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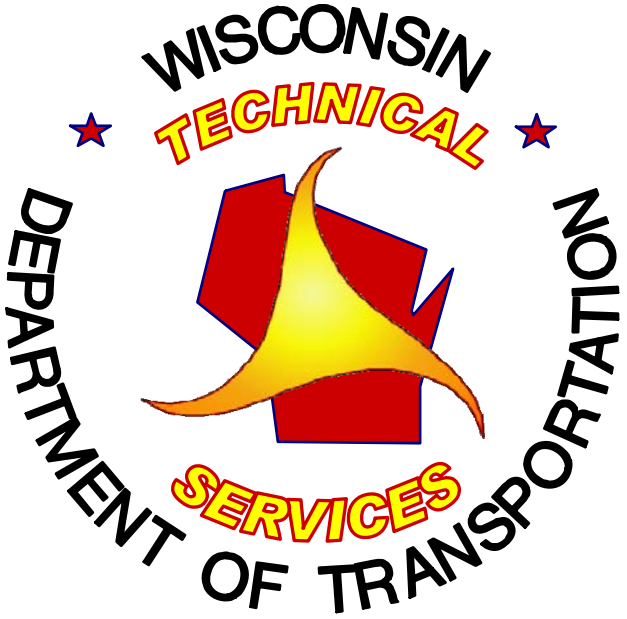
Pavement Warranty Program in Wisconsin: 12-Year Evaluation

FINAL REPORT



June 2009

Pavement Warranty Program in Wisconsin: 12-Year Evaluation

FINAL REPORT

Research Study # WI-08-02

Report # WI-03-09

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16. Abstract

The Wisconsin Department of Transportation (WisDOT) first used pavement warranties in 1995. The intent of this study was to compare performance and cost data for WisDOT pavements constructed under warranty and standard contracts to determine the cost-effectiveness of the pavement warranty program. Warranted Type 1 pavements (hot mix asphalt (HMA) constructed over flexible base) performed better than non-warranted pavements, with lower median PDI and IRI values after 12 years in service. No statistical difference was found in performance between Type 3 non-warranted and warranted pavements (HMA constructed over rigid base). These pavements performed at approximately the same level during the first 10 years in service, with relatively equal increases in PDI and IRI over that time. Non-warranted and warranted Type 8 (Portland cement concrete) pavements also performed at approximately equal levels during the analysis period. An analysis of total pavement costs showed that in recent construction seasons, warranted HMA pavements cost less than non-warranted HMA pavements. For PCC pavements, the cost analysis did not show a statistically significant difference between the two contracting types. Overall, the pavement warranty program is a cost-effective tool for WisDOT, as benefits in both pavement performance and cost have been noted.

17. Key Words Warranties, hot mix asphalt pavement, Portland cement concrete pavement, specifications		**18. Distribution Statement** Distribution unlimited Approved for public release	
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Executive Summary

Since the inception of the Wisconsin Department of Transportation (WisDOT) pavement warranty program in 1995, a total of 157 hot mix asphalt (HMA) pavements and 14 Portland cement concrete (PCC) pavements have been placed under warranty. Up to 12 years of performance and cost data are therefore available for warranted pavements. The intent of this study was to compare these data for WisDOT pavements constructed under warranty and standard contracts to determine the cost-effectiveness of the pavement warranty program.

In the performance portion of the study, pavement distress index (PDI) and international roughness index (IRI) data were analyzed for three pavement types: Type 1 (HMA over flexible base, including unbound materials and existing HMA pavement), Type 3 (HMA over existing PCC pavement) and Type 8 (doweled jointed plain concrete pavement). Over 50,000 data points were included in the analysis. Significant scatter existed in the data, but definite trends were evident.

Warranted Type 1 pavements performed better than non-warranted pavements, with median PDI values of 18 and 43, respectively, after 12 years in service. The rate of increase in PDI was greater for non-warranted pavements, indicating that Type 1 pavements might yield a longer service life when constructed under warranty. Similarly, warranted Type 1 pavements had better IRI values after 12 years, with a median value of 1.22 m/km compared to 1.70 m/km for non-warranted pavements.

The same performance enhancement noted for warranted Type 1 pavements was not evident for Type 3 pavements. Non-warranted and warranted Type 3 pavements performed at approximately the same level during the first 10 years in service, with relatively equal increases in PDI and IRI over that time. Because relatively few data points were available for warranted Type 3 pavements, performance should continue to be monitored in comparison to non-warranted Type 3 pavements.

Non-warranted and warranted Type 8 pavements performed at approximately equal levels during the analysis period. After nine years in service, non-warranted and warranted pavements' PDI values were 3.5 and 3.0, respectively, and IRI values were 1.80 and 1.31 m/km, respectively. Definite conclusions could not be drawn from the non-warranted and warranted pavement comparison for two reasons: (1) very few data points were available for warranted Type 8 pavements and (2) PCC pavement distresses typically do not initiate during the first five to ten years of service, so pavements constructed under both types of contracts would be expected to perform adequately during that time period.

In the cost analysis portion of the study, costs were analyzed for pavement bid items, pavement repair during the warranty period, and WisDOT staff time. The analysis showed that, on average for the 2006, 2007, and 2008 construction seasons, non-warranted and warranted HMA pavements cost $49.08 and $40.65 per ton, respectively. The warranted pavement cost was lower by approximately 17%. The cost analysis did not show a statistically significant difference between non-warranted and warranted PCC pavements.

One reason for the pavement warranty program's success in the State of Wisconsin is that WisDOT and each paving industry have fostered collaborative relationships, and the HMA and PCC industries have provided input on the development and maintenance of the warranty specifications. Both the Department and the industries remain dedicated to supporting the goals of the warranty program.

The pavement warranty program is a cost-effective tool for WisDOT. Benefits in both pavement performance and cost have been noted. It is recommended that the Department continue to monitor the pavement warranty program by conducting similar studies every five years.

1. Introduction

The Wisconsin Department of Transportation (WisDOT) implemented its pavement warranty program in 1995. As one of the first states to explore this contracting method, Wisconsin has been a leader in the development and implementation of pavement warranties. The state's first group of warranted pavements have now been in service for 13 years. Historic performance and cost data collected for both warranted and non-warranted pavements allowed for the comprehensive evaluation of the warranty program presented in this report.

The purpose of this study was to assess the performance and cost histories of WisDOT warranted HMA and PCC pavements and compare the results to pavements that were not constructed under warranty. A similar study conducted when the warranty program was five years old concluded that warranted pavements had better performance than non-warranted pavements and that warranties were a cost-effective contracting option *[1]*. A total of twelve years of pavement performance history and ten years of bid cost data were available when the current study began. These data were evaluated to determine if the conclusions from the five-year performance study are still valid.

2. Background

Pavement warranties were used in the United States as early as the first paved roads were being laid in the early 1900s. The warranties were offered by paving companies for periods as long as 15 years *[2]*. When the Interstate program began and the federal government began contributing to road-building costs, however, pavement warranties were not permitted. Warranties required corrective action that could be interpreted as maintenance work, and federal dollars were not allowed to be spent on maintenance activities. In the 1990s, the idea of pavement warranties was revisited, and in 1995, federal regulations were revised to allow state agencies' use of pavement warranties *[3]*.

Pavement warranties had already been utilized extensively in European nations. A European scan tour conducted in September 2002 *[4]* found that a variety of pavement warranties were used ranging from materials and workmanship warranties with one-year warranty periods to long-term performance warranties with warranty periods in excess of 20 years. The warranty programs were created with and still rely on collaborative efforts between government and industry. The European nations felt that use of warranties has resulted in improved pavement performance.

Thirty-five states have used some form of warranty provisions on construction projects, and 24 have specifically used pavement warranties *[5]*. Very few states are tracking their warranty programs or have documented their experience with warranties *[6]*. Aside from Wisconsin, three states have reported findings related to the use of pavement warranty provisions; these investigations are summarized below.

The Colorado DOT (CDOT) performed a side-by-side comparison of warranted and non-warranted HMA pavements with three to eight years of performance history. Performance data showed that warranted pavements were initially rougher than non-warranted pavements, but after the warranty period was over, the warranted pavements were smoother on average. Conversely, warranted pavements had lower rutting one year after construction, but after the warranty period was over, the warranties had greater rutting. Maintenance costs were greater for pavements that initially were under warranty than for

pavements with no initial warranty *[7]*. Therefore, CDOT concluded that a short-term materials and workmanship warranty for HMA pavements was not a cost-effective tool. CDOT recently began a program to investigate long-term performance warranties. Two pilot projects were constructed in 2002 (HMA pilot) and 2004 (PCC pilot) *[8]*.

The Indiana DOT performed a comparative analysis of HMA pavements constructed with and without a five-year performance warranty. Warranted HMA pavements were found to have lower IRI and less rutting than non-warranted HMA pavements. In addition, the resulting increased service life and decreased maintenance for warranted HMA pavements would produce an anticipated 27% cost savings over non-warranted HMA pavement *[9]*.

Between 2000 and 2004, the Illinois DOT constructed 27 projects under warranty in response to legislation that a warranty provision be implemented. The 27 projects included PCC pavements, HMA pavements, and HMA overlays. During construction, it was noted that contractors did not use innovative methods or give more attention to detail because of the warranty provision. At the time of the report, no distresses had been noted in the warranted pavements. None of the five-year warranty periods had expired, however, and it was concluded that more time was necessary to evaluate the warranted pavements' performance *[10]*.

3. Program Details and History

In the mid-1990's, FHWA declared that warranties could be used for federal aid pavement construction projects *[3]*. WisDOT had been working to prepare an HMA pavement warranty specification, and the state's first warranted pavements were constructed in 1995. Three HMA pavements were constructed that year as pilot projects for the warranty program. The PCC pavement warranty specification was developed several years later, and the first warranted PCC pavement was constructed in 1998. The number of warranted pavements constructed each year has increased since the program's inception (Figure 1). At the conclusion of the 2008 construction season, a total of 157 HMA pavements and 14 PCC pavements had been placed under warranty.

3.1 Warranty Program Goals

As outlined in the WisDOT five-year evaluation of HMA warranties, the following goals were defined for the pavement warranty program: *[1]*

1. Focus evaluations on actual performance of the final product, rather than on ingredients, the process, or surrogate tests for performance.
2. Begin to focus performance evaluations not only on the final product, but on factors considered important by the highway user.
3. Continue to strive for the goals of high quality highways, built on time and at a reasonable cost.
4. Foster contractor freedom to be innovative and creative, while maintaining WisDOT performance standards.
5. Lower WisDOT project delivery costs by reducing testing, supervision and staff involvement in the construction process.

6. Progress from method specifications and from the quality control/quality assurance concept to end result, performance-based specifications. Thus, WisDOT will let the contractor know what performance is desired and the contractor will decide how to accomplish it.
7. Gain experience in the elements of warranty specifications, such as bond requirements.
8. Help the national effort by exploring innovative specifications and alternative contracting methods.
9. Enhance pavement quality.
10. Shift product responsibility from WisDOT to the contractor.

The goals of the warranty program are largely the same today.

Support from the HMA and PCC industries is a major factor in the success of the WisDOT pavement warranty program. The warranty specifications were drafted in cooperation with the HMA and PCC industry associations. Any major change made to technical aspects of the warranty specifications is discussed within the HMA Warranty Committee or the Concrete Pavement Technical Committee. Each of these committees include WisDOT, industry, and FHWA representatives. Mutual Department and contractor commitment to the goals of pavement warranties is critical to continued success of the warranty program.

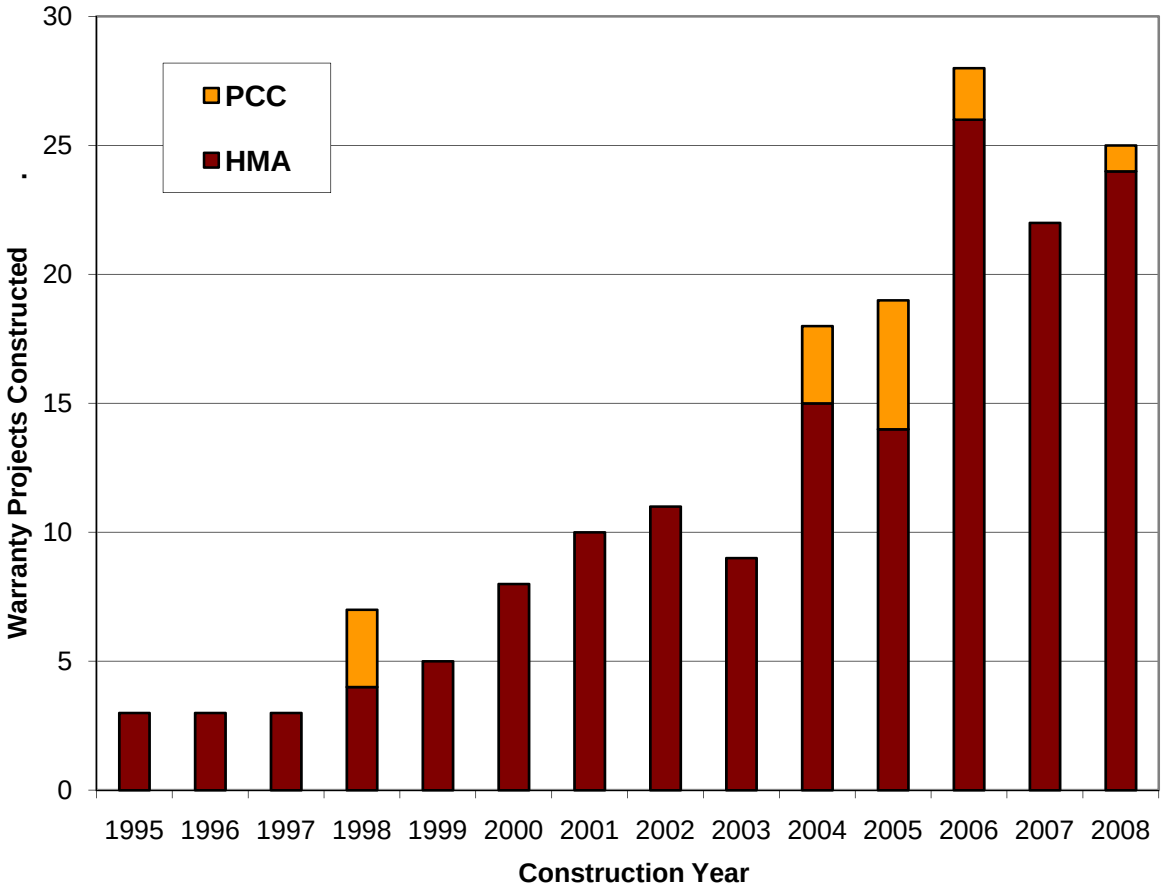

Figure 1. Projects constructed under warranty contract since program inception.

3.2 Specification Features and History

The HMA and PCC pavement warranty specifications are separate from the Department's Standard Specifications. Prior to project bidding, the specifications are inserted into contracts for individual projects that are selected for warranty contracting. The specifications are for short-term performance warranties – WisDOT is responsible for the pavement structural design and evaluation, and the contractor is responsible for the selection of materials and construction methods and is responsible for pavement performance during the warranty period. Each specification contains contractual requirements for distress threshold limits and associated remedial actions, distress monitoring, required and optional warranty work, warranty bonds, and conflict resolution.

The distress thresholds describe the maximum level of pavement distress that can occur before the contractor must perform corrective work under warranty. Limits are based on past pavement performance and expected pavement condition at the end of the five-year warranty period. Each type of distress has an associated remedial action that must be completed by the contractor if a threshold is surpassed during the warranty period. Distresses evaluated for HMA pavements include alligator cracking, block cracking, edge raveling, flushing, longitudinal cracking, longitudinal distortion, rutting, surface raveling, transverse cracking, transverse distortion, patching, potholes, slippage, and disintegration. Warranted distresses for PCC pavements include slab breakup, longitudinal and transverse joint or crack distress, transverse joint faulting, surface distress, and patching.

The specifications require that the contractor carry a bond to ensure prompt and proper completion of required warranty work. Bond amounts are set to address the Department's risk associated with warranted pavements, but not so high as to preclude a competitive bidding environment. HMA warranty bonds are calculated as 25% of the cost to place a 1.75-inch HMA overlay covering the entire warranted pavement. PCC warranty bonds are approximately 20% of the concrete pavement cost plus associated risk and safety factors.

WisDOT began to develop the HMA warranty specification in 1994 and finalized it in 1995. Since that time, the specification has evolved to better fit the needs of the warranty program. A timeline of several major changes to the specification is provided in Table 1. The HMA Warranty Committee, which is made of WisDOT, industry and FHWA representatives, evaluates and implements changes to the specification. The most recent version of the two HMA warranty specifications are included in Appendix A and Appendix B. The warranty period for new HMA construction and structural HMA overlays is five years. An additional specification was recently developed for functional overlays, with a warranty period of three years.

Table 1. HMA Warranty Specification History

Date	Event
1995	Warranty specification used for the first time.
1996	Specification expanded to include HMA overlays.
1997	Provision added to require contractor to rout and seal all cracks during the third year of the five-year warranty period.
1998	Crack rout and seal requirement changed to the fourth year of the five-year warranty period.
1999	Ancillary pavement included under warranty.
2007	Bond requirement reduced from 100% to 25% of the cost of a 1.75-inch overlay covering the entire warranted pavement.
2008	Crack rout and seal requirement moved to the fifth year of the warranty period. More definitions implemented on what cracks should be sealed and how. Warranty end date defined as November 1 of fifth year of the warranty period.
2009	Additional specification created for functional HMA overlays constructed to re-establish the riding surface, with a three-year warranty period.

The PCC warranty specification was developed and first used for three PCC construction projects in 1998. The current version of the PCC warranty specification is included in Appendix C. Several significant changes were made to the specification in 2004, and very few changes have been made since that time. The major changes to the original PCC warranty specification are described in Appendix D. The Concrete Pavement Technical Committee, which is made of WisDOT, industry and FHWA representatives, is involved in any issue related to PCC warranties. The warranty period for PCC pavements is five years.

3.3 Warranty Program Administration

The pavement warranty program is coordinated on a statewide level, but the decision to use warranties and the administration of warranties occurs at the regional level. The state is divided into five regions. Each region has a pavement warranty contact person who monitors performance, coordinates warranty work with contractors, and is involved in any issue that arises with warranted pavements. There is also a statewide bureaus (central office) position in the Bureau of Technical Services that is devoted to tracking the Department's pavement warranty program, managing the warranty specifications, and assisting with warranty issues as necessary.

4. Performance Analysis (1995-2007)

4.1 Pavement Monitoring

As part of its pavement management system, the Department monitors pavement distress and ride for its entire state trunk network once every two years. These inventory reviews currently take place in the northwest and southwest regions in odd-numbered years and in the north central, northeast and southeast regions in even-numbered years. Warranted pavement distress surveys follow a similar schedule, although surveys are conducted for warranted pavements in the first and final years of the warranty period, regardless of location.

During a pavement survey, one data record for distress and one data record for roughness are generated for a one-mile section of roadway. Within each one-mile section, a one tenth-mile segment is selected to represent that mile. This segment is the area of the pavement that is actually surveyed. The same one tenth-mile segments are surveyed each time a particular roadway is reviewed. For warranted pavements, two tenth-mile segments are surveyed, and thus four data records are generated in each mile (two for distress and two for roughness).

Pavement ride was measured and recorded according to the Department's Present Serviceability Index (PSI) until 1990, when the International Roughness Index (IRI) measurement system was adopted. PSI and IRI can be translated using specific conversion formulas. In this study, all pavement ride measurements are reported as IRI values using metric units (meters per kilometer, or m/km).

Pavement distresses have historically been recorded according to the Department's Pavement Surface Distress Survey Manual. In this system, the extent and severity of several pavement distresses are recorded. Distinct pavement distresses are measured for HMA and PCC pavements, as outlined in Tables 2 and 3. Based on the extent and severity measurement for each distress type, a dimensionless coefficient is defined and used to calculate the pavement distress index (PDI) according to Equations 1 and 2 for HMA and PCC pavements, respectively:

$$PDI = 100 * \left(1 - \frac{a}{b} * c * d * e * f * g * h * i * j * k \right) \quad \text{Eq. 1}$$

$$PDI = 100 * \left(1 - l * m * n * o * p * q \right) \quad \text{Eq. 2}$$

Coefficients *a* through *q* range in value from 0.1 to 1.0 and correspond to the distress types as defined in Tables 2 and 3. A distress rating of zero (no distress present) receives a coefficient of 1.0, and thus a pavement with no detected distress has a PDI equal to zero. As distresses increase, the PDI increases.

Table 2. HMA Pavement Distress Types

Distress	PDI Coefficient
Alligator cracking	*a*
Block cracking	*b*
Longitudinal cracking	*c*
Transverse cracking	*d*
Patching	*e*
Flushing	*f*
Edge raveling	*g*
Surface raveling	*h*
Rutting	*i*
Longitudinal distortion	*j*
Transverse distortion	*k*
Segregation	N/A
Seal coat	N/A
Crack filling	N/A

Table 3. PCC Pavement Distress Types

Distress	PDI Coefficient
Slab breakup	*l*
Distressed joints/cracks	*m*
Patching	*n*
Surface distress	*o*
Longitudinal joint distress	*p*
Transverse faulting	*q*
Joint crack filling	N/A
CRCP Pavements only	
Wide cracks	N/A
Punch outs	N/A
Diagonal cracking	N/A
Pavement deterioration	N/A
Delamination	N/A

4.2 Pavement Types

Pavements rated in WisDOT pavement distress surveys are categorized according to pavement and structure type. The six most common pavement types present on Wisconsin roadways are defined in Table 4.

HMA pavement warranty contracts are used on projects with Types 1 and 3 pavements. Type 1 pavements include HMA constructed over granular base and HMA overlays over an existing HMA surface. Type 3 pavements include HMA overlays of existing PCC surfaces. These pavement types were analyzed separately because the nature of distress progression in each is different.

Four types of PCC pavements have been constructed on Wisconsin roadways: jointed reinforced concrete pavement (JRCP), continuously reinforced concrete pavement (CRCP), and jointed plain concrete pavement (JPCP) with and without dowel bars. In recent years, only doweled JPCP has been constructed, and thus PCC pavement warranties have been placed only on Type 8 pavements.

Table 4. Pavement Type Definitions for Pavement Distress Surveys

	Pavement Type	Description
HMA Pavements	1	HMA pavement over flexible base (unbound or asphaltic)
	3	HMA pavement over rigid base (PCC)
PCC Pavements	4	Jointed reinforced concrete pavement
	5	Jointed plain concrete pavement
	6	Continuously reinforced concrete pavement
	8	Jointed plain concrete pavement with dowel bars

4.3 Analysis Notes

At the time of this report, historic PDI and IRI data were available from 1980 to 2007. The PDI and IRI databases together contain over 300,000 data records, with each data record representing approximately one mile of pavement at one point in time. Figures showing historical PDI and IRI data are available in Appendix E and Appendix F, respectively, for Types 1 and 3 pavements with ages up to 30 years and Type 8 pavements up to 20 years in age. Because the warranty program began in 1995 for HMA pavements and in 1998 for PCC pavements, only pavements constructed from those points on were included in the performance analysis. These data records were sorted based on pavement age, pavement type (as described in the previous section) and contract type (non-warranty or warranty). The number of data records that were identified and analyzed within each category is provided in Table 5. To achieve a level basis for comparison between the two contracting types, it was assumed that the non-warranted and warranted pavements included in the analysis were similar in construction, existing conditions, and pavement structure design.

Table 5. Number of Data Records Included in Analysis

Pavement Type	PDI		IRI	
	Non-warranted	Warranted	Non-warranted	Warranted
1	13,779	2,001	13,383	1,938
3	7,492	217	7,388	217
8	3,148	216	2,903	204

Because of the large number of data records used in the performance analysis, boxplot (or box-and-whisker) figures were a convenient way to present the data. Boxplots show both the median value of a dataset and the distribution of data within that dataset. The median value (50^{th} percentile) is plotted as a thick horizontal line. The height of the box is defined by the first quartile (25^{th} percentile) and the third quartile (75^{th} percentile). Whiskers extend from either end of the box to the farthest data point that is no more than 1.5 times the height of the box. Any data points outside the whiskers are considered outliers and are represented by open circles. See Figure 2 for a graphical explanation.

