	0.00	151,699	9,755
17	317.6	3.90	2.83	3.91	1.07	0.00	194,063	6,648
18	317.8	3.69	2.83	3.75	0.86	0.00	171,970	7,843
19	317.99	3.56	2.83	3.90	0.73	0.00	193,431	8,770
20	319	3.38	2.83	3.44	0.55	0.00	132,896	10,258
21	320	3.68	2.83	4.59	0.85	0.00	314,966	7,944
22	321.01	3.44	2.83	3.48	0.61	0.00	137,175	9,739
23	322	3.49	2.83	4.38	0.66	0.00	273,184	9,376
24	323.01	3.32	2.83	4.22	0.49	0.00	243,799	10,833
25	324.03	3.71	2.83	3.74	0.88	0.00	170,414	7,713
26	324.98	3.16	2.83	3.17	0.33	0.00	103,100	12,670
27	326	3.63	2.83	3.68	0.80	0.00	161,823	8,315
28	326.89	3.63	2.83	4.32	0.80	0.00	261,792	8,283
29	327.02	3.46	2.83	4.02	0.63	0.00	211,500	9,553
30	327.21	3.26	2.83	4.11	0.43	0.00	226,369	11,503
31	327.41	3.04	2.83	3.89	0.21	0.00	191,798	14,087
32	327.61	3.11	2.83	4.04	0.28	0.00	214,023	13,167
33	327.84	3.17	2.83	4.05	0.34	0.00	216,265	12,536
34	328	3.09	2.83	3.85	0.26	0.00	186,030	13,496
35	328.89	2.95	2.83	4.19	0.12	0.00	239,328	15,506
36	330	3.22	2.83	4.00	0.39	0.00	208,034	11,930
37	331.02	3.13	2.83	4.21	0.30	0.00	242,988	12,953
38	332	3.25	2.83	4.28	0.42	0.00	255,503	11,645
39	332.99	3.10	2.83	3.99	0.27	0.00	206,040	13,371
40	334.01	3.45	2.83	4.14	0.62	0.00	231,160	9,662
41	334.99	3.42	2.83	4.38	0.59	0.00	273,826	9,960
42	336.01	3.16	2.83	3.97	0.33	0.00	203,249	12,598
43	337.06	3.51	2.83	3.91	0.68	0.00	193,823	9,209
44	338.04	3.53	2.83	4.25	0.70	0.00	249,693	9,011

CHAPTER 5. FINDINGS AND RECOMMENDATIONS

A large percentage of the asphaltic paving projects performed in Wisconsin are asphaltic overlays of existing concrete or asphaltic pavements. A standard set of guidelines to determine the amount of surface preparation or rehabilitation prior to asphaltic overlay would address concerns during design and construction. It would also provide the information necessary to develop more accurate and stable project budgets for this type of work.

Literature was reviewed from WisDOT and various national sources for practices of pre-overlay repair of existing concrete and asphaltic pavements. Survey was mailed to the eight WisDOT districts to identify the practices being used for WisDOT projects. Previous WisDOT asphalt overlay projects were identified and overlay performance was analyzed. In addition, three overlay projects were studied in the field during the 2004 construction season.

5.1 SUMMARY OF FINDINGS

5.1.1 Asphalt Overlay of Existing Concrete Pavements

(1) Three base patching methods are being used for pre-overlay of existing concrete for WisDOT projects: doweled concrete, non-doweled concrete, and asphaltic base patching. It was found that overlays with doweled concrete base patching perform best, followed by non-doweled concrete base patching and then asphaltic base patching. From a standpoint of service life, an overlay with doweled concrete base patching lasted two years longer than non-doweled concrete base patching, and three

years longer than asphaltic base patching before another overlay is warranted. Doweled concrete base patching should be used to repair the existing concrete pavement.