It was often necessary to know whether a non-warranted pavement dataset was statistically different from a warranted pavement dataset. An unpaired t-test was performed in these cases to obtain the two-tailed p-value. If the p-value was less than 0.05, the two datasets in question were defined as statistically different.

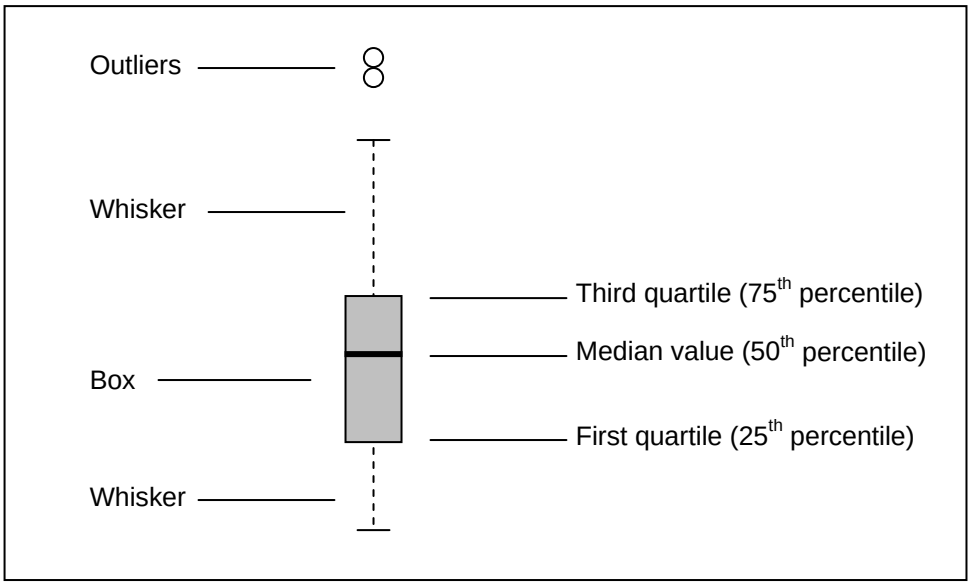

Figure 2. Graphical description of the boxplot.

4.4 Type 1 Pavement Analysis

For each boxplot figure shown in Sections 4.4.1 and 4.4.2, a corresponding table is provided in Appendix G containing values for each boxplot feature (e.g., median value, whisker limits, number of outliers, etc.).

4.4.1 PDI

PDI data for non-warranted and warranted Type 1 pavements constructed from 1995 through 2006 are shown in Figures 3 and 4, respectively. To compare the pavement distress performance over time for non-warranted and warranted pavements, a linear regression model was created for each dataset. The two models are plotted together in Figure 5.

An analysis summary is shown in Table 6 for the data presented in Figures 3 and 4. This summary reports the median PDI at each pavement age and t-test results to determine if there was a statistically significant difference between non-warranted and warranted pavement performance at each pavement age.

T-test results showed that there was a statistical difference in PDI between non-warranted and warranted Type 1 pavements at all ages except age zero. At age zero, it was expected that non-warranted and warranted pavements would perform at the same level, that is, with a very low PDI. Pavements constructed under both contract types had a PDI of zero at ages one and two. At ages three and greater, the median PDI for warranted pavements was lower than non-warranted pavements (Table 6). Furthermore, after 12 years in service, the median PDI for non-warranted pavements was 43, and for warranted pavements it was 18. Therefore, the extent and/or severity of distresses in warranted pavements was consistently lower than in non-warranted pavements. The rate of increase in distress was also lower for warranted pavements (Figure 5), indicating that these pavements could achieve a longer service life.

Table 6. Pavement Distress Index (PDI) Analysis Summary for Type 1 Pavements

Pavement Age	Median PDI		Statistical Analysis	
	Non-warranted	Warranted	p-value	Statistically Different?
0	0	0	0.453	No
1	0	0	0.008	Yes
2	0	0	< 0.001	Yes
3	7	0	< 0.001	Yes
4	7	0	< 0.001	Yes
5	13	7	< 0.001	Yes
6	13	7	< 0.001	Yes
7	18	7	< 0.001	Yes
8	19.5	7	< 0.001	Yes
9	25	13	0.001	Yes
10	30.5	13	< 0.001	Yes
11	29.5	13	0.002	Yes
12	43	18	0.001	Yes

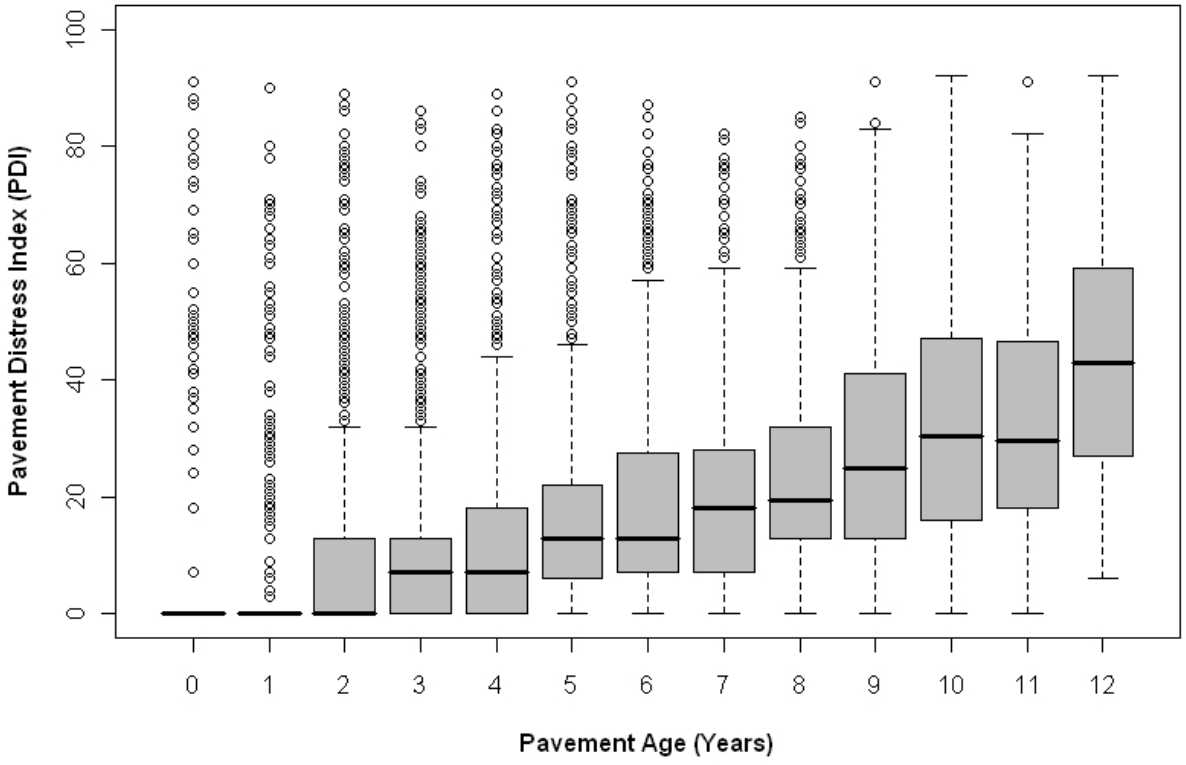

Figure 3. Pavement Distress Index (PDI) values for non-warranted Type 1 pavements constructed from 1995 to 2006. 13,779 records.

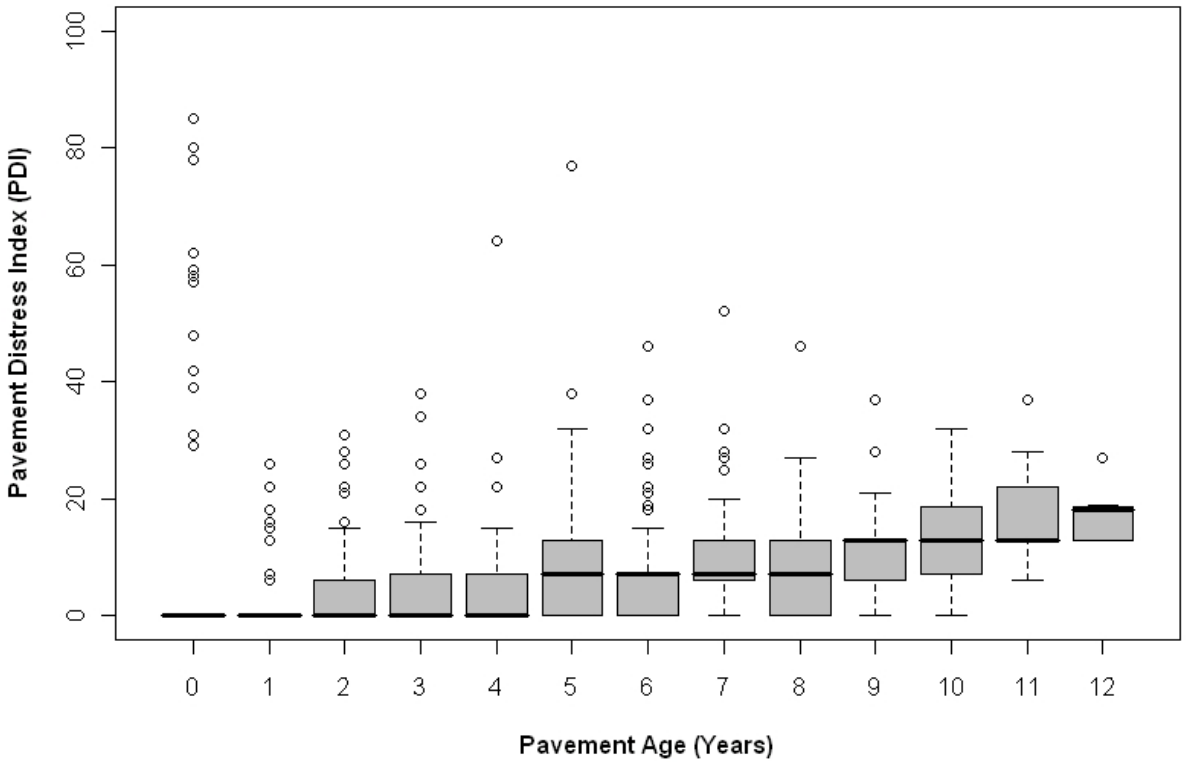

Figure 4. Pavement Distress Index (PDI) values for warranted Type 1 pavements constructed from 1995 to 2006. 2,001 records.

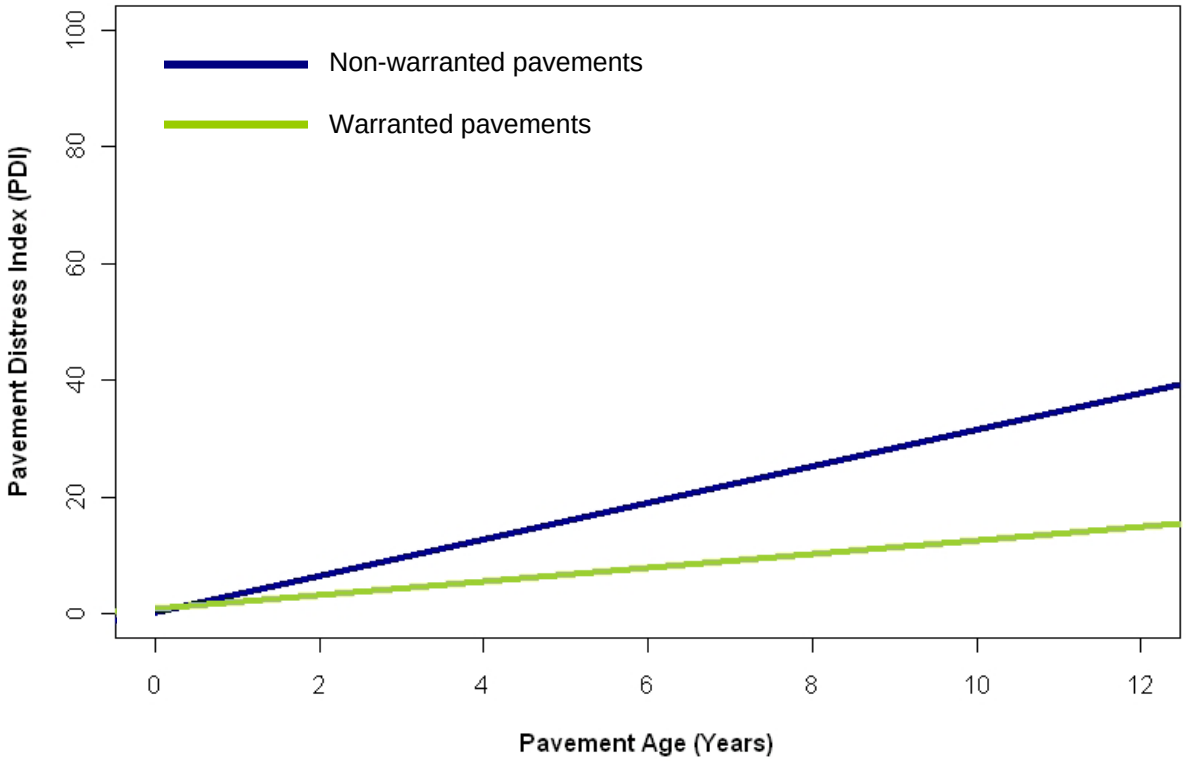

Figure 5. Linear regression models of Pavement Distress Index (PDI) for warranted Type 1 pavements and non-warranted Type 1 pavements constructed from 1995 to 2006.

4.4.2 IRI

IRI data for non-warranted and warranted Type 1 pavements constructed from 1995 through 2006 are shown in Figures 6 and 7, respectively. To compare the pavement distress performance over time for non-warranted and warranted pavements, a linear regression model was created for each dataset. The two models are plotted together in Figure 8.

An analysis summary is shown in Table 7 for the data presented in Figures 6 and 7. This summary reports the median IRI at each pavement age and t-test results to determine if there was a statistically significant difference between non-warranted and warranted pavement performance at each pavement age.

T-test results indicated that there was a statistical difference in IRI between non-warranted and warranted Type 1 pavements at all ages. The median IRI for warranted pavements was consistently lower than for non-warranted pavements. The median IRI after 12 years of service was 1.70 m/km for non-warranted pavements and 1.22 m/km for warranted pavements. This indicates that warranted pavements maintained a slightly smoother riding surface during the analysis period. Warranted pavements also showed a slower increase in IRI over the first 12 years in service, which implies that these pavements would provide a smoother ride for a longer period of time (Figure 8).

Table 7. International Roughness Index (IRI) Analysis Summary for Type 1 Pavements

Pavement Age	Median PDI		Statistical Analysis	
	Non-warranted	Warranted	p-value	Statistically Different?
0	0.77	0.71	< 0.001	Yes
1	0.90	0.74	< 0.001	Yes
2	0.90	0.79	< 0.001	Yes
3	0.93	0.80	< 0.001	Yes
4	0.96	0.82	< 0.001	Yes
5	0.96	0.79	< 0.001	Yes
6	1.03	0.80	< 0.001	Yes
7	1.06	0.78	< 0.001	Yes
8	1.18	0.79	< 0.001	Yes
9	1.23	0.98	0.001	Yes
10	1.42	0.95	< 0.001	Yes
11	1.39	1.07	0.004	Yes
12	1.70	1.22	0.007	Yes

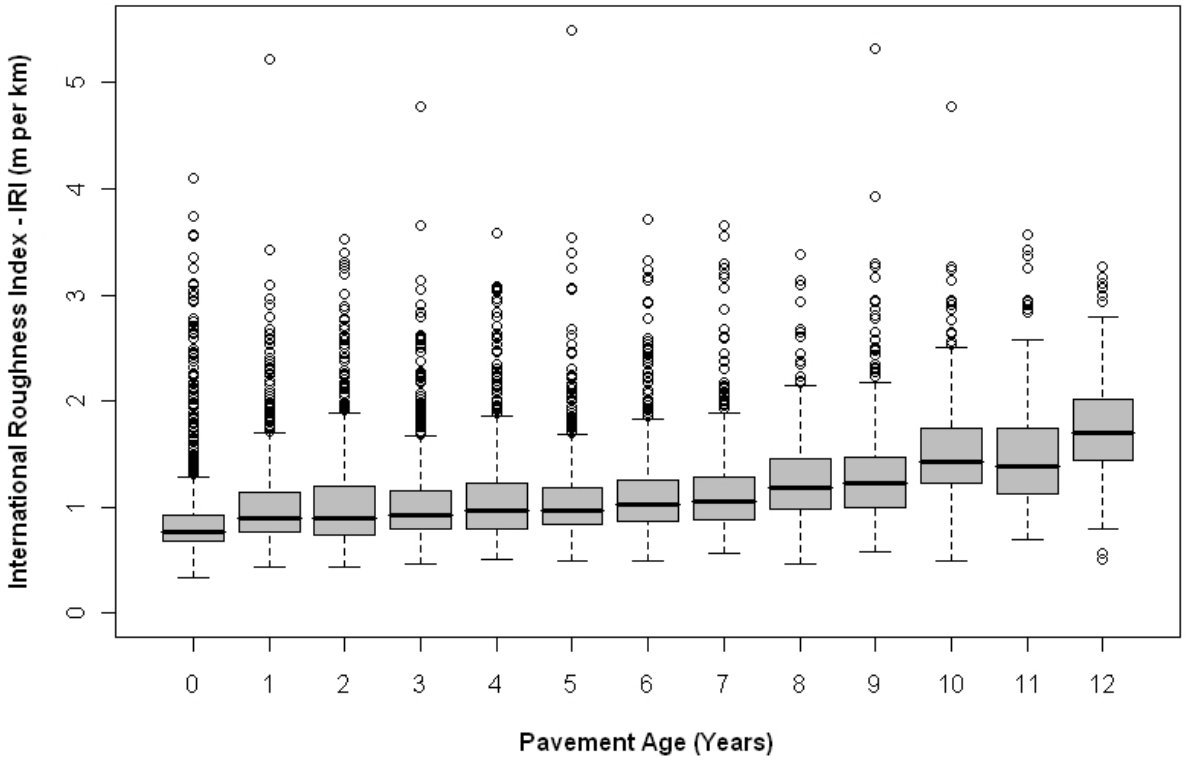

Figure 6. International Roughness Index (IRI) values for non-warranted Type 1 pavements constructed from 1995 to 2006. 13,383 records.

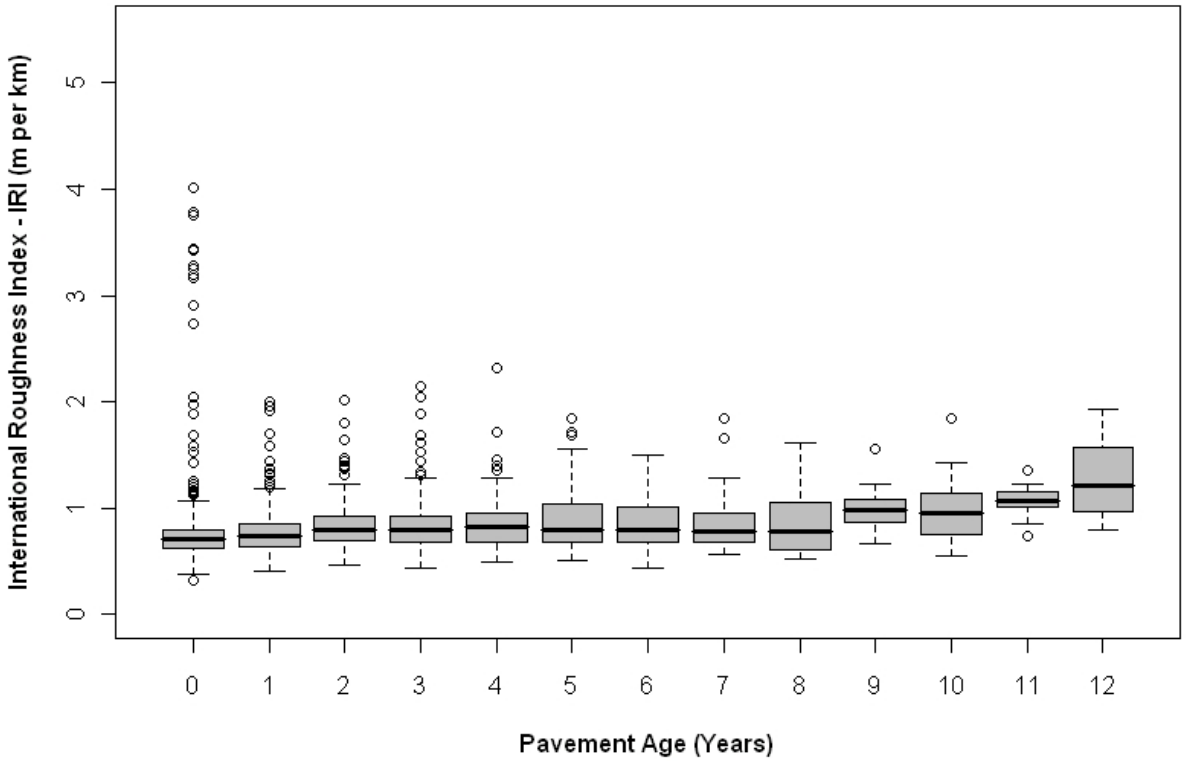

Figure 7. International Roughness Index (IRI) values for warranted Type 1 pavements constructed from 1995 to 2006. 1,938 records.

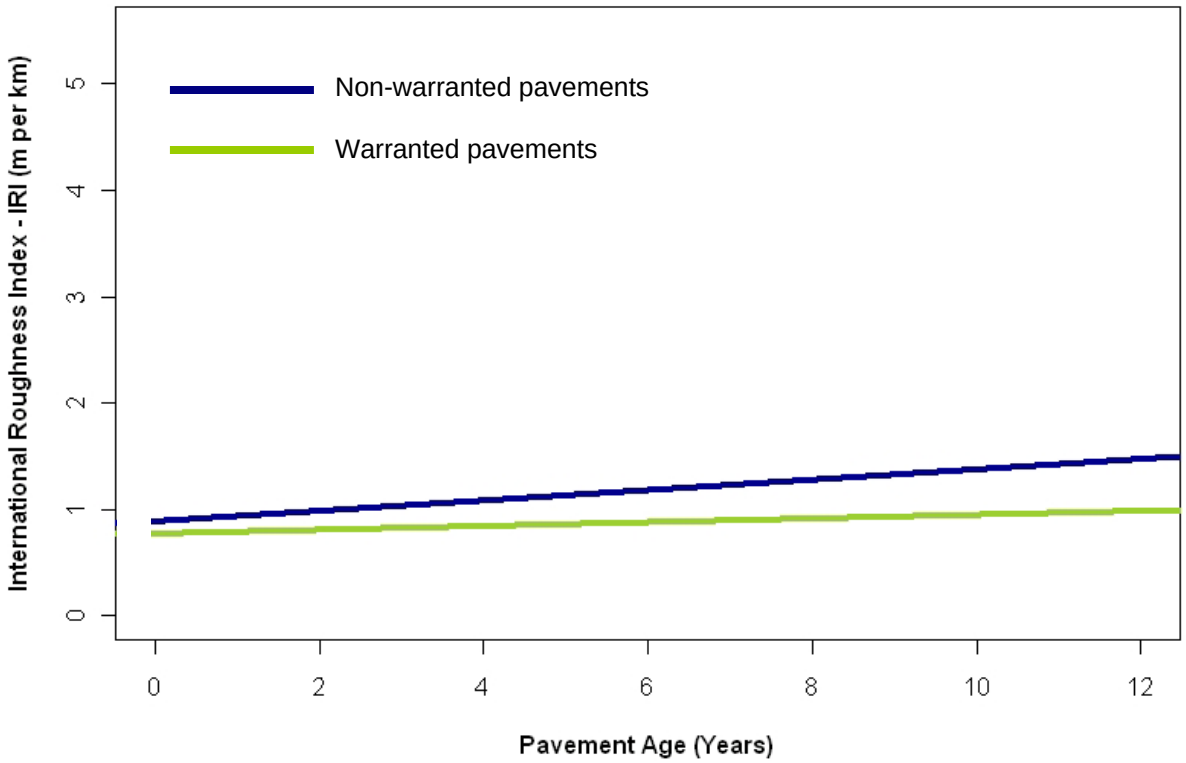

Figure 8. Linear regression models of International Roughness Index (IRI) for warranted Type 1 pavements and non-warranted Type 1 pavements constructed from 1995 to 2006.