(2) For those overlay projects which utilized partial-depth joint and crack repair to correct the medium-severity longitudinal distressed joints, no medium or severe longitudinal distressed joints occurred in overlay within about 10 years since the placement of overlay. Other overlay projects without partial depth joint/crack repair, however, exhibited varying performance of longitudinally distressed joints. It indicates that partial depth repair should be used to repair the partial-depth (medium-severity) longitudinally distressed joints.

(3) Transverse cracking development in overlay was slowed down when partial depth repair was used for medium-severity distressed transverse joint and cracks, compared to overlay without pre-overlay partial depth repair. Therefore, partial-depth transverse joint/crack distresses should be repaired utilizing partial-depth joint/crack repair.

(4) The thickness of overlay should be a minimum of three inches, practically three and half an inch, to mitigate reflective cracking. However, beyond the three inches thickness, simply increasing thickness might not be as effective.

(5) All high-severity joints/cracks/patches should be repaired prior to asphalt overlay.

(6) The rutting in asphalt overlay of existing concrete pavement is insignificant.

(7) The current IRI in overlay was highly correlated with initial IRI of overlay, indicating the importance of profile index. The roughness prediction model used in the NCHRP 1-37A 2002 design guide was calibrated with locally available data

5.1.2 Asphalt Overlay of Existing Asphalt Pavements

(1) It seems the milling and overlay projects which had an overlay thickness of more than two inches have not been affected by pre-overlay block cracking in existing asphalt pavements. Therefore, milling and overlay could be used to repair the existing asphalt pavement with block cracking prior to overlay.

(2) Milling and overlay can not prevent alligator cracking from reflecting in the overlay. For asphalt pavements with extensive alligator cracking, pulverization should be used.

(3) Milling and overlay is not effective in preventing underlying transverse cracking from reflecting into the overlay. Other than pulverization, no practices being used by WisDOT was found to be effective in controlling the adverse effects of pre-overlay transverse cracking.

(4) Increasing the ratio of overlay thickness to milling depth is an effective way to control the longitudinal cracking development in the overlays. The ratio should be kept at a minimum of three if longitudinal cracking is severe in existing asphalt pavement.

5.2 RECOMMENDATIONS

The set of guidelines developed can be included in the FDM and CMM. WisDOT *Pavement Surface Distress Survey Manual (5)* should be published online for designers and field engineers to use. A standard special provision (STSP) should be included in an STSP update for designers to use in special provisions. Other recommendations for further studies are listed as follows:

(1) For existing concrete pavement which has been overlaid at least once, more studies are needed to identify the distresses to repair prior to another overlay. Distresses that do not appear to be severe may be badly deteriorated beneath the existing overlay.

(2) Transverse cracking is a dominant distress in asphalt pavement in Wisconsin. Study is needed to effectively repair the existing transverse cracking in existing asphalt pavement prior to overlay, or to control the cracking from reflecting. Additionally, a study of current Hot Mix Asphalt mix design and asphalt binders being used by WisDOT is needed to reduce the susceptibility of asphalt pavement to thermal cracking.

(3) Pavement Information File (PIF) database is a good source to study pavement performance. However, some of weight factors are assigned incorrectly and should be corrected. The format of recording the distress, such as the 25 percent rule and distress extent range, artificially eliminated first-hand accurate survey data and brings extra errors. At this time, the purpose of the PIF is to calculate the PDI value for pavement management and six year program planning. A simple change of format could convert the PIF into an excellent pavement performance database for future study.

CHAPTER 6. GUIDELINES

ORIGINATOR **Director, Bureau of Highway Construction**		PROCEDURE 14-25-XX
CHAPTER 14	**Pavements**	
SECTION 25	**Pavement Rehabilitation**	
SUBJECT XX	**Surface Preparation of Existing Pavement Prior to Asphaltic Overlay**	

Introduction

The purpose of this guideline is to determine what and how to repair the distresses in the existing pavement prior to asphaltic overlay. This guideline should be used when the pavement type selection is complete and asphalt overlay is decided to be the rehabilitation method. This guideline could also be used to estimate the amount of repair required to perform a life cycle analysis and to determine the rehabilitation method. The definition of distresses along with severity and extent is referred to WisDOT *Pavement Surface Distress Manual*, 1993.