4.5 Type 3 Pavement Analysis

For each boxplot figure shown in Sections 4.5.1 and 4.5.2, a corresponding table is provided in Appendix G containing values for each boxplot feature (e.g., median value, whisker limits, number of outliers, etc.).

4.5.1 PDI

PDI data for non-warranted and warranted Type 3 pavements constructed from 1995 through 2006 are shown in Figures 9 and 10, respectively. The first warranted Type 3 pavement was constructed in 1996, and it was last surveyed for PDI in 2006. Therefore, there were ten years of data available for warranted Type 3 pavements. To compare the pavement distress performance over time for non-warranted and warranted Type 3 pavements, a linear regression model was created for each dataset. The two models are plotted together in Figure 11 for pavement ages up to ten years.

An analysis summary is shown in Table 8 for the data presented in Figures 9 and 10. This summary reports the median PDI at each pavement age and t-test results to determine if there was a statistically significant difference between non-warranted and warranted pavement performance at each pavement age.

The median PDI values for warranted Type 3 pavements do not show as clear a trend as for non-warranted Type 3 pavements (Figures 9 and 10). This is likely due to the relatively small number of data points available for warranted Type 3 pavements. The statistical analysis showed that PDI values for non-warranted and warranted pavements were typically not statistically different (Table 8). In addition,

the linear regression models shown in Figure 11 indicate that non-warranted and warranted Type 3 pavements perform at approximately the same level during the first 10 years of service.

Table 8. Pavement Distress Index (PDI) Analysis Summary for Type 3 Pavements

Pavement Age	Median PDI		Statistical Analysis	
	Non-warranted	Warranted	p-value	Statistically Different?
0	0	0	0.164	No
1	0	0	0.288	No
2	7	6	0.002	Yes
3	13	7	0.002	Yes
4	13	20	0.982	No
5	18	13	0.279	No
6	21	18	0.534	No
7	27	13	0.148	No
8	26	34	0.218	No
9	28	N/A	N/A	N/A
10	28.5	55	0.001	Yes
11	32	N/A	N/A	N/A
12	51	N/A	N/A	N/A

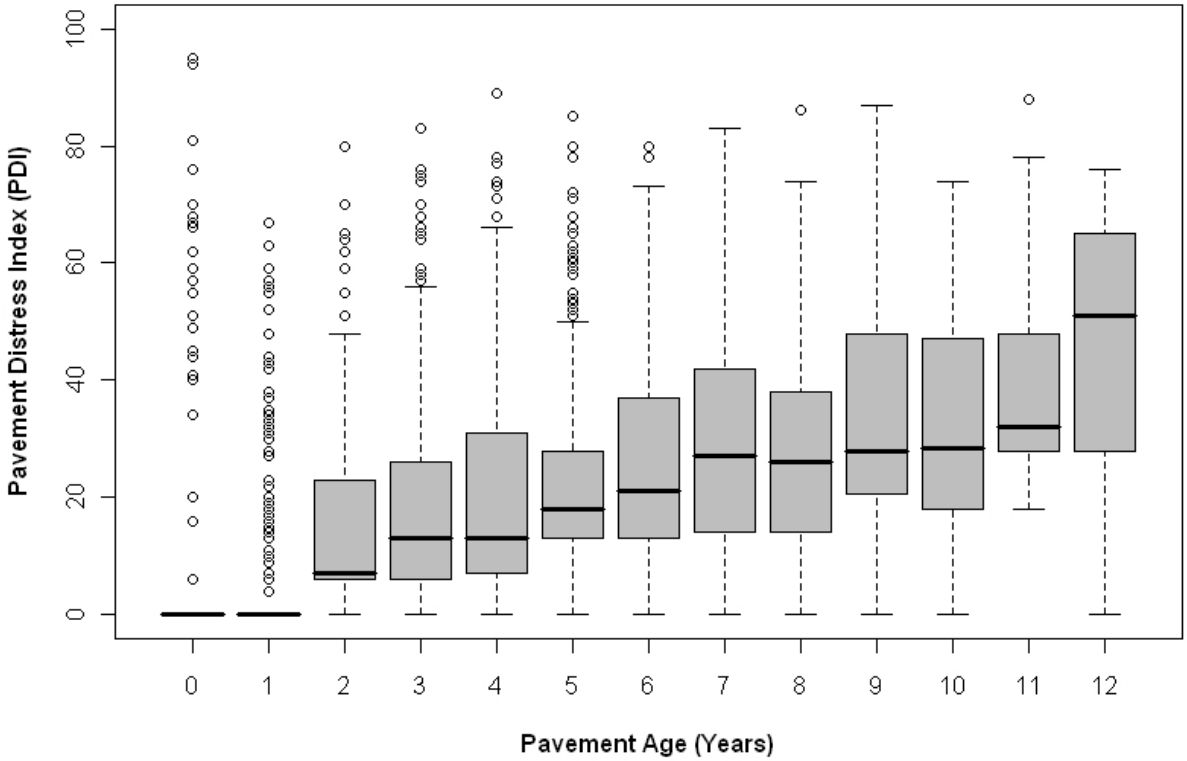

Figure 9. Pavement Distress Index (PDI) values for non-warranted Type 3 pavements constructed from 1995 to 2006. 7,492 records.

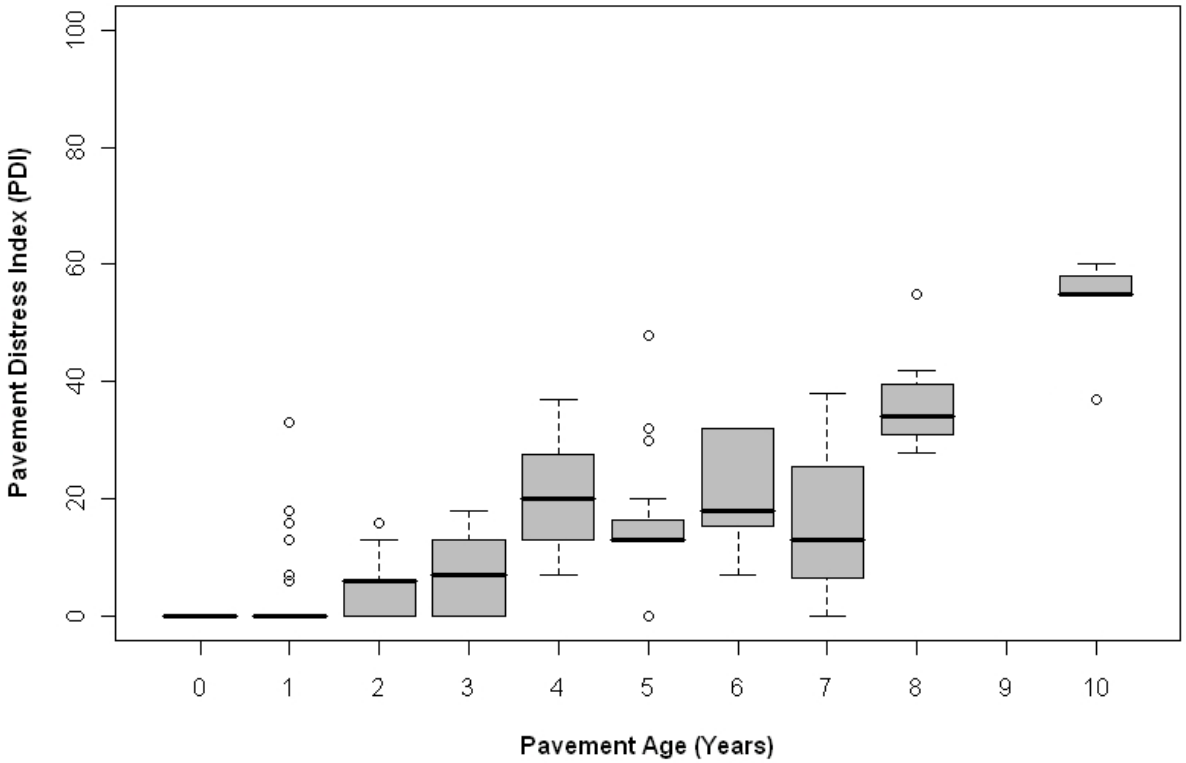

Figure 10. Pavement Distress Index (PDI) values for warranted Type 3 pavements constructed from 1996 to 2006. 217 records.

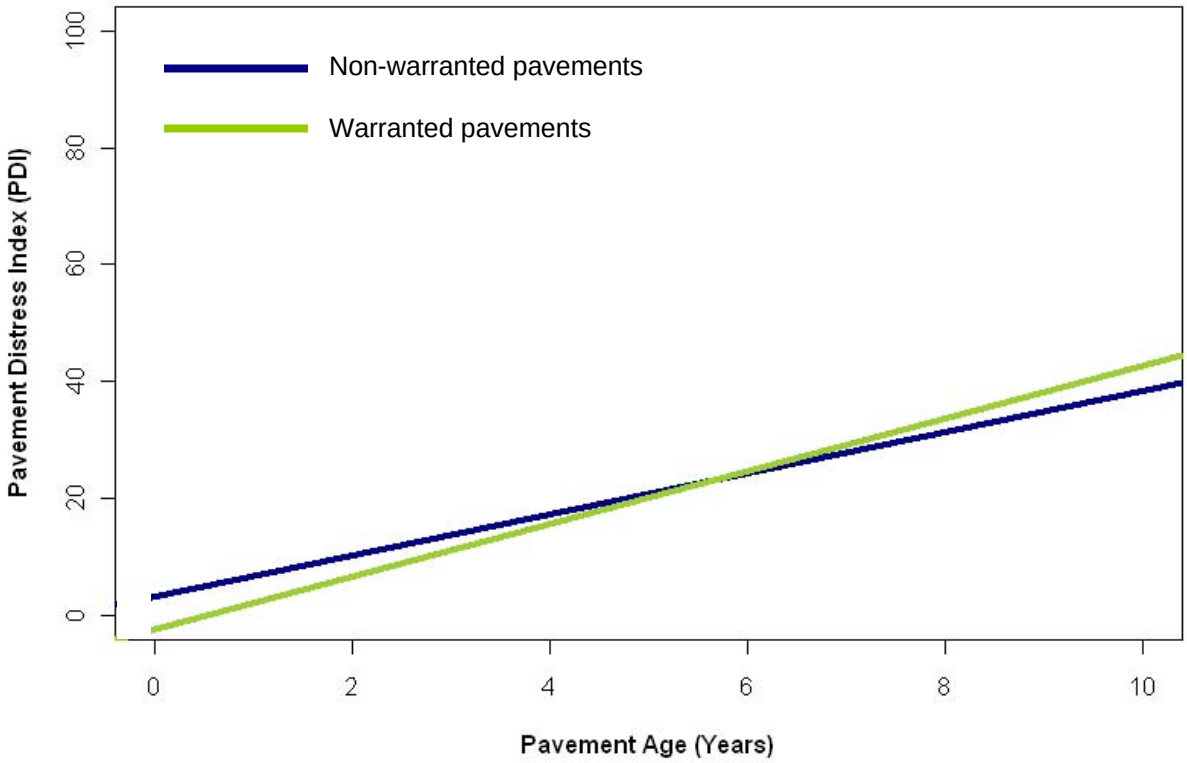

Figure 11. Linear regression models of Pavement Distress Index (PDI) for warranted Type 3 pavements and non-warranted Type 3 pavements constructed from 1996 to 2006.

4.5.2 IRI

IRI data for non-warranted and warranted Type 3 pavements constructed from 1995 through 2006 are shown in Figures 12 and 13, respectively. To compare the pavement distress performance over time for non-warranted and warranted pavements, a linear regression model was created for each dataset. The two models are plotted together in Figure 14.

An analysis summary is shown in Table 9 for the data presented in Figures 12 and 13. This summary reports the median IRI at each pavement age and t-test results to determine if there was a statistically significant difference between non-warranted and warranted pavement performance at each pavement age.

For Type 3 pavements, IRI data showed trends similar to PDI data: slightly more variability in the warranted pavement dataset (Figure 13) and approximately equal performance over time for the two types of pavements (Figure 14). The statistical analysis showed some pavement ages where there was a difference between non-warranted and warranted pavements, and some ages where there was no difference (Table 9). The median 10-year IRI values for non-warranted and warranted pavements were 1.25 and 1.64 m/km, respectively.

Table 9. International Roughness Index (IRI) Analysis Summary for Type 3 Pavements

Pavement Age	Median PDI		Statistical Analysis	
	Non-warranted	Warranted	p-value	Statistically Different?
0	0.82	0.68	< 0.001	Yes
1	0.95	0.74	< 0.001	Yes
2	0.99	0.74	0.011	Yes
3	0.98	0.76	< 0.001	Yes
4	1.03	1.26	0.340	No
5	1.03	0.95	0.280	No
6	1.12	1.37	0.888	No
7	1.22	0.91	0.070	No
8	1.10	1.34	0.217	No
9	1.28	N/A	N/A	N/A
10	1.25	1.64	0.008	Yes
11	1.45	N/A	N/A	N/A
12	1.50	N/A	N/A	N/A

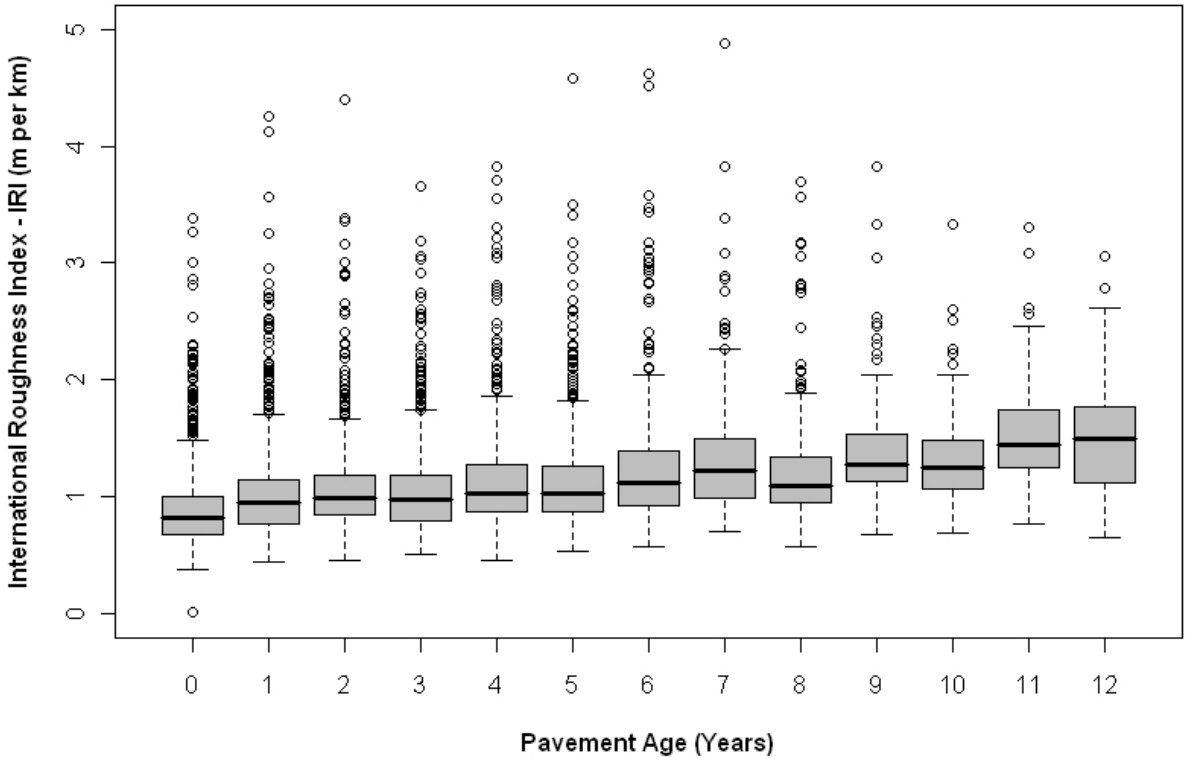

Figure 12. International Roughness Index (IRI) values for non-warranted Type 3 pavements constructed from 1995 to 2006. 7,388 records.

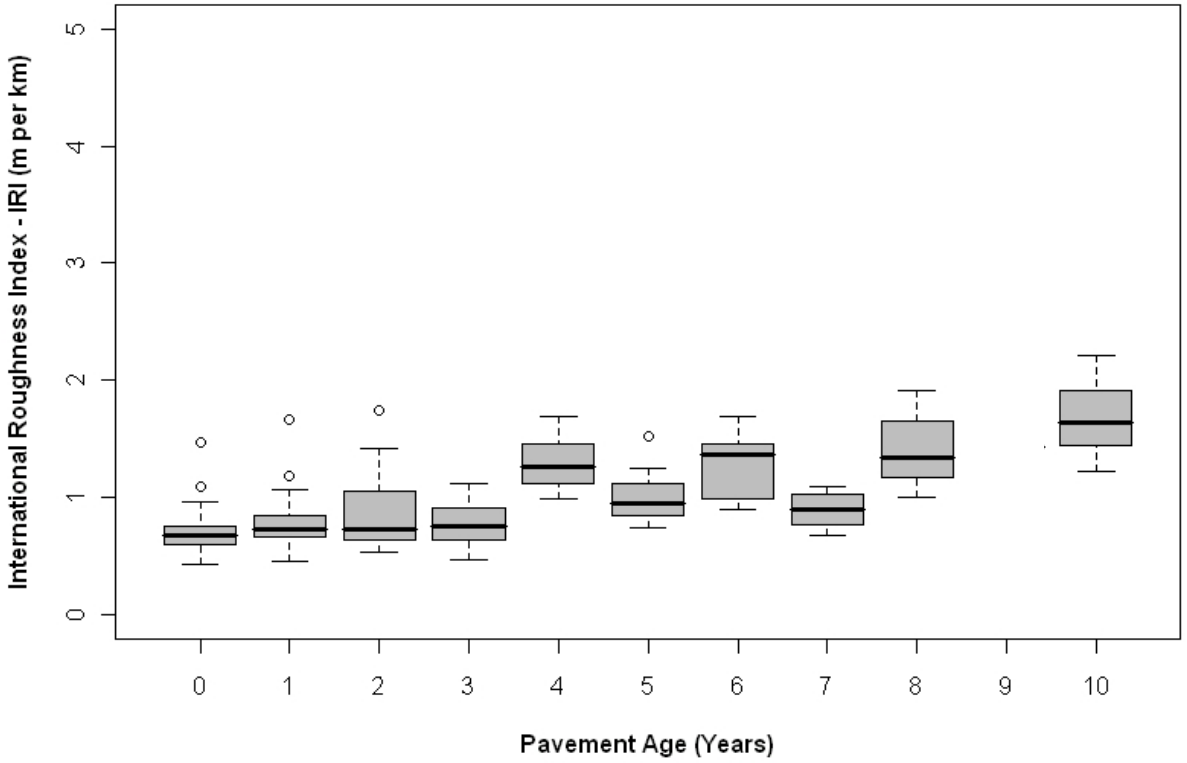

Figure 13. International Roughness Index (IRI) values for warranted Type 3 pavements constructed from 1996 to 2006. 217 records.

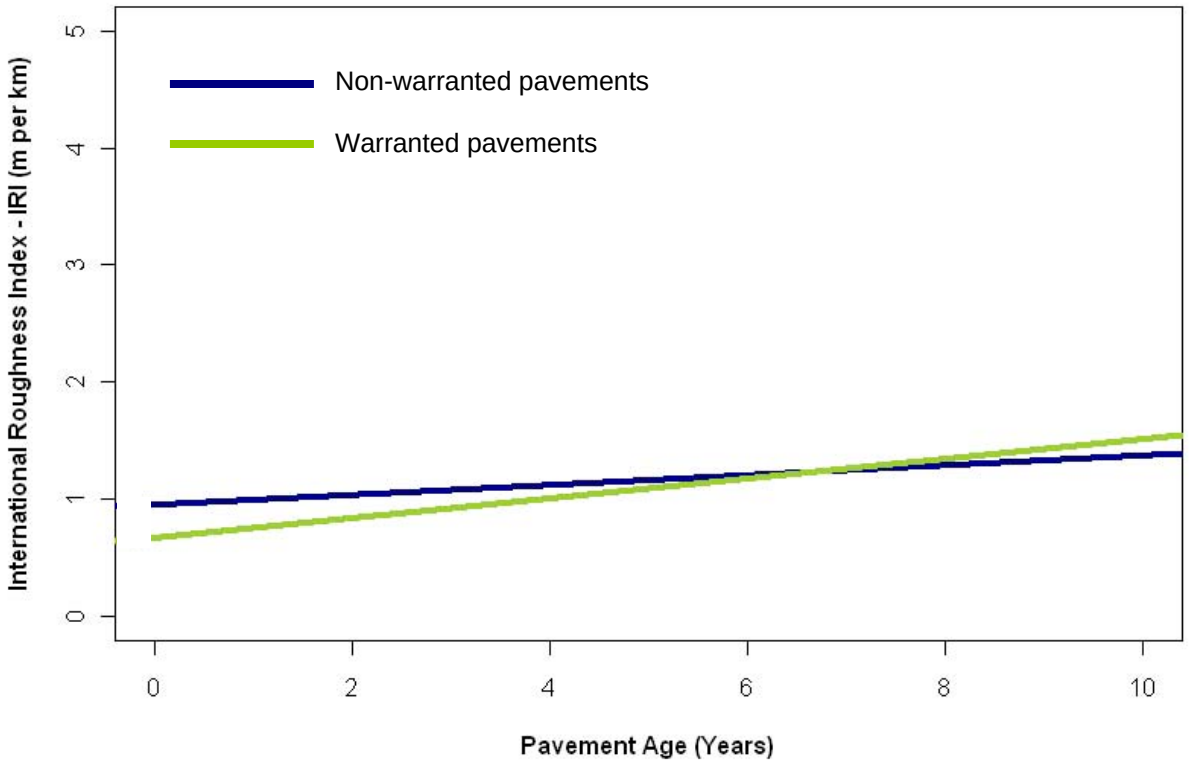

Figure 14. Linear regression models of International Roughness Index (IRI) for warranted Type 3 pavements and non-warranted Type 3 pavements constructed from 1996 to 2006.

4.6 Type 8 Pavement Analysis

For each boxplot figure shown in Sections 4.6.1 and 4.6.2, a corresponding table is provided in Appendix G containing values for each boxplot feature (e.g., median value, whisker limits, number of outliers, etc.).

4.6.1 PDI

PDI data for non-warranted and warranted Type 8 pavements constructed from 1998 through 2006 are shown in Figures 15 and 16, respectively. To compare the pavement distress performance over time for non-warranted and warranted pavements, a linear regression model was created for each dataset. The two models are plotted together in Figure 17.

A summary is shown in Table 10 for the data presented in Figures 15 and 16. This summary reports the median PDI at each pavement age and t-test results to determine if there was a statistically significant difference between non-warranted and warranted pavement performance at each pavement age.

Regardless of contract type, Type 8 pavements showed very little distress during the first nine years of service. The median PDI values for non-warranted and warranted pavements at nine years were 3.5 and 3.0, respectively. No statistical difference between the two was observed at any age (Table 10). In addition, the rates of distress increase were nearly identical for both pavement types (Figure 17). Because of the limited number of data points for Type 8 warranted pavements, however, it was difficult to make definitive comparisons between the two contracting methods.