Guidelines of Surface Preparation of Existing Concrete Pavement

1. High-severity distressed joints/cracks or high-severity patches should be repaired with full-depth concrete base patching (doweled) in accordance with Standard Detail Drawing (SDD)13C14-2. Concrete slabs with Slab Breakup of severities 3

or 4 should be replaced with concrete pavement repair in accordance with SDD 13C9-6b.

2. Only doweled concrete base patching should be used for full depth repair. Non-doweled concrete base patching or asphaltic base patching should not be used. When the pavement needs to be open to traffic in a short time, high early strength doweled concrete base patching can be used.

3. Medium-severity transverse joints/cracks should be repaired with partial depth joint/cracks repair with asphaltic mixtures.

4. Medium-severity longitudinal joints should be repaired with partial depth joint/cracks repair with asphaltic mixtures.

5. The average in-place thickness of overlay should be a minimum of three and half an inch.

Guidelines for Surface Preparation of Existing Asphalt Pavement

1. When the majority of existing asphalt pavement exhibits extensive alligator cracking, pulverization should be adopted.

2. Pavement of localized alligator cracking should be removed and replaced. Often base or subgrade will also need to be repaired. Patching should be performed prior to milling, if any.

3. When block cracking occurs over the pavement surface, mill and overlay should be used.

4. Milling should be used to correct the rutting in existing asphalt pavement. When severe rutting is the reason for overlay, the underlying base course and subgrade soils should be investigated.

5. When longitudinal cracking is severe in the existing pavement, the ratio of overlay thickness to milling depth should be a minimum of three to control reflective cracking in overlay.

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44. National Cooperative Highway Research Program, (NCHRP) 1-37A Final Report, “Guide for Mechanistic-Empirical Design for New and Rehabilitated Pavement Structures”, Transportation Research Board, National Research Council, March 2004.
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APPENDIX A. QUESTIONNAIRE

QUESTIONS

Asphaltic Overlay of Existing Asphalt Pavement

1. This questionnaire is for roadways with ADT of more than 5,000 vehicle per day. For ADT > 5,000, do you perform distress repair work based on traffic volume in roadways? (e.g., for ADT from 5,000 to 7,500; 7,500 to 10,000; etc.)

   Yes_____
   No _____

   If your answer is yes in Question 1, please indicate the traffic volume category for distress repair work in the rest of the questions

2. In Table 1, what methods are used to repair each distress before asphaltic overlays over flexible pavements? Also indicate the amount of repair (if performed) as a percent of total repair (e.g., 100% when all distresses are repaired before an overlay and 0% when no repair work is performed).

3. In your District, is there any benefit of repairing distresses before asphaltic overlays (e.g., extended pavement life, smoother ride, etc.)? How do you measure the benefits?

   _____
   _____
   _____
   _____
   _____

4. Is tack coat required prior to the placement of asphaltic overlay?

   Yes_____
   No _____

5. What are your state's techniques of reflective crack control in asphaltic overlay over existing asphaltic pavement?

   Geotexitle Fabric_____
   Cold In-place Recycling_____
   Pulverization (Full-depth Reclamation)_____
   Others _____

6. How is the base or soil weakness identified for asphalt overlay and taken care of?

   _____

_____
_____
_____
_____

7. Is subdrainage repair considered prior to overlay placement? If “yes”, please briefly describe.
   Yes____
   _____
   _____
   _____
   No ____

8. Is the amount of repair incorporated in the overlay design and therefore, affect the thickness of asphaltic overlay?
   Yes_____
   No _____

Asphaltic Overlay of Existing Concrete Pavement

9. In Table 2, what methods are used to repair each distress before asphaltic overlays over rigid pavements? Also indicate the amount of repair (if performed) as a percent of total repair (e.g., 100% when all distresses are repaired before an overlay and 0% when no repair work is performed).