Table 10. Pavement Distress Index (PDI) Analysis Summary for Type 8 Pavements

Pavement Age	Median PDI		Statistical Analysis	
	Non-warranted	Warranted	p-value	Statistically Different?
0	0	0	0.273	No
1	0	0	0.138	No
2	3	3	0.197	No
3	3	3	0.791	No
4	3	3	0.720	No
5	3	3	0.927	No
6	3	3.5	0.765	No
7	3	3	0.772	No
8	3	3	0.334	No
9	3.5	3	0.741	No

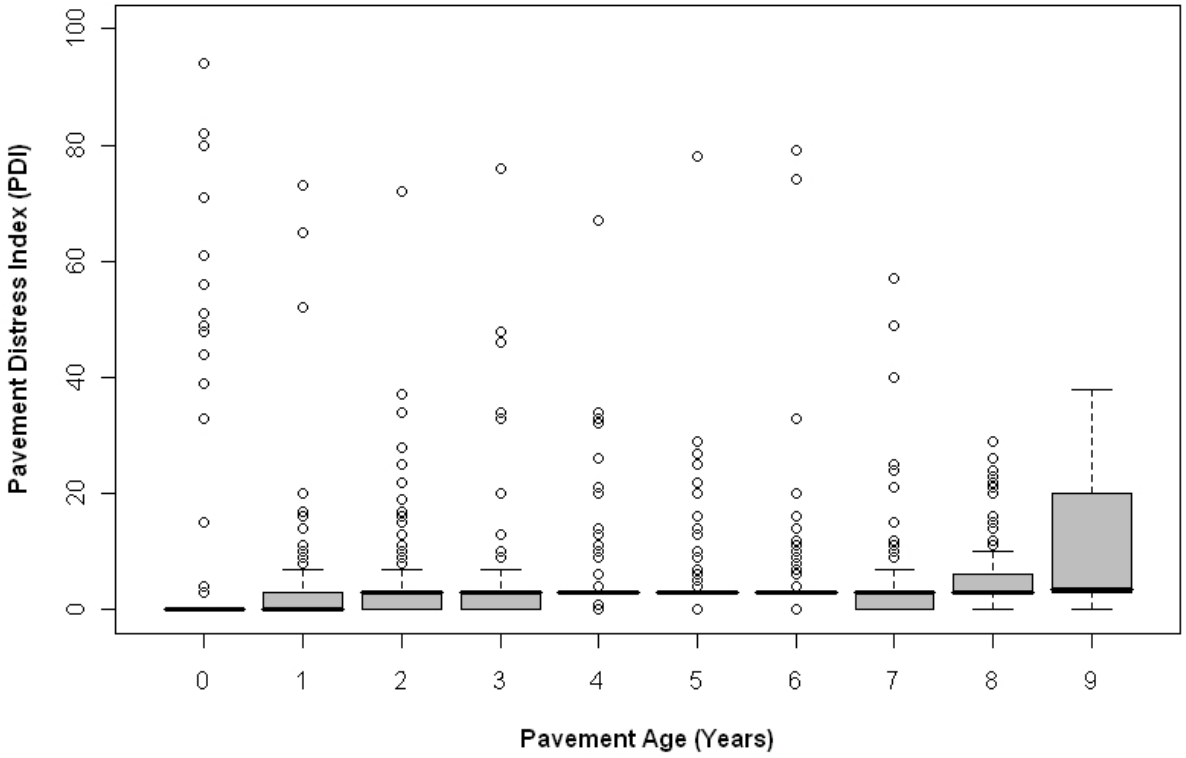

Figure 15. Pavement Distress Index (PDI) values for non-warranted Type 8 pavements constructed from 1998 to 2006. 3,148 records.

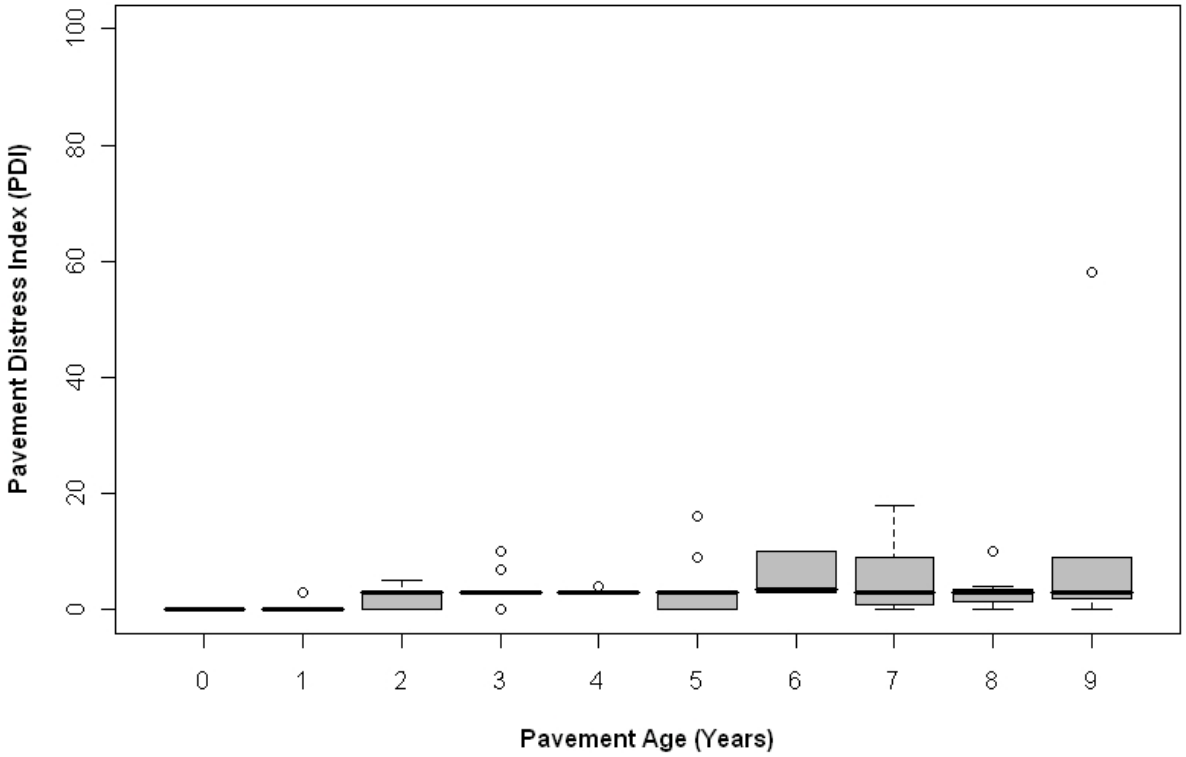

Figure 16. Pavement Distress Index (PDI) values for warranted Type 8 pavements constructed from 1998 to 2006. 216 records.

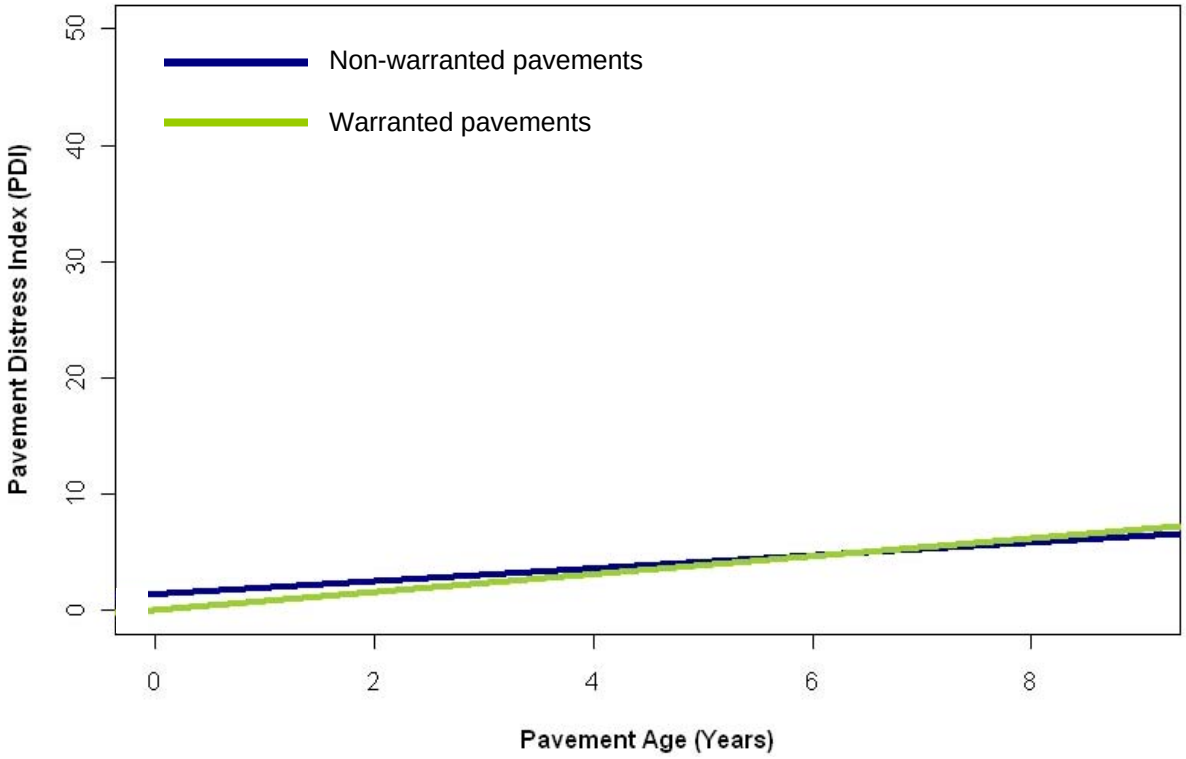

Figure 17. Linear regression models of Pavement Distress Index (PDI) for warranted Type 8 pavements and non-warranted Type 8 pavements constructed from 1998 to 2006.

4.6.2 IRI

IRI data for non-warranted and warranted Type 8 pavements constructed from 1998 through 2006 are shown in Figures 18 and 19, respectively. To compare the pavement distress performance over time for non-warranted and warranted pavements, a linear regression model was created for each dataset. The two models are plotted together in Figure 20.

A summary is shown in Table 11 for the data presented in Figures 18 and 19. This summary reports the median IRI at each pavement age and t-test results to determine if there was a statistically significant difference between non-warranted and warranted pavement performance at each pavement age.

The statistical analysis showed that there was a difference in IRI between non-warranted and warranted pavements at some ages, but this was not consistent at all ages. There was a slight upward trend in IRI for non-warranted pavements (Figure 20). A downward trend was noted for warranted pavements, but this is likely due to the relatively few data points available for warranted Type 8 pavements. In conclusion, the smoothness of non-warranted and warranted Type 8 pavements was approximately equal during the nine-year analysis period.

Table 11. International Roughness Index (IRI) Analysis Summary for Type 8 Pavements

Pavement Age	Median IRI		Statistical Analysis	
	Non-warranted	Warranted	p-value	Statistically Different?
0	1.45	1.53	0.104	No
1	1.47	1.55	0.819	No
2	1.44	1.47	0.490	No
3	1.50	1.33	0.021	Yes
4	1.44	1.25	0.060	No
5	1.50	1.27	0.018	Yes
6	1.56	1.48	0.308	No
7	1.52	1.33	0.029	Yes
8	1.61	1.47	0.230	No
9	1.80	1.31	0.003	Yes

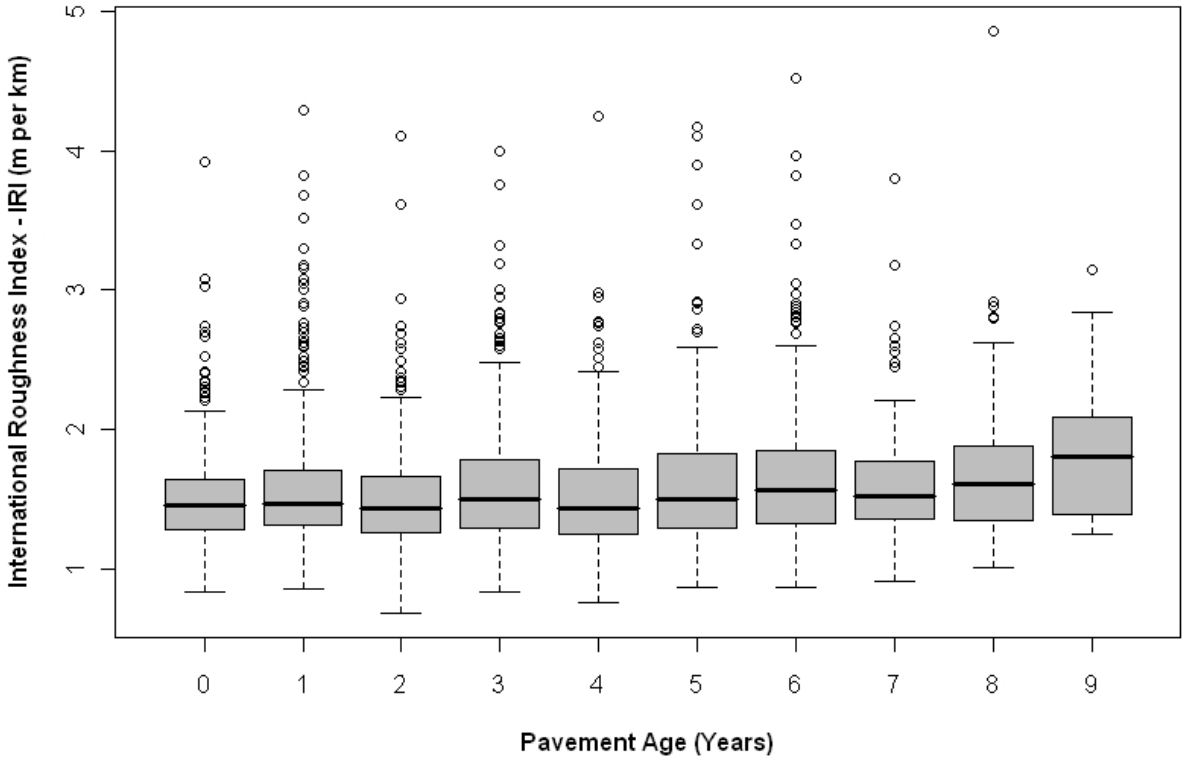

Figure 18. International Roughness Index (IRI) values for non-warranted Type 8 pavements constructed from 1998 to 2006. 2,903 records.

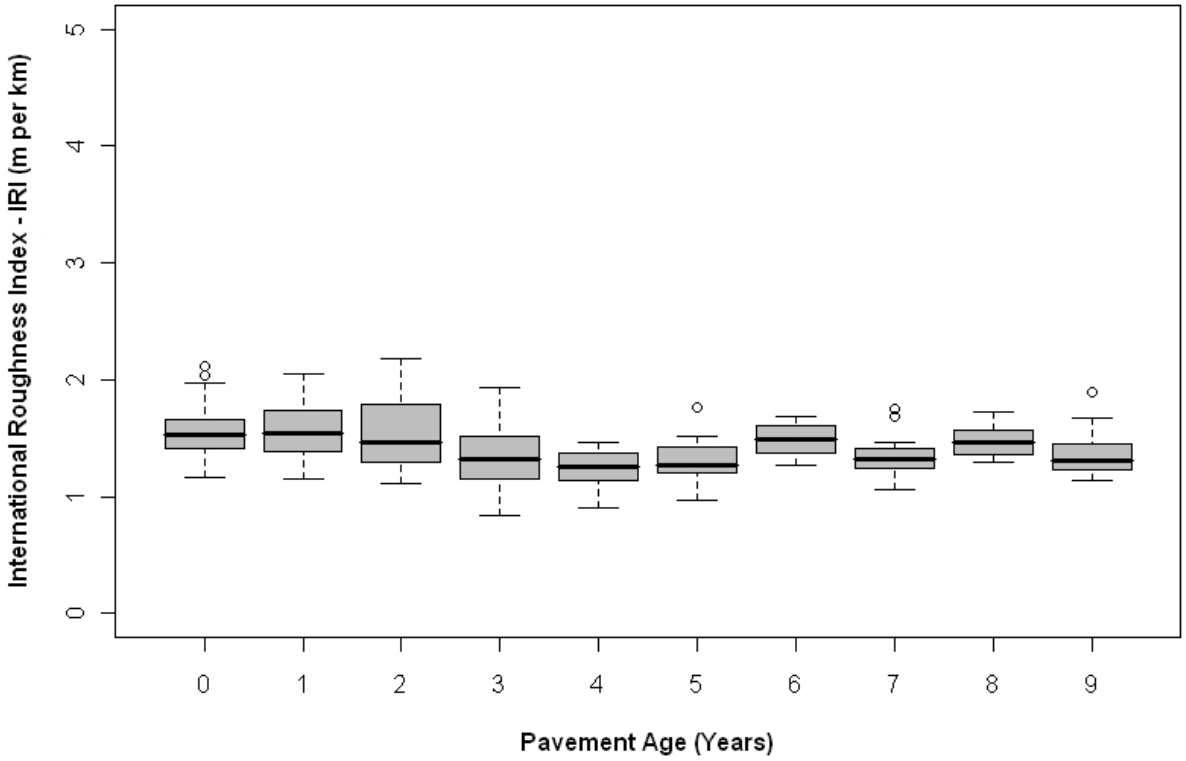

Figure 19. International Roughness Index (IRI) values for warranted Type 8 pavements constructed from 1998 to 2006. 204 records.

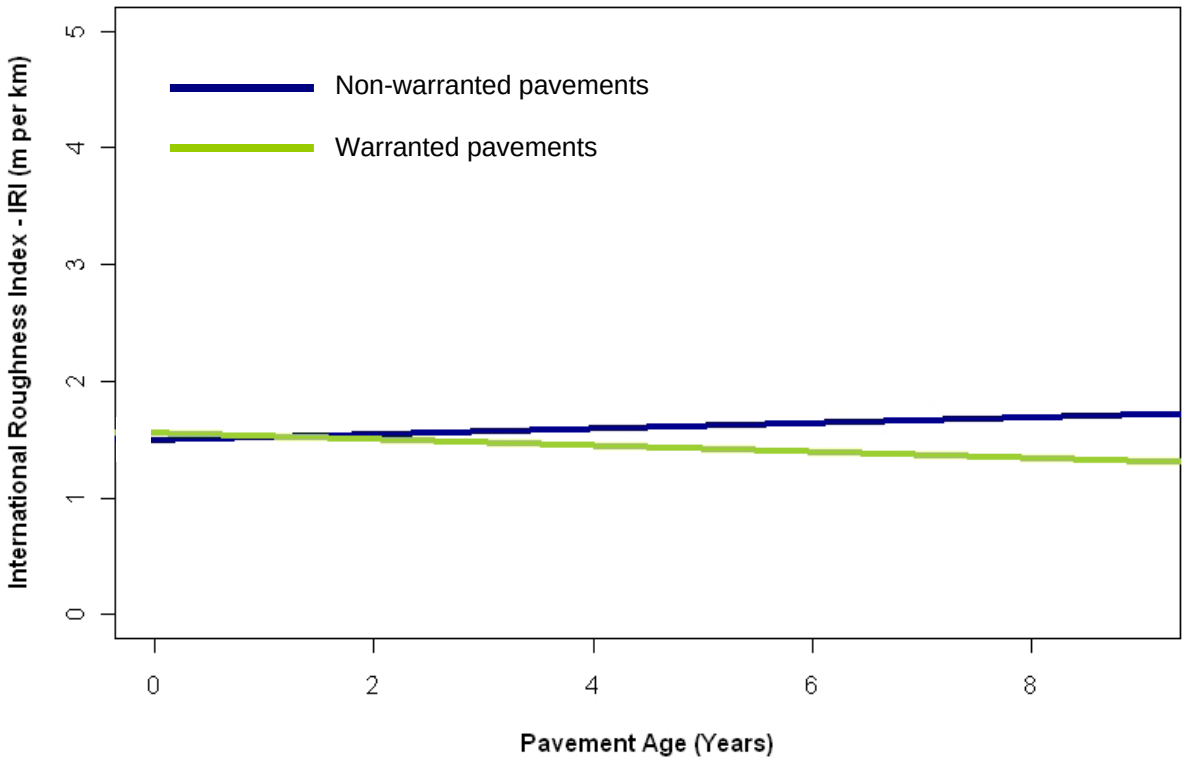

Figure 20. Linear regression models of International Roughness Index (IRI) for Type 8 warranted pavements and Type 8 non-warranted pavements constructed from 1998 to 2006.

5. Cost Analysis (1999-2008)

5.1 Bid Cost Analysis

5.1.1 HMA Pavements

Historic bid data for HMA pavement construction contracts were available for the 1999 construction year through the 2008 construction year. Bid items that were tracked for the cost analysis are shown in Table 12. Non-warranted HMA pavement contracts include bid items for three materials (mixture, binder and tack coat) and several quality management program (QMP) and incentive items, including QMP tests for materials, nuclear density testing of the pavement and a density incentive item.

Warranted pavement contracts do not include individual bid items for materials, because specific materials are determined by the contractor and not by the Department. Two bid items are included in HMA pavement warranty contracts: one for mainline pavement (travel lanes and shoulders) and one for ancillary pavement (ramps, turning lanes, side roads, driveways and other secondary pavement items).

Table 12. Bid Items Associated with Warranted and Non-Warranted HMA Pavement Contracts

Contract Type	Bid Item	Unit of Measurement
Non-Warranted HMA	HMA Mixture	Ton
	Asphaltic Material for Binder	Ton
	Asphaltic Material for Tack Coat	Gallon
	QMP Material Testing	Dollars
	QMP Nuclear Density Testing	Dollars
	Incentive Density HMA Pavement	Dollars
Warranted HMA	HMA Pavement Mainline	Ton
	HMA Pavement Ancillary	Ton

All warranted HMA pavement contracts for which bid data were available were included in the analysis. Most total warranted HMA mixture tonnages (mainline and ancillary pavement) were greater than 10,000 tons. Therefore, non-warranted pavement contracts analyzed included mainline paving construction with HMA mixture tonnages of approximately 10,000 tons or more. A summary of the contracts included in the cost analysis is provided in Table 13.

Table 13. Summary of HMA Pavement Contracts Included in Cost Analysis

	Non-Warranted HMA Pavement	Warranted HMA Pavement
Contracts Analyzed	612	123
Average Tonnage	29,269	41,132
Maximum Tonnage	153,878	171,351
Minimum Tonnage	9,896	2,900

The total unit bid price (dollars per ton of HMA mixture) was calculated by summing the total cost of all bid items included for a particular contract and dividing by the contract's total HMA mixture tonnage (see Equations 3 and 4). Total costs versus construction year are plotted for non-warranted and warranted HMA pavement contracts in Figures 21 and 22, and annual median total bid costs are provided in Table 14. Values for each boxplot feature (e.g., median value, whisker limits, number of outliers, etc.) are provided in Appendix G for Figures 21 and 22.

$$\text{Total Bid Cost}_{\text{Non-Warranty Contract}} = \frac{\text{Total Cost}[\text{HMA Mixture} + \text{Binder} + \text{Tack Coat} + (\text{QMP} + \text{Incentive})]}{\text{Total HMA Mixture Tonnage}} \quad \text{Eq. 3}$$

$$\text{Total Bid Cost}_{\text{Warranty Contract}} = \frac{\text{Total Cost}[\text{Mainline Pavement} + \text{Ancillary Pavement}]}{\text{Total Mainline and Ancillary Pavement Tonnages}} \quad \text{Eq. 4}$$

The median total unit bid cost for non-warranted HMA pavement contracts was just under $30 per ton between the 1999 and 2004 construction years. The median cost increased steadily starting in 2005 and was $56.67 per ton in 2008. The variability in bid costs also increased during this period. The increase in unit cost and bid variability was due to rising material costs, most notably for the asphaltic material (binder and tack coat).

The median total unit bid cost for warranted HMA pavement contracts was close to $30 per ton until the 2006 construction year, and the median cost was $49.18 per ton in 2008. The variability of warranted pavement bid costs was greater in 2008 than in the previous construction years.

A t-test statistical analysis of the bid cost data was performed to determine if the total unit bid costs were significantly different for non-warranted and warranted contracts in each year; results are shown in Table 14. A statistical difference was noted in 2005, 2006 and 2007. In these years, median bid costs were approximately $5 to $7 lower per ton for warranted HMA pavement contracts than for non-warranted contracts.

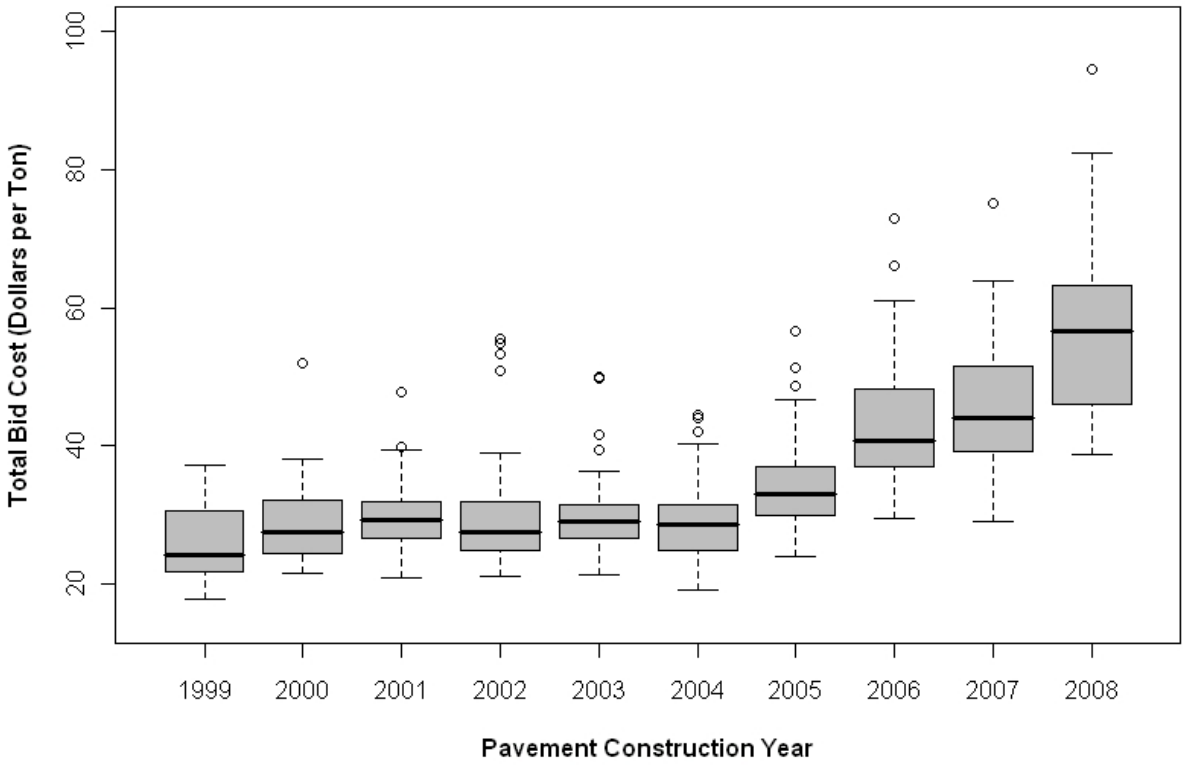

Figure 21. Total bid cost values for non-warranted HMA pavement contracts for the 1999 through 2008 construction years. 612 records.

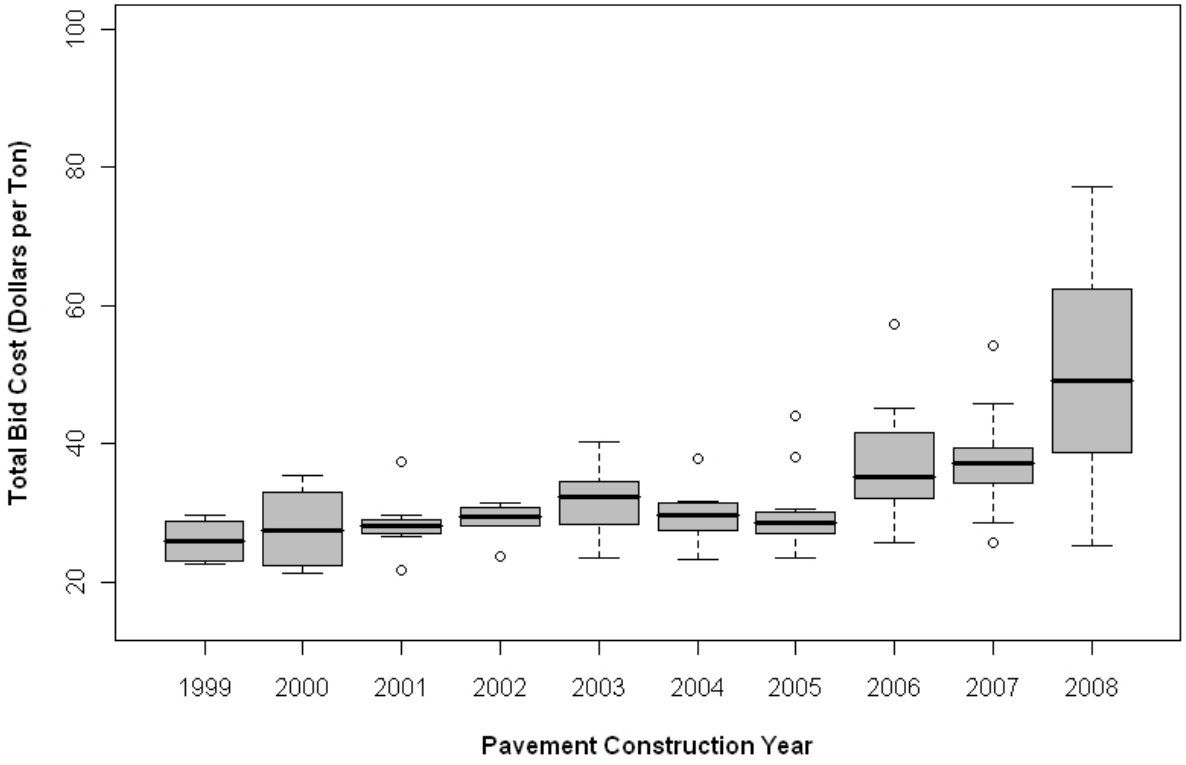

Figure 22. Total bid cost values for warranted HMA pavement contracts for the 1999 through 2008 construction years. 123 records.

Table 14. Median Total Unit Bid Price and Statistical Summary for Non-Warranted and Warranted HMA Pavement Contracts

Pavement Construction Year	Median Total Unit Bid Price		Statistical Analysis		
	Non-Warranted	Warranted	p-value	Statistically Different?	Difference
1999	$24.33	$25.78	0.997	No	-
2000	$27.61	$27.40	0.747	No	-
2001	$29.35	$27.99	0.472	No	-
2002	$27.61	$29.47	0.669	No	-
2003	$29.12	$32.24	0.410	No	-
2004	$28.76	$29.66	0.949	No	-
2005	$33.08	$28.55	0.036	Yes	$4.53
2006	$40.74	$35.22	0.004	Yes	$5.52
2007	$43.99	$37.15	< 0.001	Yes	$6.84
2008	$56.67	$49.18	0.062	No	-

5.1.2 PCC Pavements

Historic bid data for PCC pavement construction contracts were available starting with the 1999 construction year; however, because there were no warranted PCC pavements constructed between 1999 and 2004, the bid cost analysis was performed for the 2004 through the 2008 construction years. Bid items that were tracked for the cost analysis are shown in Table 15. Non-warranted PCC pavement contracts include bid items for the concrete pavement, QMP testing for the concrete pavement materials and a strength incentive item. The PCC pavement thickness is specified in an individual contract's bid item, and the bid item is measured in square yards (SY). Warranted pavement contracts include one bid item for PCC pavement with an associated thickness.

Table 15. Bid Items Associated with Warranted and Non-Warranted PCC Pavement Contracts

Contract Type	Bid Item	Unit of Measurement
Non-Warranted PCC	PCC Pavement (thickness)	SY
	QMP Material Testing	Dollars
	Incentive Strength	Dollars
Warranted PCC	Warranted PCC Pavement (thickness)	SY

All warranted PCC pavement contracts for which bid data were available were included in the analysis. The total yardages for most warranted PCC pavements were greater than 70,000 SY. Therefore, non-warranted pavement contracts included in the cost analysis had approximately 70,000 or more square yards. A summary of the contracts included in the cost analysis is provided in Table 16.

Table 16. Summary of PCC Pavement Contracts Included in Cost Analysis

	Non-Warranted PCC Pavement	Warranted PCC Pavement
Contracts Analyzed	34	11
Average SY	137,260	127,365
Maximum SY	327,277	329,248
Minimum SY	68,083	10,400

The total unit bid price (dollars per SY per inch) was calculated by summing the total cost of all relevant bid items included for a particular contract, dividing by the contract's total SY of PCC pavement, and dividing by the pavement thickness specified in the bid item (see Equations 5 and 6). Dividing by pavement thickness normalized the unit costs so that bids for various pavement thicknesses could be compared. PCC pavement contracts often include bid items for multiple pavement thicknesses; only one pavement thickness per contract was included in this analysis. Total unit costs versus construction year are plotted for non-warranted and warranted PCC pavement contracts in Figure 23.

$$\text{Total Bid Cost}_{\text{Non-Warranty Contract}} = \frac{\dfrac{\text{Total Cost}[\text{PCC Pavement} + \text{QMP} + \text{Incentive}]}{\text{PCC Pavement SY}}}{\text{PCC Pavement thickness}} \quad \text{Eq. 5}$$

$$\text{Total Bid Cost}_{\text{Warranty Contract}} = \frac{\dfrac{\text{Total Cost}[\text{Warranted PCC Pavement}]}{\text{PCC Pavement SY}}}{\text{PCC Pavement thickness}} \quad \text{Eq. 6}$$

For the contracts included in this cost analysis, the total unit costs per SY per inch were very similar for non-warranted and warranted PCC pavements. There is a slight upward trend in cost for non-warranted PCC pavement. Unpaired t-tests comparing unit costs for non-warranted and warranted pavement bid costs indicated that, for each year from 2004 to 2008, the difference between costs for the two types of contracts was not statistically significant.

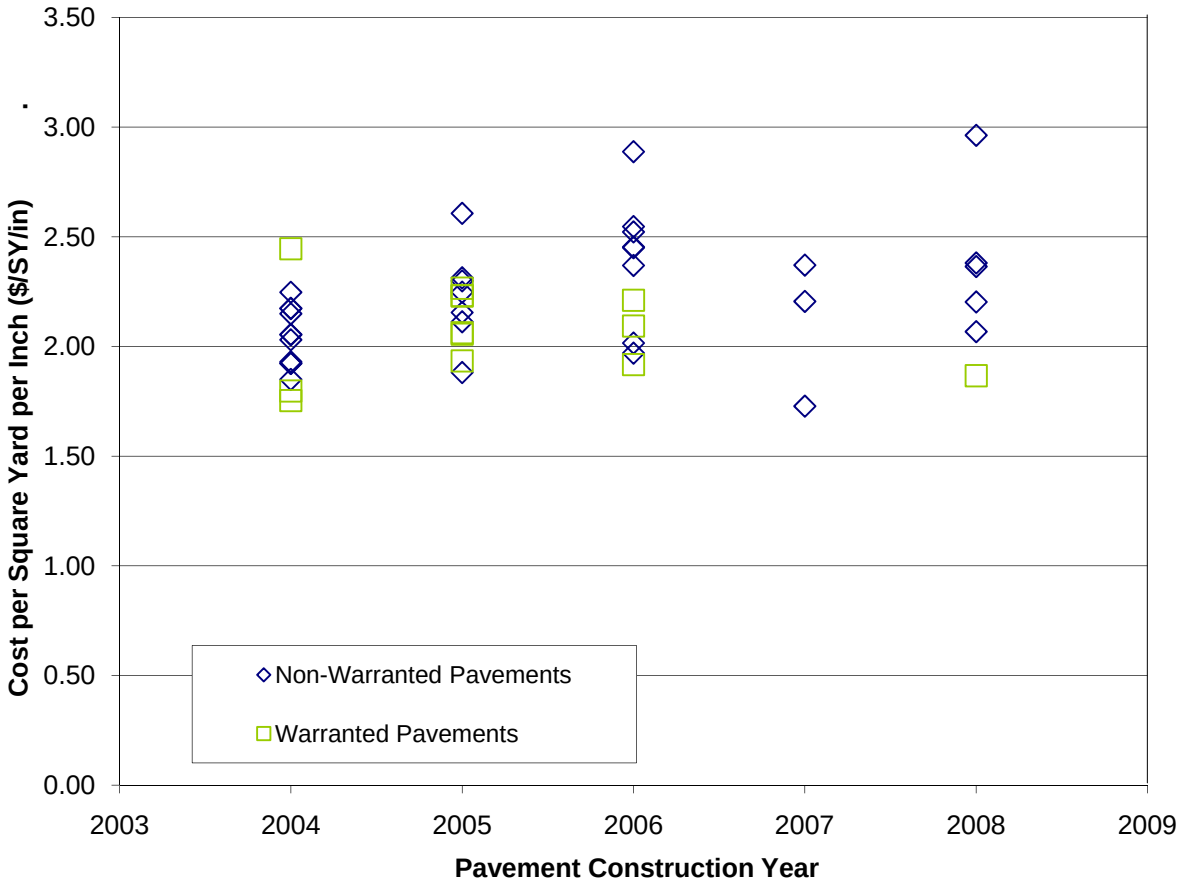

Figure 23. Total bid cost values for non-warranted and warranted PCC pavement contracts for the 2004 through 2008 construction years. 45 records.

5.2 WisDOT Staff Time

While staff time devoted to paving projects is the same for many aspects of standard and warranted pavement contracts (e.g., scoping, plan development, distress monitoring, etc.), several aspects differ. These areas include materials testing for standard contracts and administration, increased distress monitoring, and conflict resolution for warranty contracts. These areas where a difference in WisDOT staff time occurs are analyzed in the following sections.

The cost for all staff hours is assumed to be $50 per hour. This estimate represents an average hourly wage including benefits for WisDOT staff.

5.2.1 Warranty Projects

Staff time devoted to warranty contracts above and beyond what is required for standard contracts includes time for central office coordination, regional office coordination, warranty committee meetings, pavement distress monitoring, and conflict resolution. Each of these categories is discussed below.

To relate the yearly staff time costs to the bid prices calculated in the previous section, the costs had to be presented in a per ton and per SY basis for HMA and PCC pavements respectively. Therefore, the annual staff time costs in each category were divided by the average total tonnages or square yards constructed under warranty each year. To calculate these average tonnage and SY values, warranty projects constructed between 2006 and 2008 were considered. The number of warranted HMA and PCC pavements constructed during these three most recent years was relatively constant (see Figure 1). The average tonnage (mainline and ancillary HMA) used in warranted HMA pavements was 917,900 tons per year. The average square yards of concrete used in warranted PCC pavements was 177,046 SY per year.

Because WisDOT staff time costs were calculated for the pavement warranty program as a whole, the actual time devoted to warranted HMA and PCC pavements had to be distributed proportionately. Much of the staff time devoted to warranty projects involves analysis of a length of pavement after construction, and thus the total roadway miles constructed in each warranty category were used to determine the correct distribution factor. Looking again at the warranty program between 2006 and 2008, the total roadway miles of warranted HMA and PCC pavement constructed were 493.4 and 51.1 miles, respectively. Therefore the portion of staff time devoted to HMA and PCC pavement warranties was 90.6% and 9.4%, respectively, as calculated in Equations 7 and 8.

HMA factor = 493.4 miles / (493.4 + 51.1) miles x 100% = 90.6% Eq. 7

PCC factor = 51.1 miles / (493.4 + 51.1) miles x 100% = 9.4% Eq. 8

5.2.1.1 Central office coordination

WisDOT devotes 40 percent of a full-time position to monitor and coordinate the warranty program on a statewide level. This position will be referred to as the Statewide Warranty Coordinator (SWC). The estimated annual cost to the Department for the hours spent by the SWC is shown in Equation 9, with a full-time position equal to 2,080 hours.

$$\frac{2{,}080\ \text{hours}}{\text{year}} \times \frac{\$50}{\text{hour}} \times 40\%\ \text{time} = \$41{,}600/\text{year} \qquad \text{Eq. 9}$$

$$\div \frac{917{,}900\ \text{tons}}{\text{year}} \times 90.6\% = \mathbf{\$0.041/ton}$$

$$\div \frac{177{,}000\ \text{SY}}{\text{year}} \times 9.4\% = \mathbf{\$0.022/SY}$$

5.2.1.2 Regional office coordination

Many aspects of the pavement warranty program are handled on a regional level, including the decision to warrant a pavement, monitoring distresses in warranted pavements, and coordinating warranty work with contractors. While the method for administering warranty contracts is different in each of the state's five regions, each region has developed or is in the process of developing a procedure for tracking warranted pavements after construction.

To better understand each region's process and determine the associated staff costs, a survey was sent to regional staff involved in warranty administration. Responses to this survey varied greatly among regions. Some responders indicated an increased workload associated with the pavement warranty program, while others felt that time was saved by using warranty contracts as compared to standard (non-warranty) contracts. These varied results were not surprising, as the five regions have varying numbers of pavements under warranty and have chosen to administer their warranty projects in different ways. To achieve a conservative regional staff cost estimate, the maximum time responses for each category were used for calculation. These responses are shown in Table 17.

Table 17. Regional Staff Time Survey Responses

Category	Hours spent on one warranty project
Decision to use a warranty contract	1
Calculation of warranty bond	1
Fielding questions about a project's warranty	4
Reviewing warranty distress reports	10
Reviewing warranted pavement in the field	12
Coordinating remedial work	8
Coordinating crack sealing operation (HMA warranties only)	4
Updating State Warranty Database	1
Other	1
Total hours per warranty project	**42**

Between 2006 and 2008, an average of 25 warranted pavements were constructed each year (Figure 1). Based on these figures, the average annual cost to the Department for the hours spent by regional staff on warranty projects is shown in Equation 10.

$$\frac{42\ \text{hours}}{\text{project}} \times \frac{\$50}{\text{hour}} \times \frac{25\ \text{projects}}{\text{year}} = \$52{,}500/\text{year} \qquad \text{Eq. 10}$$

$$\div \frac{917{,}900\ \text{tons}}{\text{year}} \times 90.6\% = \mathbf{\$0.052/ton}$$

$$\div \frac{177{,}000\ \text{SY}}{\text{year}} \times 9.4\% = \mathbf{\$0.028/SY}$$

5.2.1.3 Warranty committee meetings

At the time of this report, the HMA Warranty Committee met several times per year to discuss issues related to warranted HMA pavement construction and the HMA pavement warranty specification. This cost was only included in the HMA warranted pavement cost analysis (not the PCC cost analysis). Five WisDOT staff typically participated in these meetings and traveled from various parts of the state to attend the meetings in Madison (on average 8.4 travel hours per participant and 466 miles traveled total per

meeting). Three meetings were held per year and were generally three hours in length. The average annual cost to the Department for warranty committee meetings is computed in Equation 11.

$$\frac{3\text{ meetings}}{\text{year}}\times\left[\left(\frac{3\text{ meeting hours}+8.4\text{ travel hours}}{\text{meeting}}\times\frac{\$50}{\text{hour}}\right)\times 5\text{ WisDOT Staff}+\left(\frac{466\text{ miles traveled}}{\text{meeting}}\times\frac{\$0.32}{\text{mile}}\right)\right]$$

$$= \$8{,}997/\text{year} \qquad \text{Eq. 11}$$

$$\div\frac{917{,}900\text{ tons}}{\text{year}} = \mathbf{\$0.010/ton}$$

It should be noted that for recent meetings, efforts have been made to provide teleconference and web-conference options for any committee member with a long travel distance. If these communication resources are used regularly, the cost to the Department for warranty committee meetings would be significantly reduced.

5.2.1.4 Pavement distress monitoring

The Pavement Data Unit designates specific staff time to the collection and analysis of warranted pavement distress data. Occasional special requests to analyze additional warranted pavement sections are also handled by this unit. The costs are outlined in Equations 12 through 14 below.

Data collection:

$$\frac{3\text{ weeks}}{\text{year}}\times\frac{40\text{ hours}}{\text{week}}\times\frac{\$50}{\text{hour}}\times 2\text{ WisDOT Staff} = \$12{,}000/\text{year} \qquad \text{Eq. 12}$$

Data analysis:

$$\frac{2\text{ segments surveyed}}{\text{mile}}\times\frac{0.25\text{ survey hours}}{\text{segment surveyed}}\times\frac{7\text{ miles}}{\text{project}}\times\frac{25\text{ projects}}{\text{year}}\times\frac{\$50}{\text{hour}} = \$4{,}375/\text{year} \qquad \text{Eq. 13}$$

Special requests:

$$\frac{10\text{ segments surveyed}}{\text{mile}}\times\frac{0.25\text{ survey hours}}{\text{segment surveyed}}\times\frac{3\text{ miles}}{\text{request}}\times\frac{4\text{ requests}}{\text{year}}\times\frac{\$50}{\text{hour}} = \$1{,}500/\text{year} \qquad \text{Eq. 14}$$

Total = \$17,875/year

$$\div\frac{917{,}900\text{ tons}}{\text{year}}\times 90.6\% = \mathbf{\$0.018/ton}$$

$$\div\frac{177{,}000\text{ SY}}{\text{year}}\times 9.4\% = \mathbf{\$0.010/SY}$$

5.2.1.5 Conflict resolution

Although no warranty contract has entered the formal conflict resolution process, there have been issues with several contracts that require more attention and thus more staff hours. Historically, there have been two warranty projects per year that require additional field reviews, meetings with the contractor, or other non-routine activities. Regional staff estimated that the additional time required to resolve these problems

varies from 40 staff hours to over 100 staff hours per project. For a conservative estimate, 100 hours per project were used in cost calculations. The total annual cost to the Department is given in Equation 15.

$$\frac{2\text{ projects}}{\text{year}} \times \frac{100\text{ hours}}{\text{project}} \times \frac{\$50}{\text{hour}} = \$10{,}000/\text{year} \qquad \text{Eq. 15}$$

$$\div \frac{917{,}900\text{ tons}}{\text{year}} \times 90.6\% = \textbf{\$0.010/ton}$$

$$\div \frac{177{,}000\text{ SY}}{\text{year}} \times 9.4\% = \textbf{\$0.010/SY}$$

5.2.2 Standard Contracts

There are costs associated with the Department's quality management program (QMP) that pertain to standard contracts but not warranty contracts. These QMP items include quality verification testing, independent assurance testing, and nuclear density testing. The testing cost was accounted for in standard contract bid costs (Section 5.1). Staff time for QMP activities is additional. Regional Technical Services and Project Development sections were surveyed to determine staff hours devoted to QMP. For HMA pavement projects, the average time committed is 4.4 hours per 1000 tons of HMA. For PCC pavement projects, the average time committed is 1.2 hours per 1000 SY of concrete. These staff hours translate into the costs calculated in Equations 16 and 17.

HMA pavement projects:

$$\frac{4.4\text{ hours}}{1000\text{ tons}} \times \frac{\$50}{\text{hour}} = \textbf{\$0.22/ton} \qquad \text{Eq. 16}$$

PCC pavement projects:

$$\frac{1.2\text{ hours}}{1000\text{ SY}} \times \frac{\$50}{\text{hour}} = \textbf{\$0.06/SY} \qquad \text{Eq. 17}$$

5.3 Pavement Repair Costs

WisDOT does not bear the cost of pavement repair during the 5-year warranty period; thus any work performed on HMA and PCC pavements constructed under a warranty contract were considered cost savings to the Department. After the warranty period is over, future pavement repair costs are assumed to be equal for non-warranted and warranted pavements.

For typical PCC pavements, there are no repair activities performed during the first five years of pavement service.

For HMA pavements, cracks are typically routed and sealed once during the first five years of pavement service. Under the warranty contract, the contractor is responsible for routing and sealing cracks during the final year of the warranty period. This warranty work activity adds value to warranty contracts and was included in the cost analysis.

The Department's Pavement Maintenance Management Program assumes a cost of $4,900 per lane mile for crack sealing. Based on distress surveys from five-year-old warranted HMA pavements that expired in

the last five years (2004 through 2008), there were an average of 3,000 total lineal feet per lane-mile of longitudinal and transverse cracks that would be sealed under the warranty contract provision. This equates to approximately $1.60 per lineal foot of crack sealing. During the 2006 to 2008 analysis period, an average of 330 lane miles of warranted HMA pavement were constructed each year. As in the previous section, the average of 917,900 warranted HMA tons constructed per year was used to create a cost per ton value. The cost to the Department for the crack sealing operation if these pavements had not been warranted is calculated in Equation 18.

$$\frac{330\ \text{warranted lane miles}}{\text{year}} \times \frac{3{,}000\ \text{lineal feet sealed}}{\text{warranted lane mile}} \times \frac{\$1.60}{\text{lineal foot}} = \$1{,}584{,}000/\text{year} \qquad \text{Eq. 18}$$

$$\div \frac{917{,}900\ \text{tons}}{\text{year}} = \mathbf{\$1.73/ton}$$

5.4 Cost Analysis Summary

5.4.1 HMA Pavements

A total cost per ton value was calculated based on the bid costs, WisDOT staff time costs, and pavement repair costs calculated for warranted HMA pavements in Sections 5.1 through 5.3. Average bid costs were calculated based on the median bid costs from the 2006, 2007, and 2008 construction seasons (Table 14). The unit cost summaries are presented in Tables 18 and 19 for standard and warranty contracts, respectively.