10. In your District, is there any benefit of repairing distresses before asphaltic overlays (e.g., extended pavement life, smoother ride, etc.)? How do you measure the benefits?
    _____
    _____
    _____
    _____
    _____

11. If partial-depth or full-depth repairs are used, what are the materials used to patch?

    Asphaltic Materials ____
    Concrete ____

12. How is the amount of repairs quantified in the estimate of costs and actual construction costs? If pay items are used, please give a list.

_____
_____
_____
_____
_____

13. Is tack coat required prior to the placement of asphaltic overlay?

    Yes_____
    No _____

14. What are your state's techniques of reflective crack control in asphaltic overlay over existing concrete pavement?

    _____
    _____
    _____
    _____
    _____
    _____

15. How is the base or soil weakness identified for asphalt overlay and taken care of?

    _____
    _____
    _____
    _____
    _____

16. Is subdrainage repair considered? If "yes", please briefly describe.
    Yes____
    _____
    _____
    _____
    No ____

17. Is the amount of repair incorporated in the overlay design and therefore, affect the thickness of asphaltic overlay?
    Yes_____
    No _____

APPENDIX B. SAMPLE STSP FOR PARTIAL-DEPTH REPAIR OF JOINT AND CRACK

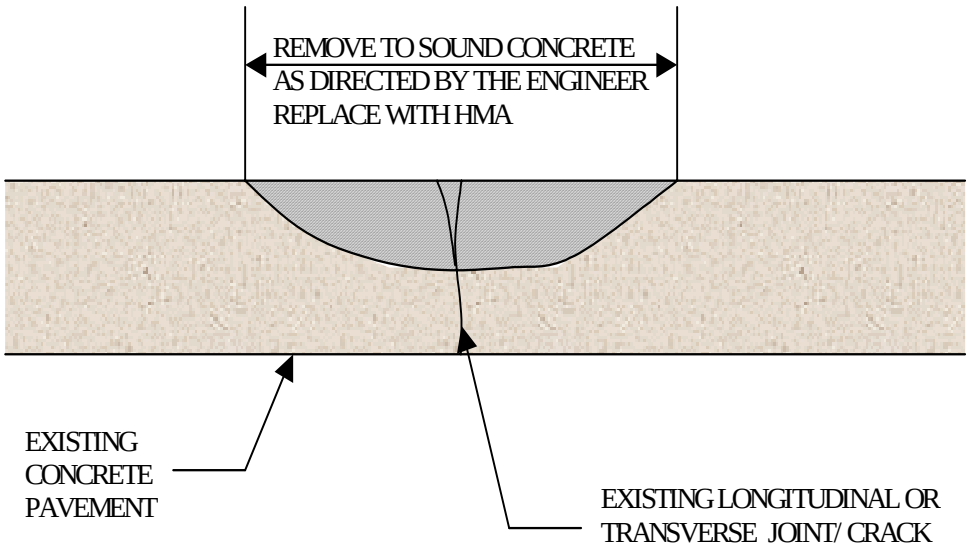
1. SAMPLE STANDARD SPECIAL PROVISION (STSP) FOR PARTIAL-DEPTH REPAIR OF JOINT AND CRACK

A. Description. This work consists of removing any loose or spalled concrete and asphaltic patching, cleaning the joints and cracks, filling with asphaltic material, and compacting with an approved mechanical tamper at locations determined by the engineer.

B. Method of Measurement. Joint and Crack Repair will be measured, by length in feet, of longitudinal and transverse joints and cracks repaired.

C. Basis of Payment. Joint and Crack Repair, measured as provided above, will be paid for at the contract unit price per linear foot, which price shall be full compensation for removing and disposing of all loose or spalled concrete and asphaltic patching; for cleaning joints and cracks; for filling the joints and cracks, including the asphaltic material; and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

2. SAMPLE CONSTRUCTION DETAIL FOR PARTIAL-DEPTH REPAIR OF JOINT AND CRACK



Sample Construction Detail For Partial-Depth Joint/Crack Repair

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