Considering all costs that go into the construction, quality checks, and administration of HMA pavement contracts, standard HMA pavements cost $49.08 per ton, and warranted HMA pavements cost $40.65 per ton. Warranted HMA pavements cost approximately $8 per ton, or 17%, less than non-warranted HMA pavements.

Table 18. Total Unit Costs for HMA Pavements Constructed Under Standard Contracts

Item	Cost per ton
Average Bid Costs	$47.13
Field staff time	$0.22
Pavement Repair	$1.73
TOTAL	**$49.08**

Table 19. Total Unit Costs for HMA Pavements Constructed Under Warranty Contracts

Item	Cost per ton
Average Bid Costs	$40.52
Central Office Coordination	$0.041
Regional Office Coordination	$0.052
Warranty Committee Meetings	$0.010
Pavement Distress Monitoring	$0.018
Conflict Resolution	$0.010
TOTAL	**$40.65**

5.4.2 PCC Pavements

A total cost per SY per inch value was calculated based on the bid costs, WisDOT staff time costs, and pavement repair costs calculated for warranted PCC pavements in Sections 5.1 through 5.3. Average bid costs were calculated based on the bid costs from the 2006, 2007, and 2008 construction seasons. The average cost per SY per inch value obtained was then multiplied by ten to assume a 10-inch PCC pavement. The unit cost summaries are presented in Tables 20 and 21 for standard and warranty contracts, respectively.

Considering all costs that go into the construction, quality checks, and administration of PCC pavement contracts, a typical 10-inch PCC pavement constructed with a standard contract costs $23.50 per SY. The average cost for a typical 10-inch warranted PCC pavement is $20.29 per SY. This analysis shows that warranted PCC pavements cost less than non-warranted PCC pavements; however, the statistical analysis noted in Section 5.2.2 did not indicate a statistical difference in cost between the two contracting types.

Table 20. Total Unit Costs for PCC Pavements Constructed Under Standard Contracts

Item	Cost per SY (10-inch pavement)
Average Bid Costs	$23.44
Field staff time	$0.06
Pavement Repair	$0
TOTAL	**$23.50**

Table 21. Total Unit Costs for PCC Pavements Constructed Under Warranty Contracts

Item	Cost per SY (10-inch pavement)
Average Bid Costs	$20.22
Central Office Coordination	$0.022
Regional Office Coordination	$0.028
Pavement Distress Monitoring	$0.010
Conflict Resolution	$0.010
TOTAL	**$20.29**

6. Industry Perspectives

Both the HMA and PCC paving industries continue to support collaboration with WisDOT on all issues relating to the pavement warranty program. The Department welcomes the industries' involvement, as common understanding of the warranty program's goals and progress results in fewer problems during and after construction. Each paving industry was asked for their thoughts on the state of the warranty program. These perspectives are summarized in the following sections. The industries' perspectives do not necessarily reflect the Department's viewpoints.

6.1 HMA Paving Industry Perspective *[11]*

Possible reasons for increased performance of warranted over non-warranted pavements:

- Contractors feel more ownership of warranted pavements and place a greater emphasis on monitoring materials and placement techniques.
- Because the contractor is able to define most aspects of the paving process, changes that could improve future performance can be made during construction without approval from the Department. Under standard contracts, these changes would only be made if Department approval and/or contract modifications were obtained.
- More time and effort is spent customizing materials used for warranted pavements.
- In some cases, contractors opt to use higher-grade binders and/or a higher E-mix design than would normally be specified by the Department for a non-warranted pavement.

Possible reasons for lower bid costs on warranted contracts:

- Mix designs are more cost-effective when the contractor has the control to define and modify them.
- The paving operation is more efficient under warranty construction. For instance, if a change is necessary in the field, the contractor does not have to halt construction and wait for WisDOT approval. These time savings result in cost savings to the contractor, which are anticipated and passed to the Department as lower bid costs.
- Contractors can obtain more cost-competitive contracts for the crack sealing operation.
- Prior to bidding, contractors can predict more precisely the amount of binder required for a warranty project. Bid costs for standard contracts reflect the engineer's estimate of quantities for binder, which do not reflect the potential for binder savings due to use of recycled asphalt materials.
- QMP testing is more efficient under warranty construction. Depending on how smoothly warranted pavement production is running, the contractor might increase or reduce testing frequencies. Under standard contracts, testing occurs at a specified frequency, regardless of how production is running.

Other observations from the HMA paving industry:

- The HMA industry is supportive of the warranty program.
- While innovation is a goal for both industry and the Department, contractors are cautious about trying new methods that deviate too far from the Department's standard specifications. This is to

avoid a negative perception that might occur if a new method results in decreased performance or a failure.

6.2 PCC Paving Industry Perspective *[12]*

The bonding requirement for PCC pavement warranties has been an issue with the warranty program in the past and could continue to be problematic if WisDOT expands the PCC warranty program. The following issues were noted:

- Bonding agencies are not completely supportive of providing bonds for pavement warranties. Bonds are supplied now because a precedent has been set.
- If the PCC pavement warranty program expands, smaller companies' bond capacities may be exceeded. If these companies can no longer bid on warranty projects, the competitive bidding environment would be compromised.
- Little potential exists to lengthen the warranty period for PCC pavements because the resultant increase in bond requirement would be hindered by both issues bulleted above.

A potential solution to some of these issues might be to create a bonding system where a portion of the bond is released annually if good pavement performance continues. This could relieve both the burden on contracting companies' bonding capacities and the ultimate risk to the bonding companies.

There has been less contractor innovation than initially predicted for the construction of PCC warranted pavements. Because the contractor will be responsible for the pavement's performance, he is more inclined to use tried-and-true methods that he knows will result in long-term performance.

7. Conclusions

- During the 12-year analysis period, warranted Type 1 pavements had lower distress levels and better ride quality than non-warranted Type 1 pavements. For non-warranted and warranted Type 1 pavements at age 12, PDI values were 43 and 18, respectively, and IRI values were 1.7 and 1.22 m/km, respectively.

- For Type 3 pavements, a statistically significant difference was not observed between the PDI and IRI for non-warranted and warranted pavements for most years of the 10-year analysis period. Linear regression models show that Type 3 pavements perform at approximately the same level, regardless of contract type. Type 3 pavements should continue to be monitored to determine if the use of a warranty provision results in a change in pavement performance over time.

- During the nine-year analysis for Type 8 pavements, the difference in PDI was not statistically significant between non-warranted and warranted pavements. There was a statistical difference in IRI at several pavement ages, but no conclusive trend was evident. All Type 8 pavements included in the analysis performed well, regardless of contract type. The expected initial service life of PCC pavements is at least 25 years *[13]*, and significant distresses are not anticipated to occur prior to that time. It is therefore difficult to determine from the nine years of available data whether warranted Type 8 pavements provide enhanced performance compared to non-warranted pavements.

- Bid cost data for HMA pavement construction contracts showed a statistically significant difference between non-warranted and warranted costs in 2005, 2006 and 2007, and the unpaired t-test result for 2008 was very close to showing a statistical difference. Median bid costs for warranted HMA pavements were lower than for non-warranted HMA pavements from 2005 to 2008. In 2008, the Department's average total cost per ton, including materials, staff time and pavement repair, was $49.08 for non-warranted HMA pavements and $40.65 for warranted HMA pavements.

- No statistical difference was noted in bid costs for non-warranted and warranted PCC pavements. Relatively few warranted PCC pavements were constructed between 1999 and 2008, and their costs were similar to PCC pavements constructed under standard contracts. Administrative costs for PCC warranties were approximately $0.07/SY, while field staff time for standard PCC paving contracts cost approximately $0.06/SY. These minimal costs offset each other and further indicate that the cost to the Department for non-warranted and warranted PCC pavement construction is approximately equal.

- The HMA and PCC pavement industries have played a major role in the development and maintenance of the Department's pavement warranty program. This collaboration has provided a benefit, as both the Department and the industries are supportive of the goals required for the warranty program's success.

- The pavement warranty program is a cost-effective tool for the Department for HMA pavements. There are not enough performance or cost data points to make that determination for PCC pavements.

8. Recommendations

- Given the improved performance of Type 1 warranted pavements and the lower total cost per ton of warranted pavements overall, continued use of warranty contracts is recommended for HMA paving projects. Current guidelines for selection of projects suitable for warranty should continue to be applied.
- A benefit of warranting PCC pavements has not yet been realized, as a statistical difference was not noted for performance nor for cost in the comparison of non-warranted and warranted Type 8 pavements. In addition, the five-year warranty term might not be a suitable proving period for PCC pavements, which typically have initial service lives in excess of 25 years. Alternative performance-based specifications should be further investigated to enhance PCC pavement performance and reduce life cycle costs.
- Comprehensive warranty program evaluations should be performed at 5-year intervals to determine whether the results of this study remain the same or change in the future.

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Appendix A

HMA Warranty Specification
5-Year New Construction, Reconstruction, and Structural Overlay

Warranted HMA Pavement Mainline, Item 460.1905.S; Warranted HMA Pavement Ancillary, Item 460.1955.S.

A Description

A.1 General

(1) Construct and warrant HMA pavement conforming to the lines and grades shown on the plans as directed by the engineer. Establish the job mix formula, select all materials and be responsible for the pavement performance and warranty work on the finished pavement for the warranty period defined in Section A.4. The provisions of the warranty work apply to all HMA mixtures placed under the Warranted HMA Pavement bid items. For the Warranted HMA Pavement bid items, sections 450 through 490 of the standard specifications are deleted with the exception of subsection 450.3.2.9.

A.2 Warranted HMA Pavement Mainline

(1) This bid item consists of all HMA pavement placed on both the mainline traveled way and its adjacent mainline shoulders in accordance to the typical finished sections.

A.3 Warranted HMA Pavement Ancillary

(1) This bid item consists of all HMA pavement placed on side roads, private and public entrances, ramps, tapers, turn lanes, the new pavement placed within 50 feet (15 m) of a bridge deck, and other locations not described as Warranted HMA Pavement Mainline.

A.4 Warranty Period

(1) The warranty period will begin when the warranted pavement is completed and opened to public traffic. The warranty period will end on November 1 of the year five years after the year during which the warranted pavement was completed and opened to public traffic.

B Warranty

(1) The necessary warranty bond for the warranted HMA pavement items will be in effect for the entire warranty period defined in Section A.4. The bonding company must have an AM. Best rating of "A-" or better and the contractor will provide proof of the bond commitment before execution of the contract.

(2) The warranty bond will be $_____ for the warranted HMA pavement. The bond will insure the proper and prompt completion of required warranty work for the duration of the warranty period, including payments for all labor, equipment and materials used according to this specification.

(3) Provide documentation that the warranty bond will remain in effect for the duration of the warranty period. For the first year of the warranty bond, provide documentation that the contract bond, which remains in effect for one year beyond the completion of the project, will also include warranty work, as described in Section G.

(4) If a subcontractor places the warranted pavement, the subcontractor may provide the warranty bond for the remaining warranty period after expiration of the contract bond. If the subcontractor does provide the bond, it shall be a dual obligee bond, naming the contractor and the Wisconsin Department of Transportation as obligees. The subcontractor will provide documentation that the warranty bond will remain in effect for the portion of the warranty period after expiration of the contract bond.

(5) Failure of the contractor, subcontractor or its surety to issue or renew the warranty bond will be considered a default and will result in forfeiture of the face amount of the bond to the department.

(6) All warranty work will be as prescribed in Section G. At the end of the warranty period, the contractor will be relieved of the responsibility to perform further warranty work, provided all previous warranty work has been completed.

C Quality Control and Documentation

(1) Prior to construction, provide the engineer with a Quality Control Plan. The Quality Control Plan shall outline the contractor's material and construction control processes. At a minimum the plan shall include each of the following:

1. A list of the quality control tests that will be used to control the material and construction quality.
2. The quality control sampling, testing and documentation frequencies.
3. The HMA pavement job mix formulas (JMF) planned for the project and the method used to develop the JMF. Submit the JMF for tracking purposes according to the department's test method 1559.
4. A list of project materials.

(2) At the completion of the project, provide documentation of the project to the engineer. This documentation shall consist of all quality control test results performed to control materials and construction, and any changes made to typical widths and depths of subgrade, subbase, base and surface.

D Conflict Resolution Team

(1) The Conflict Resolution Team will have the final authority to make decisions if a conflict occurs. The team will resolve disputes by a majority vote. The team will consist of two contractor representatives, two department (region and statewide bureaus) representatives and a third party mutually agreed upon by both the department and the contractor. The cost of the third party will be equally shared between the department and the contractor. The team will reference the department's Pavement Surface Distress Survey Manual in the case that a distress survey of the pavement is needed for the resolution of a dispute.

E Pavement Distress Surveys, Pavement Evaluations and Contractor Monitoring

E.1 Warranted Mainline HMA Pavement Distress Surveys

(1) The department's Bureau of State Highway Programs, Data Management Section, Pavement Data Unit will conduct warranted mainline HMA pavement distress surveys. The region or contractor may also perform visual pavement distress surveys of the mainline pavement at any time. The department's Pavement Surface Distress Survey Manual will be used to determine and measure the different types of distress.

(2) The Pavement Data Unit will conduct mainline pavement distress surveys according to the following schedule, at a minimum:

1. An initial mainline pavement distress survey, to occur during the first year of the warranty period.
2. A final mainline pavement distress survey, to occur during the final year of the warranty period.
3. During the remaining years of the warranty period, the Pavement Data Unit will conduct mainline pavement distress surveys according to the normal surveying cycle of the unit. The unit's normal surveying cycle is dependent on the location of the highway.

(3) The Pavement Data Unit will conduct additional mainline pavement distress surveys if requested by the region.

(4) Mainline pavement distress surveys will be conducted as follows. The mainline pavement will be divided into nominal one-mile sections, using the department's reference point location procedure for division of the highway system. Two 0.1-mile segments in each mile will be evaluated for pavement distress. One of the segments evaluated will be between 0.3 and 0.4 miles from the start of the one-mile section. The department will randomly select the second 0.1-mile segment and evaluate this segment in all subsequent surveys.

(5) If areas other than the surveyed segments are suspected of meeting or exceeding a threshold level as defined in Section F, the region may request that the Pavement Data Unit perform a distress survey in additional segments of the project. In this case, the department will divide the entire mainline pavement into 0.1-mile segments and conduct a distress survey in any, or all, segment(s), as requested.

(6) All mainline pavement distress survey results will be made available for access by the region, statewide bureaus, contractor and FHWA.

(7) If at any point during the warranty period a threshold level as defined in Section F is met or exceeded in the mainline pavement and the contractor agrees with the validity of the distress survey results, the contractor will remedy the distress. Remedial work shall be performed according to Section G. If a threshold level is met in the mainline pavement and the contractor does not agree with the validity of the distress survey results, the need for remedial work, or the type of remedial work requested, written

notification of the dispute will be made to the engineer. The Conflict Resolution Team will resolve the dispute.

E.2 Warranted Ancillary HMA Pavement Evaluations

(1) The department or contractor may review and evaluate the warranted ancillary HMA pavement at any time during the warranty period. The department's Pavement Surface Distress Survey Manual will be used to determine and measure the different types of distress. The ancillary pavement will be evaluated for performance in regards to its intended purpose.

(2) If at any point during the warranty period remedial work is required in the ancillary pavement and the contractor agrees with the need for remedial work, the contractor will remedy the distress. Remedial work shall be performed according to Section G. If the contractor does not agree with the need for remedial work or the type of remedial work requested, written notification of the dispute will be made to the engineer. The Conflict Resolution Team will resolve the dispute.

E.3 Warranted Mainline and Ancillary HMA Pavement Evaluation, Fifth Year

(1) In the fifth year of the warranty period, a region and a contractor representative will, together, review and evaluate the performance of the warranted mainline and ancillary HMA pavement. All warranted pavement will be evaluated for performance in regards to its intended purpose.

(2) If both the department representative and the contractor representative agree on the pavement's performance and remedial work is required, the contractor will remedy the distress. If the two evaluators are not in agreement on the need for or type of remedial work, the Conflict Resolution Team will resolve the dispute.

E.4 Contractor Monitoring

(1) During the warranty period, the contractor may monitor the pavement using nondestructive procedures. Coring, milling or other destructive procedures may not be performed by the contractor without approval of the engineer in accordance to the permit requirements of Section G.

F Table of Distress Types, Threshold Levels and Remedial Action

(1) The department will include each of the distress types listed below in the mainline pavement surveys. The table lists the remedial action required for each distress type when the corresponding threshold level criterion is met.

DISTRESS TYPE	THRESHOLD LEVELS	REMEDIAL ACTION [1]
Alligator Cracking[2]	≥1% of the area in a segment.	Remove and replace distressed layer(s). The removal area shall be equal to 150% of the distressed surface to a depth not to exceed the warranted pavement.

DISTRESS TYPE	THRESHOLD LEVELS	REMEDIAL ACTION [1]
Block Cracking	≥1% of the area in a segment.	Remove and replace distressed layer(s). The removal area shall be equal to 110% of the distressed surface to a depth not to exceed the warranted pavement.
Edge Raveling	≥10% of the segment length.	Remove and replace distressed layer(s). The removal area shall be equal to 110% of the distressed surface to a depth not to exceed the warranted pavement.
Flushing	≥20% of the segment length.	Remove and replace distressed surface mixture full depth.
Longitudinal Cracking (shoulder line cracking is excluded from the segment measurements)	>1000 linear feet for cracks which average greater than ½ inch in width	Rout and seal all cracks with rubber crack filling material, or agreed upon equal.
	>1000 linear feet with 25% of the linear feet having band cracking or dislodgement.	If band cracking or dislodgement is less than or equal to 1000 feet, place a patch 2 feet in width and 2 feet longer than the crack length, for the affected depth or agreed upon equal. If over 1000 feet, remove pavement and replace for the affected depth.
Longitudinal Distortion	≥1% of the segment length.	Remove and replace distressed layer(s). The removal area shall be equal to 110% of the distressed surface to a depth not to exceed the warranted pavement.
Rutting [3]	≥0.25 inches in depth, <0.5 inches in depth.	Remove ruts by milling surface with fine-tooth mill, overlaying, or micro surfacing.
	≥0.5 inches in depth.	Remove and replace surface layer.

DISTRESS TYPE	THRESHOLD LEVELS	REMEDIAL ACTION [1]
Surface Raveling	≥Slight (for segregation, a slight rating is three or more segregated areas per segment. A segregated area is 30 square feet or more in size).	Apply a chip seal coat or partial depth repair.
Transverse Cracking [4]	When the warranted HMA pavement is constructed over a granular base course material, >25 cracks per segment which have a average open width greater than ½ inch.	Rout and seal all cracks with a rubberized crack filler, or approved equal.
	When the warranted HMA pavement is constructed over concrete pavement, >50 cracks per segment which have an average open width greater than ½ inch.	Rout and seal all cracks with a rubberized crack filler, or approved equal.
	>25 cracks per segment with 25% of the linear feet of cracking having band cracking or dislodgement.	Remove and replace distressed layer(s) to a depth not to exceed the warranted pavement.
Transverse Distortion	≥1% of the segment length.	Remove and replace distressed layer(s). The removal area shall be equal to 110% of the distressed surface to a depth not to exceed the warranted pavement.
Patching [2], [4]	≥150 linear feet of patching per segment (excluding longitudinal cracking remedial action).	Remove and replace the surface layer or place a minimum 1¼" overlay.

DISTRESS TYPE	THRESHOLD LEVELS	REMEDIAL ACTION [1]
Potholes, slippage areas and other disintegrated areas.	Any presence of this type of distress.	Remove and replace the distressed area(s). The removal area will be equal to 150% of the distressed area to a depth not to exceed the warranted pavement.

[1] No remedial action shall be taken that changes the lines and grades as constructed without the approval of the engineer.

[2] Rutting depth and length will be initially identified using standard WisDOT procedures. If rutting depth meets the threshold criterion, the final rut depth and length will be established by a method mutually agreed upon by the contractor and the department.

[3] When the warranted HMA pavement is constructed over a granular base course material, the contractor will be relieved of the responsibility for remedial action for Alligator Cracking if the area in question is of proper thickness (not thinner than 0.5 inches from plan thickness) and the average recovered penetration of the surface course asphalt cement is above 30 and one (or more) of the following are true:

1. The base is plan thickness minus 2.0 inches or thinner or
2. The subgrade density is less than 90% of optimum.

[4] When the warranted HMA pavement is constructed over concrete pavement, the contractor will be relieved of the responsibility for remedial action for Transverse Cracking and Patching of the pavement if the area in question is of proper thickness (not thinner than plan thickness minus 0.5 inches) and the concrete pavement below the warranted pavement has experienced a blow up, joint disintegration, or similar failure.

G Warranty Work

(1) During the warranty period, perform warranty work at no additional cost to the department. Warranty work consists of remedial work, elective/preventive maintenance and the required fifth-year crack sealing operation. Maintain insurance for performing warranty work as specified in 107.26 of the standard specifications throughout the warranty period.

(2) During warranty work operations, traffic control will be as specified in section 643 of the standard specifications and all will conform to Part 6 of the Wisconsin Manual on Uniform Traffic Control Devices.

(3) If warranty work necessitates a corrective action to the adjacent lane(s) or shoulders, or both, that additional corrective action will be the responsibility of the contractor.

(4) If warranty work causes damage to, or removal of, the pavement markings, replacement of the pavement markings will be the responsibility of the contractor. Replace the pavement markings in accordance to subsections 646.1 through 646.3 of the standard specifications. Use replacement materials of the same kind specified in the original contract unless mutually agreed otherwise by the engineer and the contractor.

(5) The contractor will not be held responsible for distresses that are caused by factors beyond the control of the contractor. Repairs of these distresses will be the responsibility of the department. The area defined by the length of the pavement repair and the width of the mainline traveled way and its adjacent mainline shoulder will be excluded from the warranty.

(6) All warranty work including, but not limited to, remedial work, elective/preventive maintenance and the fifth-year crack sealing operation shall require a permit from the region. The region will provide contact information for obtaining a permit to the contractor.

(7) Document all warranty work performed. Use the department's form DT2305 to annually provide this information to the region.

G.1 Remedial Work

(1) Remedial work will be based on the results of the mainline pavement distress surveys or the ancillary pavement evaluations. Perform remedial work in the same calendar year that the threshold distresses were recorded, unless determined otherwise by the engineer. Remedial work to be performed and materials to be used will be the joint decision of the contractor and the engineer. The contractor will not be responsible for damages that result from coring, milling or other destructive procedures conducted by the department.

(2) For mainline pavement segments that meet the distress threshold level criterion of the table in Section F, perform the remedial work prescribed in the remedial action column of the table. Perform the remedial work in all segments of the project where a threshold level is met. Apply the remedial work to the entire segment(s) and the adjacent lanes and HMA shoulders unless mutually agreed otherwise by the engineer and the contractor.

(3) For distressed ancillary pavement and distressed mainline shoulders not adjacent to distressed mainline pavement, perform remedial work as mutually determined by the contractor and the engineer.

(4) If, at anytime during the warranty period, 30 percent or more of the project segments require or have received remedial action, then perform remedial action on the entire project as mutually determined by the contractor and the engineer.

(5) The contractor will have the first option to perform the remedial work. If, in the opinion of the engineer, the problem requires immediate attention for the safety of the traveling public, and the contractor cannot perform the remedial work within eight hours, the engineer may have the remedial work performed by other forces and at the contractor's expense. Remedial work performed by other forces will not alter the requirements, responsibilities, or obligations of the warranty.

G.2 Elective/Preventive Maintenance

(1) Elective/preventive maintenance will be a contractor option. The contractor and the engineer will coordinate elective/preventive maintenance to be performed and materials to be used.

G.3 Required Fifth-Year Crack Sealing Operation

(1) During the fifth year of warranted pavement service and prior to the end of the warranty period, rout and seal cracks in the mainline and ancillary pavement as follows:

CRACK WIDTH	REQUIRED ACTION(S)
< ¼-inch	None
≥ ¼-inch to < ½-inch	1. Rout a uniform reservoir with a 1:1 width to depth ratio and a final width equal to the crack width plus 1/8 inch. 2. Clean with compressed air so that all vegetation, loose dirt and foreign material are removed. 3. Seal with a rubberized crack filler such that it is placed flush to 1/8 inch below the pavement surface.
≥ ½-inch	1. Rout at contractor's option. 2. Clean with compressed air so that all vegetation, loose dirt and foreign material are removed. 3. Seal with a rubberized crack filler such that it is placed flush to 1/8 inch below the pavement surface.

(2) Perform the crack sealing operation when the pavement temperature is 40° F or higher. Ensure that cracks are free of moisture prior to sealing. Allow sealant to cure before opening to traffic. Remove all routed debris from the road surface.

H Measurement

(1) The department will measure the Warranted HMA Pavement bid items by the ton, based on the quantity of mixture placed, completed and accepted. The contractor will present certified records of shipment for the quantities placed under this special provision.

(2) The department will measure Warranted HMA Pavement Mainline as specified above up to a maximum of 105% of the plan quantity.

(3) The department will measure Warranted HMA Pavement Ancillary as specified above up to a maximum of 105% of the plan quantity, or the quantity mutually agreed to by the contractor and engineer.

I Payment

(1) The department will pay for measured quantities at the contract unit price under the following bid items:

ITEM NUMBER	DESCRIPTION	UNIT
460.1905.S	Warranted HMA Pavement Mainline	Ton
460.1955.S	Warranted HMA Pavement Ancillary	Ton

(2) Payment is full compensation for furnishing, preparing, hauling, mixing and placing all materials, including asphaltic materials; for compacting mixtures; for preparing the foundation unless otherwise provided; for the warranty bond(s) and warranty work; for providing the Quality Control Plan and required documentation; for performing traffic control; and for furnishing all labor, tools, equipment, and incidentals necessary to complete the contract work.

(090208) 460-001

Appendix B

HMA Warranty Specification
3-Year Functional Overlay

Warranted HMA Pavement Functional Overlay Mainline, Item SPV.0195.461; Warranted HMA Pavement Functional Overlay Ancillary, Item SPV.0195.462.

A Description

A.1 General

(1) Construct and warrant HMA pavement conforming to the lines and grades shown on the plans as directed by the engineer. Establish the job mix formula, select all materials and be responsible for the pavement performance and warranty work on the finished pavement for the warranty period defined in Section A.4. The provisions of the warranty work apply to all HMA mixtures placed under the Warranted HMA Pavement Functional Overlay bid items. For the Warranted HMA Pavement Functional Overlay bid items, sections 450 through 490 of the standard specifications are deleted with the exception of subsection 450.3.2.9.

A.2 Warranted HMA Pavement Functional Overlay Mainline

(1) This bid item consists of all HMA pavement placed on both the mainline traveled way and its adjacent mainline shoulders in accordance to the typical finished sections.

A.3 Warranted HMA Pavement Functional Overlay Ancillary

(1) This bid item consists of all HMA pavement placed on side roads, private and public entrances, ramps, tapers, turn lanes, the new pavement placed within 50 feet (15 m) of a bridge deck, and other locations not described as Warranted HMA Pavement Functional Overlay Mainline.

A.4 Warranty Period

(1) The warranty period will begin when the warranted pavement is completed and opened to public traffic. The warranty period will end on November 1 of the year three years after the year during which the warranted pavement was completed and opened to public traffic.

B Warranty

(1) The necessary warranty bond for the warranted HMA pavement items will be in effect for the entire warranty period defined in Section A.4. The bonding company must have an AM. Best rating of "A-" or better and the contractor will provide proof of the bond commitment before execution of the contract.

(2) The warranty bond will be $_____ for the warranted HMA pavement. The bond will insure the proper and prompt completion of required warranty work for the duration of the warranty period, including payments for all labor, equipment and materials used according to this specification.

(3) Provide documentation that the warranty bond will remain in effect for the duration of the warranty period. For the first year of the warranty bond, provide documentation that the contract bond, which remains in effect for one year beyond the completion of the project, will also include warranty work, as described in Section G.

(4) If a subcontractor places the warranted pavement, the subcontractor may provide the warranty bond for the remaining warranty period after expiration of the contract bond. If the subcontractor does provide the bond, it shall be a dual obligee bond, naming the contractor and the Wisconsin Department of Transportation as obligees. The subcontractor will provide documentation that the warranty bond will remain in effect for the portion of the warranty period after expiration of the contract bond.

(5) Failure of the contractor, subcontractor or its surety to issue or renew the warranty bond will be considered a default and will result in forfeiture of the face amount of the bond to the department.

(6) All warranty work will be as prescribed in Section G. At the end of the warranty period, the contractor will be relieved of the responsibility to perform further warranty work, provided all previous warranty work has been completed.

C Quality Control and Documentation

(1) Prior to construction, provide the engineer with a Quality Control Plan. The Quality Control Plan shall outline the contractor's material and construction control processes. At a minimum the plan shall include each of the following:

1. A list of the quality control tests that will be used to control the material and construction quality.
2. The quality control sampling, testing and documentation frequencies.
3. The HMA pavement job mix formulas (JMF) planned for the project and the method used to develop the JMF. Submit the JMF for tracking purposes according to the department's test method 1559.
4. A list of project materials.

(2) At the completion of the project, provide documentation of the project to the engineer. This documentation shall consist of all quality control test results performed to control materials and construction, and any changes made to typical widths and depths of subgrade, subbase, base and surface.

D Conflict Resolution Team

(1) The Conflict Resolution Team will have the final authority to make decisions if a conflict occurs. The team will resolve disputes by a majority vote. The team will consist of two contractor representatives, two department (region and statewide bureaus) representatives and a third party mutually agreed upon by both the department and the contractor. The cost of the third party will be equally shared between the department and the contractor. The team will reference the department's Pavement Surface Distress Survey Manual in the case that a distress survey of the pavement is needed for the resolution of a dispute.

E Pavement Distress Surveys, Pavement Evaluations and Contractor Monitoring

E.1 Warranted Mainline HMA Pavement Distress Surveys

(1) The department's Bureau of State Highway Programs, Data Management Section, Pavement Data Unit will conduct warranted mainline HMA pavement distress surveys. The region or contractor may also perform visual pavement distress surveys of the mainline pavement at any time. The department's Pavement Surface Distress Survey Manual will be used to determine and measure the different types of distress.

(2) The Pavement Data Unit will conduct mainline pavement distress surveys according to the following schedule, at a minimum:

1. An initial mainline pavement distress survey, to occur during the first year of the warranty period.
2. A final mainline pavement distress survey, to occur during the final year of the warranty period.
3. During the remaining year of the warranty period, the Pavement Data Unit will conduct mainline pavement distress surveys according to the normal surveying cycle of the unit. The unit's normal surveying cycle is dependent on the location of the highway.

(3) The Pavement Data Unit will conduct additional mainline pavement distress surveys if requested by the region.

(4) Mainline pavement distress surveys will be conducted as follows. The mainline pavement will be divided into nominal one-mile sections, using the department's reference point location procedure for division of the highway system. Two 0.1-mile segments in each mile will be evaluated for pavement distress. One of the segments evaluated will be between 0.3 and 0.4 miles from the start of the one-mile section. The department will randomly select the second 0.1-mile segment and evaluate this segment in all subsequent surveys.

(5) If areas other than the surveyed segments are suspected of meeting or exceeding a threshold level as defined in Section F, the region may request that the Pavement Data Unit perform a distress survey in additional segments of the project. In this case, the department will divide the entire mainline pavement into 0.1-mile segments and conduct a distress survey in any, or all, segment(s), as requested.

(6) All mainline pavement distress survey results will be made available for access by the region, statewide bureaus, contractor and FHWA.

(7) If at any point during the warranty period a threshold level as defined in Section F is met or exceeded in the mainline pavement and the contractor agrees with the validity of the distress survey results, the contractor will remedy the distress. Remedial work shall be performed according to Section G. If a threshold level is met in the mainline pavement and the contractor does not agree with the validity of the distress survey results, the need for remedial work, or the type of remedial work requested, written

notification of the dispute will be made to the engineer. The Conflict Resolution Team will resolve the dispute.

E.2 Warranted Ancillary HMA Pavement Evaluations

(1) The department or contractor may review and evaluate the warranted ancillary HMA pavement at any time during the warranty period. The department's Pavement Surface Distress Survey Manual will be used to determine and measure the different types of distress. The ancillary pavement will be evaluated for performance in regards to its intended purpose.

(2) If at any point during the warranty period remedial work is required in the ancillary pavement and the contractor agrees with the need for remedial work, the contractor will remedy the distress. Remedial work shall be performed according to Section G. If the contractor does not agree with the need for remedial work or the type of remedial work requested, written notification of the dispute will be made to the engineer. The Conflict Resolution Team will resolve the dispute.

E.3 Warranted Mainline and Ancillary HMA Pavement Evaluation, Third Year

(1) In the third year of the warranty period, a region and a contractor representative will, together, review and evaluate the performance of the warranted mainline and ancillary HMA pavement. All warranted pavement will be evaluated for performance in regards to its intended purpose.

(2) If both the department representative and the contractor representative agree on the pavement's performance and remedial work is required, the contractor will remedy the distress. If the two evaluators are not in agreement on the need for or type of remedial work, the Conflict Resolution Team will resolve the dispute.

E.4 Contractor Monitoring

(1) During the warranty period, the contractor may monitor the pavement using nondestructive procedures. Coring, milling or other destructive procedures may not be performed by the contractor without approval of the engineer in accordance to the permit requirements of Section G.

F Table of Distress Types, Threshold Levels and Remedial Action

(1) The department will include each of the distress types listed below in the mainline pavement surveys. The table lists the remedial action required for each distress type when the corresponding threshold level criterion is met.

DISTRESS TYPE	THRESHOLD LEVELS	REMEDIAL ACTION [1]
Alligator Cracking[2]	≥1% of the area in a segment.	Remove and replace distressed layer(s). The removal area shall be equal to 150% of the distressed surface to a depth not to exceed the warranted pavement.

DISTRESS TYPE	THRESHOLD LEVELS	REMEDIAL ACTION [1]
Flushing	≥20% of the segment length.	Remove and replace distressed surface mixture full depth.
Non-Reflective Longitudinal Cracking[3]	>300 linear feet for cracks that average greater than ½ inch in width.	Rout and seal all cracks with rubber crack filling material, or agreed upon equal.
Longitudinal Cracking[3]	>300 linear feet with ½-inch wide band cracking or dislodgement within 1 foot of the longitudinal crack.	Remove pavement and replace for the affected depth.
Rutting[2], [4]	≥0.25 inches in depth and <0.5 inches in depth.	Remove ruts by milling surface with fine-tooth mill, overlaying, or micro surfacing.
	≥0.5 inches in depth.	Remove and replace upper layer.
Surface Raveling	≥Slight (for segregation, a slight rating is three or more segregated areas per segment. A segregated area is 30 square feet or more in size).	Apply a chip seal coat or partial depth repair.
Potholes, slippage areas and other disintegrated areas.	Any presence of this type of distress.	Remove and replace the distressed area(s). The removal area will be equal to 150% of the distressed area to a depth not to exceed the warranted pavement.

[1] No remedial action shall be taken that changes the lines and grades as constructed without the approval of the engineer.

[2] The contractor will be relieved of the responsibility for remedial action for Alligator Cracking and structural Rutting if the area in question is of proper thickness (not thinner than 0.5 inches from plan thickness) and the average recovered penetration of the upper layer asphalt cement is above 30.

[3] Shoulder line cracking is excluded from the segment measurements.

[4] Rutting depth and length will be initially identified using standard WisDOT procedures. If rutting depth meets the threshold criterion, the final rut depth and length will be established by a method mutually agreed upon by the contractor and the department.

G Warranty Work

(1) During the warranty period, perform warranty work at no additional cost to the department. Warranty work consists of remedial work, elective/preventive maintenance and the required crack sealing operation. Maintain insurance for performing warranty work as specified in 107.26 of the standard specifications throughout the warranty period.

(2) During warranty work operations, traffic control will be as specified in section 643 of the standard specifications and all will conform to Part 6 of the Wisconsin Manual on Uniform Traffic Control Devices.

(3) If warranty work necessitates a corrective action to the adjacent lane(s) or shoulders, or both, that additional corrective action will be the responsibility of the contractor.

(4) If warranty work causes damage to, or removal of, the pavement markings, replacement of the pavement markings will be the responsibility of the contractor. Replace the pavement markings in accordance to subsections 646.1 through 646.3 of the standard specifications. Use replacement materials of the same kind specified in the original contract unless mutually agreed otherwise by the engineer and the contractor.

(5) The contractor will not be held responsible for distresses that are caused by factors beyond the control of the contractor. Repairs of these distresses will be the responsibility of the department. The area defined by the length of the pavement repair and the width of the mainline traveled way and its adjacent mainline shoulder will be excluded from the warranty.

(6) All warranty work including, but not limited to, remedial work, elective/preventive maintenance and the required crack sealing operation shall require a permit from the region. The region will provide contact information for obtaining a permit to the contractor.

(7) Document all warranty work performed. Use the department's form DT2305 to annually provide this information to the region.

G.1 Remedial Work

(1) Remedial work will be based on the results of the mainline pavement distress surveys or the ancillary pavement evaluations. Perform remedial work in the same calendar year that the threshold distresses were recorded, unless determined otherwise by the engineer. Remedial work to be performed and materials to be used will be the joint decision of the contractor and the engineer. The contractor will not be responsible for

damages that result from coring, milling or other destructive procedures conducted by the department.

(2) For mainline pavement segments that meet the distress threshold level criterion of the table in Section F, perform the remedial work prescribed in the remedial action column of the table. Perform the remedial work in all segments of the project where a threshold level is met. Apply the remedial work to the entire segment(s) and the adjacent lanes and HMA shoulders unless mutually agreed otherwise by the engineer and the contractor.

(3) For distressed ancillary pavement and distressed mainline shoulders not adjacent to distressed mainline pavement, perform remedial work as mutually determined by the contractor and the engineer.

(4) If, at any time during the warranty period, 30 percent or more of the project segments require or have received remedial action, then perform remedial action on the entire project as mutually determined by the contractor and the engineer.

(5) The contractor will have the first option to perform the remedial work. If, in the opinion of the engineer, the problem requires immediate attention for the safety of the traveling public, and the contractor cannot perform the remedial work within eight hours, the engineer may have the remedial work performed by other forces and at the contractor's expense. Remedial work performed by other forces will not alter the requirements, responsibilities, or obligations of the warranty.

G.2 Elective/Preventive Maintenance

(1) Elective/preventive maintenance will be a contractor option. The contractor and the engineer will coordinate elective/preventive maintenance to be performed and materials to be used.

G.3 Required Crack Sealing Operation

(1) For a mainline plan thickness of 2.5 inches or less, perform the crack sealing operation in the second year of the warranty period. For a mainline plan thickness greater than 2.5 inches, perform the crack sealing operation in the third year of the warranty period. Rout and seal cracks in the mainline and ancillary pavement as follows:

CRACK WIDTH	REQUIRED ACTION(S)
< ¼-inch	None
≥ ¼-inch and < ½-inch	1. Rout a uniform reservoir with a 1:1 width to depth ratio and a final width equal to the crack width plus 1/8 inch. 2. Clean with compressed air so that all vegetation, loose dirt and foreign material are removed. 3. Seal with a rubberized crack filler such that it is placed flush to 1/8 inch below the pavement surface.
≥ ½-inch	1. Rout at contractor's option. 2. Clean with compressed air so that all vegetation, loose dirt and foreign material are removed. 3. Seal with a rubberized crack filler such that it is placed flush to 1/8 inch below the pavement surface.

(2) Perform the crack sealing operation when the pavement temperature is 40° F or higher. Ensure that cracks are free of moisture prior to sealing. Allow sealant to cure before opening to traffic. Remove all routed debris from the road surface.

H Measurement

(1) The department will measure the Warranted HMA Pavement Functional Overlay bid items by the ton, based on the quantity of mixture placed, completed and accepted. The contractor will present certified records of shipment for the quantities placed under this special provision.

(2) The department will measure Warranted HMA Pavement Functional Overlay Mainline as specified above up to a maximum of 105% of the plan quantity.

(3) The department will measure Warranted HMA Pavement Functional Overlay Ancillary as specified above up to a maximum of 105% of the plan quantity, or the quantity mutually agreed upon by the contractor and engineer.

I Payment

(1) The department will pay for the measured quantity at the contract unit price under the following bid item.

ITEM NUMBER	DESCRIPTION	UNIT
SPV.0195.461	Warranted HMA Pavement Functional Overlay Mainline	Ton
SPV.0195.462	Warranted HMA Pavement Functional Overlay Ancillary	Ton

(2) Payment is full compensation for furnishing, preparing, hauling, mixing and placing all materials, including asphaltic materials; for compacting mixtures; for preparing the foundation unless otherwise provided; for the warranty bond(s) and warranty work; for providing the Quality Control Plan and required documentation; for performing traffic control; and for furnishing all labor, tools, equipment, and incidentals necessary to complete the contract work.

Appendix C

PCC Warranty Specification
5-Year New Construction

Concrete Pavement (Thickness) Warranted, Item SPV.0180.01
A Description
This special provision describes construction of warranted concrete pavement in conformance with the lines and grades shown on the plans as directed by the engineer and as hereinafter provided.

The contractor will be responsible for the pavement performance, and shall warranty the work for the finished roadway for a period of five (5) years following completion of the concrete pavement and opening to public traffic.

The provisions of the warranty work will apply to all concrete mixtures placed as mainline pavement including integrally placed shoulders, curb and curb and gutter.

Sections 415 and 501 of the Standard Specifications are deleted in entirety, except for the following Subsections: 415.2, Materials; 415.3.2, Foundation; 415.3.11.6, Final Surface Finish; 415.3.11.8.3, Pavement Grinding and Removal; 415.3.18, Tolerance in Pavement Thickness; and 501.2 Material (except 501.2.5.3.4 and 501.2.5.4.4 are deleted).

B Warranty and Insurance
The necessary warranty bond for the concrete pavement items will be in effect for the entire five-year warranty period beginning when the warranted pavement is completed and open to public traffic. The bonding company must have an A.M. Best rating of "A-" or better and the contractor will provide proof of a five-year bond commitment before execution of the contract.

The warranty bond will be $_____ for the warranted concrete pavement. The bond will insure the proper and prompt completion of required warranty work following completion of the pavement, including payments for all labor, equipment, and materials used according to this specification.

The contract bond, which remains in effect for one year beyond the completion of the project, will also include warranty work, as described in Section G. For the remaining four-year warranty period, the contractor shall provide documentation that the warranty bond will be provided in one of the following manners:

1. A single-term four-year warranty bond.
2. A two-year renewable, non-cumulative warranty bond for two consecutive terms.

If a subcontractor rather than the contractor places the warranted pavement, the subcontractor performing the warranted work may provide the warranty bond for the remaining four-year warranty period. If a subcontractor does provide the bond, it shall be a dual obligee bond,

naming the contractor and the Wisconsin Department of Transportation as obligees. The subcontractor warranty bond will be one of the following:

1. A single-term, four-year warranty bond.
2. A two-year renewable, non-cumulative warranty bond for two consecutive terms.

Failure of the contractor, subcontractor or its surety to issue or renew the warranty bond will be considered a default and will result in forfeiture of 20% of the face amount of the bond to the department.

All warranty work will be as prescribed in Section G. At the end of the warranty period, the contractor will be relieved of the responsibility to perform further warranty work, provided all previous warranty work has been completed.

The contractor shall maintain insurance, in the course of performing warranty work, as specified in Section 107.26 of the Standard Specifications throughout the five-year warranty period.

C Quality Control and Documentation

Prior to construction, the contractor will provide the engineer with a Quality Control Plan. The Quality Control Plan shall outline the contractor's material and construction control processes. At a minimum the plan shall include each of the following:

1. A list of the quality control tests that will be used to control the material and construction quality.
2. The quality control sampling, testing and documentation frequencies.
3. The concrete mix design and the method used to develop it.
4. A list of types and sources of materials associated with the warranty work.

Project quality control tests will be provided to the engineer at the end of each week. At the completion of the project, the contractor shall provide documentation of the project quality control to the engineer. This documentation shall consist of all quality control test results used to control materials and construction. The contractor shall supply certification that all concrete produced and placed was in accordance with the mix design as submitted to the engineer.

D Conflict Resolution Team (CRT)

The Conflict Resolution Team will have the final authority to make decisions if a conflict occurs. The team will resolve disputes by a majority vote. The team will consist of two contractor representatives, two department (District & Central Office) representatives, and a third party mutually agreed upon by both the department and the contractor. The cost of the third party will be equally shared between the department and the contractor. The team will receive the department Pavement Surface Distress Survey Training, when it is determined necessary to make a distress survey of the pavement to resolve a dispute. The team members will be appointed at the time of conflict.

E Pavement Distress Surveys and Contractor Monitoring

E.1 Pavement Distress Surveys

The department's Bureau of Highway Construction will conduct distress surveys of the mainline pavement according to the normal surveying cycle of the bureau; or if requested by the

contractor or district. The bureau's surveying cycle is dependent on the location of the highway and the highway classification. The department's Pavement Surface Distress Survey Manual will be used to determine and measure the different types of distress.

The pavement distress surveys will be conducted by dividing the highway system into nominal one-mile sections. Two one-tenth mile segments in each mile will be evaluated for pavement distress. One of the segments evaluated will be between 0.3 and 0.4 miles from the start of the section. The department will randomly select the second one-tenth mile segment. If areas other than the surveyed segments are suspected of meeting or exceeding a threshold level, the department will divide the entire mainline project pavement into 0.1-mile segments and conduct a distress survey in any, or all, segment(s). The distress survey results will be made available to the district, central office, contractor and FHWA. Pavement distress threshold criteria are listed in Section F.

The random one-tenth mile segments will be determined by the department the first year and surveyed through the warranty period. The first survey will identify the segment locations, which will not change thereafter.

If any of the threshold level criteria are met and the contractor does not agree to the validity of the pavement distress survey results, written notification of the dispute will be made to the engineer. The Conflict Resolution Team will resolve the dispute.

E.2 Contractor Monitoring

During the warranty period, the contractor may monitor the pavement using nondestructive procedures. Coring, milling, grinding or other destructive procedures may not be performed by the contractor, without approval of the engineer in accordance with the permit requirements of Section G.

F Table of Distress Types, Threshold Levels, and Remedial Action

The department will include each of the distress types listed below in the mainline pavement survey. The table lists the remedial action required for each distress type when the corresponding threshold level criterion is met.

DISTRESS TYPE	THRESHOLD LEVELS	REMEDIAL ACTION
Slab Breakup *	Transverse cracks or slabs broken into two pieces. More than four cracked slabs per segment (0.1 mile) at three years of age and more than eight slabs per segment at five years of age. A slab is defined as a section of pavement bounded on the ends by joints and on the sides by a centerline joint and/or the edge of pavement. One or more slabs broken into three or more pieces.	Evaluate per the Department's Construction and Materials Manual or alternative method as approved by the engineer or CRT. Remove entire slab and replace.
Distressed Transverse Joints and Cracks**	Distress 2 inches or more in width in the wheel paths on 5 joints or cracks in any one 0.1 mile segment.	If distress is between 2 and 4 inches in width, clean and remove all debris and patch distress with epoxy concrete or alternative method as approved by the CRT. If distress is greater than four inches, repair pavement with a six-foot full-lane width full depth repair or partial depth repair of affected area, or alternative method as approved by the CRT. If distress is less than 2 feet in length and is adjacent to a joint or crack a full depth repair can be performed on the affected area only.

DISTRESS TYPE	THRESHOLD LEVELS	REMEDIAL ACTION
Longitudinal Joint or Crack Distress	Any distress greater than 2 inches in width or any faulting less than ½ inch at the longitudinal joint or crack within a 0.1-mile segment.	If distress is less than four inches in width, clean and remove debris from joint and fill with epoxy concrete or other material as approved by the CRT. If distress is greater than 4 inches in width and one-half the pavement thickness or greater, remove and repair full depth. Repair limits are from transverse joint to transverse joint with the exception of distress less than 2 feet from a joint. If distress is less than one half the pavement thickness in depth, repair should be in accordance with accepted partial depth repair methods.
	Faulted longitudinal joint (greater than ½ inch).	Retrofitting tie bars and diamond grinding affected areas.
Transverse Faulting***	Three or more faulted joints or cracks per station with faulting greater than ¼ inch	Retrofit dowel bars across cracks or repair full depth, repair joints full depth and spot diamond grind if necessary to restore ride

DISTRESS TYPE	THRESHOLD LEVELS	REMEDIAL ACTION
Surface Distress****	Distress is present on greater than 0.5% but less than 10% of the surface area on any one 0.1-mile segment. If distress is less than 1 inch and greater than 10% of the surface area is affected, or distress is greater than 1 inch in depth, regardless of the percentage of surface area affected.	If surface distress is less than 1 inch in depth, distressed area should be milled partial depth repaired partial depth with concrete. Repair full depth or partial depth repair method as approved by the engineer.
Patching	No distressed patches. Any patch present must be in good condition and performing satisfactorily.	Full depth repair and replacement of all patches not in good condition. All remedial action under this item is contingent upon the repair originally being performed by the contractor as part of a remedial action to another distress.

All terms, thresholds, dimensions, survey methods, etc., outlined in the above table are consistent with those set forth in the Wisconsin Department of Transportation' s Pavement Surface Distress Survey Manual, 1993 version.

*The contractor will be relieved of the responsibility for remedial action for slab breakup if it is determined the cracking was the result of factors beyond the contractor's control.

**The contractor will be relieved of the responsibility for remedial action for distressed joints and cracks when the distress is D-cracking, provided the contractor uses an approved WisDOT aggregate source that meets the soundness, wear testing and freeze-thaw testing of the coarse aggregate requirements outlined in subsection 501.2.5.4.3 of the standard specifications.

***The contractor will be relieved of the responsibility for remedial action for transverse joint faulting if the following is true: dowel bars have been installed in accordance with the plan and specifications; and the concrete strengths are at acceptable levels for compressive strength.

****The contractor will be relieved of the responsibility for remedial action for surface distress if the cause is by chemical or fuel spills, vehicle fires, snow plows and other equipment, or mechanical damage.

G Warranty Work
G.1. General

The contractor shall perform warranty work, during the five-year warranty period, at no additional cost to the department. Warranty work consists of remedial work and elective/preventive maintenance.

During warranty work operations, traffic control will be as specified in section 643 of the standard specifications and will conform to Part 6 of the Wisconsin Manual on Uniform Traffic Control Devices.

The contractor will document all warranty work performed and annually provide this information to the Pavement Performance Section of the department's Bureau of Highway Construction.

If warranty work necessitates a corrective action to the pavement markings, raised pavement markers, adjacent lane(s), or shoulders, that additional corrective action will be the responsibility of the contractor.

All warranty work including, but not limited to, remedial work and elective/preventive maintenance shall require a permit from the department by contacting the District Pavement Engineer.

G.2 Remedial Work

Remedial work will be based on the results of the mainline pavement distress surveys.

If any of the conditions described in the footnotes of the table in Section F are met, the contractor will be relieved of performing the remedial action for the described pavement distress. The contractor will not be responsible for damages that result from coring, milling, grinding, or other destructive procedures conducted by the department.

If any of the threshold level criteria of the table in Section F are met on the mainline pavement, and the contractor agrees to the validity of the pavement distress survey results, the contractor shall perform the remedial work prescribed in the remedial action column of the table. Remedial work to be performed and materials to be used will be the joint decision of the contractor and the engineer. The remedial work shall be performed in all segments of the project where a threshold level is met unless otherwise noted under the remedial action. The remedial work shall be applied to the entire segment(s).

Remedial action work required on the mainline roadway will also be performed on the integral concrete shoulders, curb and curb and gutter. Auxiliary lanes impacted by the distress in the mainline warranted concrete pavement will also be repaired as part of the remedial action. If an impasse develops, the Conflict Resolution Team will make a final determination.

Remedial work shall be performed in the same calendar year that the pavement distresses were recorded.

The contractor, with the engineer's approval, may elect to delay the remedial actions in order to minimize the impacts of delay and inconvenience to the traveling public.

If, at anytime during the warranty period, 30 percent or more of the project segments require or have received remedial action, then the entire project will receive remedial action as mutually determined by the contractor and the engineer.

The contractor will have the first option to perform the remedial work. If, in the opinion of the engineer, the problem requires immediate attention for the safety of the traveling public, and the contractor cannot perform the remedial work within eight hours, the engineer may have the remedial work done by other forces and at the contractor's expense. Remedial work performed by other forces will not alter the requirements, responsibilities, or obligations of the warranty.

If remedial action work or elective/preventive action work performed by the contractor necessitates a corrective action to the pavement marking(s), raised pavement markers, adjacent lane(s) or shoulders then such corrective action to the pavement markings, raised pavement markers, adjacent lanes or shoulders will be the responsibility of the contractor.

The contractor will not be held responsible for distresses that are caused by factors beyond the control of the contractor (see the asterisked items in the table in Section F). However, due to the fact that the pavement is under the warranty, the contractor will be given the option to make these repairs at a cost to be negotiated with the engineer. Costs for these repairs will be based upon time, materials, labor, equipment costs and traffic control costs and will be consistent with the normal cost of maintenance traditionally performed by county highway forces.

G.3 Elective/Preventive Maintenance

Elective/preventive maintenance will be a contractor option. The contractor and the engineer will jointly coordinate elective/preventive maintenance to be performed and materials to be used.

H Concrete Mix Design

H.1 Concrete Mix Design

The maximum limit for the percentage of material passing the 200 sieve is deleted from Subsections 501.2.5.3.1 and 501.2.5.4.2 of the standard specifications.

H.2 Submittal

At least fifteen (15) working days prior to the start of concrete production, the contractor shall provide the engineer two copies of a Concrete Pavement Mix Design. The mix design shall meet all necessary criteria and be developed by the contractor and/or their agent of a recognized laboratory as defined in Subsection H.5, herein.

H.3 Documentation

The mix design documentation shall ensure the materials used are in accordance with all the requirements described in subsection 501.2 of the standard specifications unless modified herein, or waived by the engineer. The documentation shall include test dates, the name and location of the laboratory used to develop the mix design, material proportions, compressive strength obtained from the concrete at 28 days, concrete air content, and material information including: type; brand; source; batch masses; aggregate air correction factor; and aggregate gradations, absorption, and specific gravities. In lieu of a laboratory mix design, the contractor may elect to use a mix design previously used on other highway projects that meet the mix design

requirements of this specification. In either case, the documentation and data submitted shall demonstrate that the mix design meets all the necessary requirements of subsection 501.2 of the standard specifications unless modified herein.

H.4 Mix Design Physical Requirements

The compressive strength for the concrete pavement mix design shall be qualified by the average compressive strength of a minimum of five pairs of test cylinders cured for 28 days, either by laboratory testing or by previous field test data which utilized the same mix design.

The minimum cement content shall be 565 lb/cubic yard. Class C fly ash may be used as a partial replacement for Portland cement at a replacement ratio of 1.0 of fly ash per 1.0 pound of cement up to a maximum cement replacement of 30%. Alternatively, Grade 100 or 120 slag may be used as a partial replacement for cement at a replacement ratio of 1.0 pound of slag per 1.0 pound of cement up to a maximum cement replacement of 50% for mainline slip form pavement and a maximum cement replacement of 30 % for handwork.

H.5 Development Facility

The department shall qualify the laboratory used to develop the mix design.

H.6 Mix Changes

The contractor will submit a modified mix design, for informational purposes, prior to incorporation into the work. Modified mix designs are required for all changes in: 1) the source of any material, 2) the amounts of cementitious materials, 3) adjustment of fine to total aggregate greater than ±3 percent by mass, or 4) the addition or deletion of admixtures.

I Measurement

Concrete Pavement (Thickness) Warranted will be measured by area in square yards and the quantity to be paid for shall be the number of square yards of concrete pavement completed, accepted, measured complete in place. The width for measurement will be the width from outside to outside of completed pavement, but not to exceed the width as shown on the plans. The length will be the actual length measured along the riding surface.

Fillets for widened sections or at drain basins and similar locations, placed monolithic with the pavement, will be measured as pavement.

No deduction will be made for any fixture located within the limits of the pavement when such fixture has a surface area, in the plane of the pavement surface, of one square yard or less.

J Payment

Concrete Pavement (Thickness) Warranted, measured as provided above, will be paid for at the contract unit price per square yard of pavement, which price will be full compensation for furnishing, preparing, hauling, mixing, and placing all materials, unless otherwise provided; for the warranty; warranty bond(s); for performing warranty work; for the Quality Control Plan; for testing; for record keeping; for sampling; for traffic control; and for all labor, tools, equipment and incidentals necessary to complete the work.

Appendix D

Changes to PCC Warranty Specification in 2004

Threshold and remedial action changes

1998 Version	2004 Version
Slab Breakup *Threshold* – More than eight slabs per segment *Remedial action* – Install retrofit dowel bars (6 per lane) across all cracks, 6-foot wide full-depth repair or alternative method as approved by the CRT	Slab Breakup *Threshold* – More than four cracked slabs per segment at three years of age and more than eight slabs per segment at five years of age *Remedial action* – Evaluate per the Department's Construction and Materials Manual or alternative method as approved by the engineer or CRT
Distressed Transverse Joints and Cracks *Threshold* – Ten joints or cracks per 0.1-mile segment	Distressed Transverse Joints and Cracks *Threshold* – Five joints or cracks per 0.1-mile segment
Longitudinal Joint or Crack Distress *Exclusion* – The contractor will be relieved of the responsibility for remedial action for longitudinal joint distress when the parting strip or sawcut is in the correct position, orientation, depth, size, sawed in a timely manner, etc., when the distress is faulting of the centerline joint and it has been determined the longitudinal tie steel has been installed in the correct position, orientation, and spacing as outlined in the standard detail drawings in the plan and the concrete strength is at acceptable levels for compressive strength.	Longitudinal Joint or Crack Distress *Exclusion* – none
Transverse Faulting *Exclusion* – The contractor will be relieved of the responsibility for remedial action for transverse faulting if the following is true: dowel bars have been installed in accordance with the plan and specifications; and the concrete strength is at acceptable levels for compressive strength. The contractor will also be relieved of the responsibility for a remedial action if the faulting is caused by frost heaves, uneven roadbed support or base related problems.	Transverse Faulting *Exclusion* – The contractor will be relieved of the responsibility for remedial action for transverse faulting if the following is true: dowel bars have been installed in accordance with the plan and specifications; and the concrete strength is at acceptable levels for compressive strength.

Conflict Resolution Team (CRT) changes

1998 Version	2004 Version
CRT members now appointed prior to construction	CRT members appointed at time of conflict
Pavement distress manual training given to all CRT members, regardless of type of conflict	Pavement distress manual training given to CRT members only when necessary

Distress survey changes

1998 Version	2004 Version
Pavement distress surveys conducted by central office DOT pavement engineers	Pavement distress surveys conducted by Pavement Data Unit

Concrete mix design requirements

1998 Version	2004 Version
Maximum cement replacement with fly ash: 25%	Maximum cement replacement with fly ash: 30%
Maximum cement replacement with slag cement: 50%	Maximum cement replacement with slag cement: 50% for slip form placement and 30% for hand placement

Quality control and documentation requirements

Specific requirements for quality control and documentation were removed from the 1998 version of the PCC warranty specification. In the 2004 version, requirements for the following areas are as mandated in the relevant sections of the Department's Standard Specifications:

- Materials
- Foundation
- Final surface finish
- Pavement grinding and removal
- Tolerance in pavement thickness

Appendix E

Historic Pavement Distress Index (PDI) Data
Pavements with ages up to 30 years – HMA pavements
Pavements with ages up to 20 years – PCC pavements

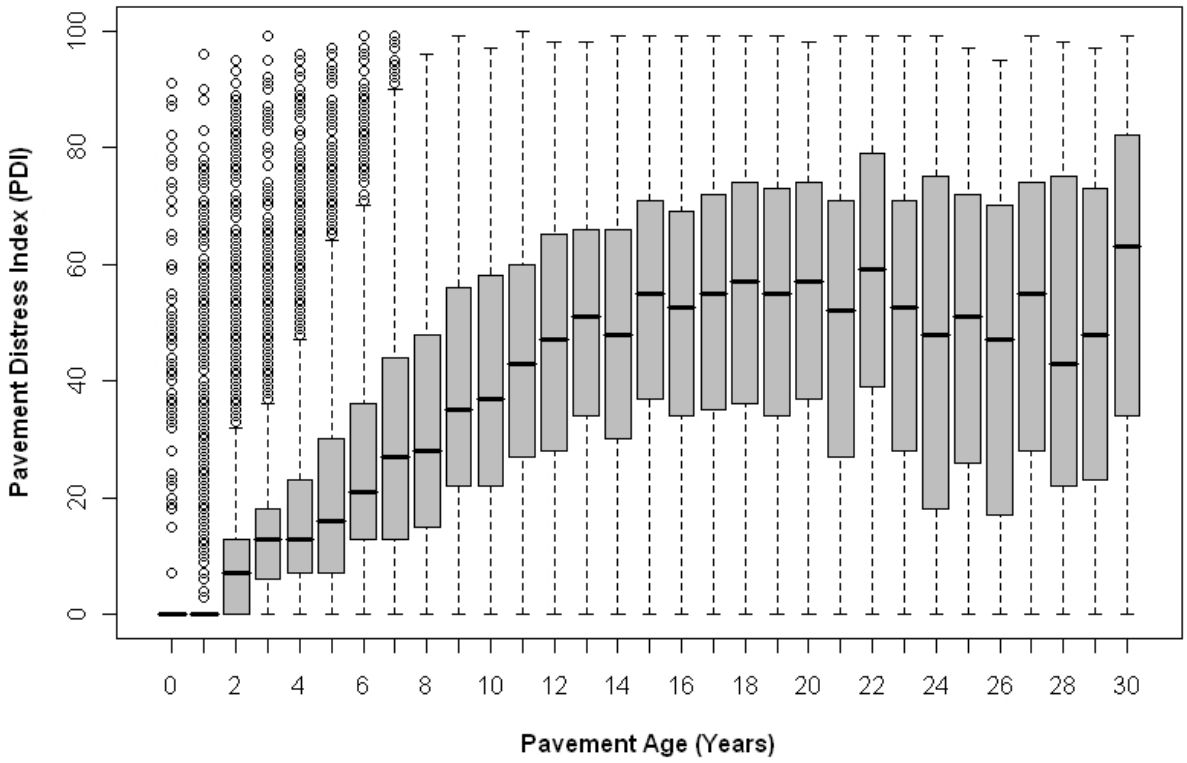

Figure E-1. Pavement Distress Index (PDI) values for non-warranted Type 1 pavements with an age of thirty years or less. 57,029 records.

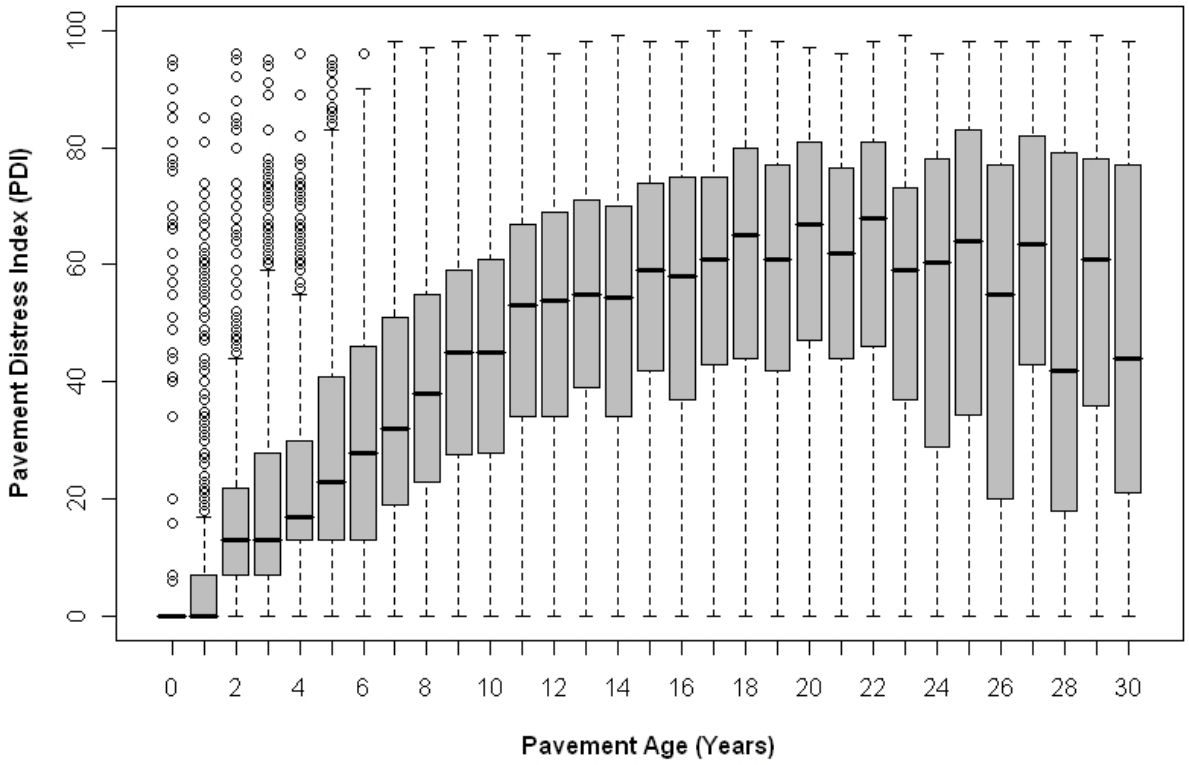

Figure E-2. Pavement Distress Index (PDI) values for non-warranted Type 3 pavements with an age of thirty years or less. 36,107 records.

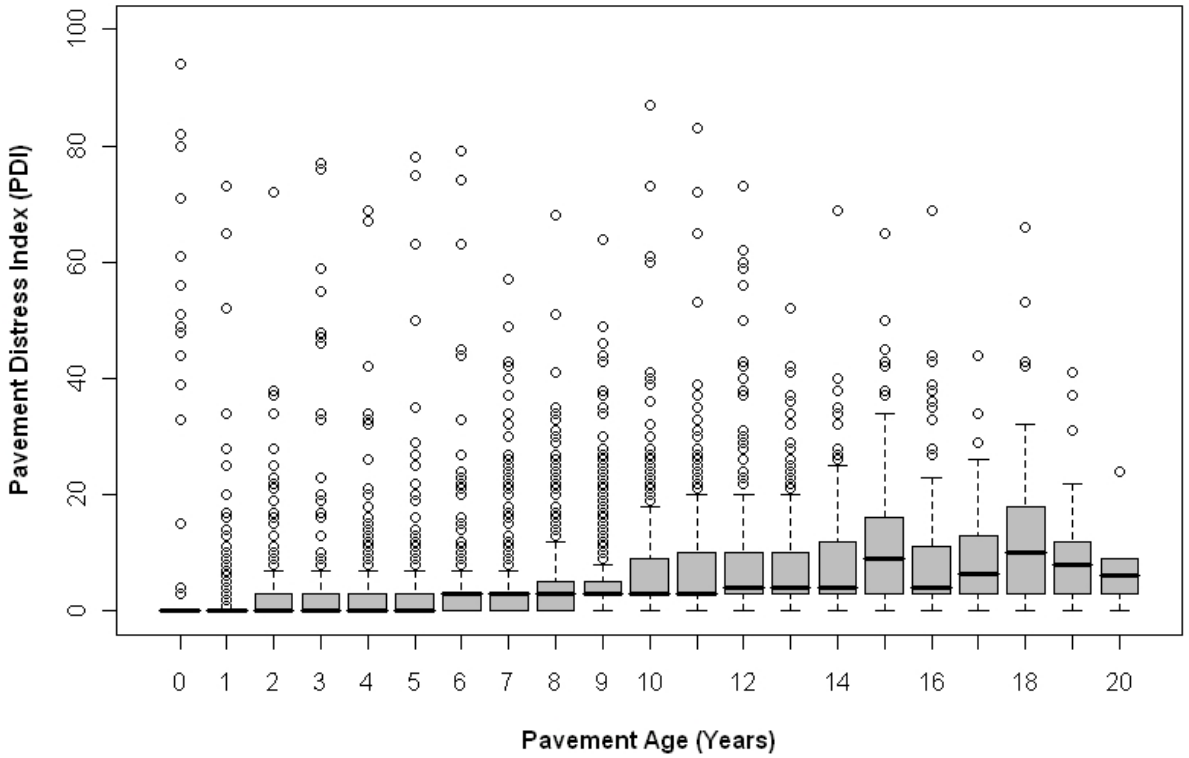

Figure E-3. Pavement Distress Index (PDI) values for non-warranted Type 8 pavements with an age of twenty years or less. 10,462 records.

Appendix F

Historic International Roughness Index (IRI) Data
Pavements with ages up to 30 years – HMA pavements
Pavements with ages up to 20 years – PCC pavements

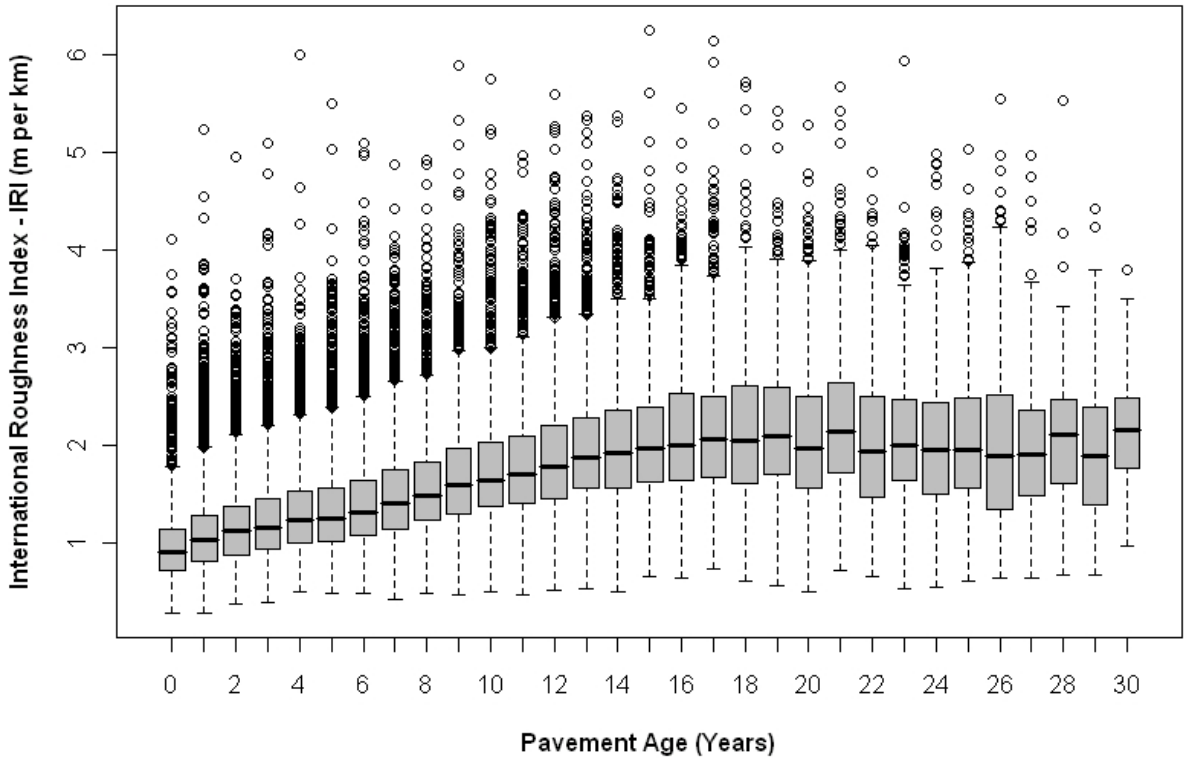

Figure F-1. International Roughness Index (IRI) values for non-warranted Type 1 pavements with an age of thirty years or less. 62,900 records.

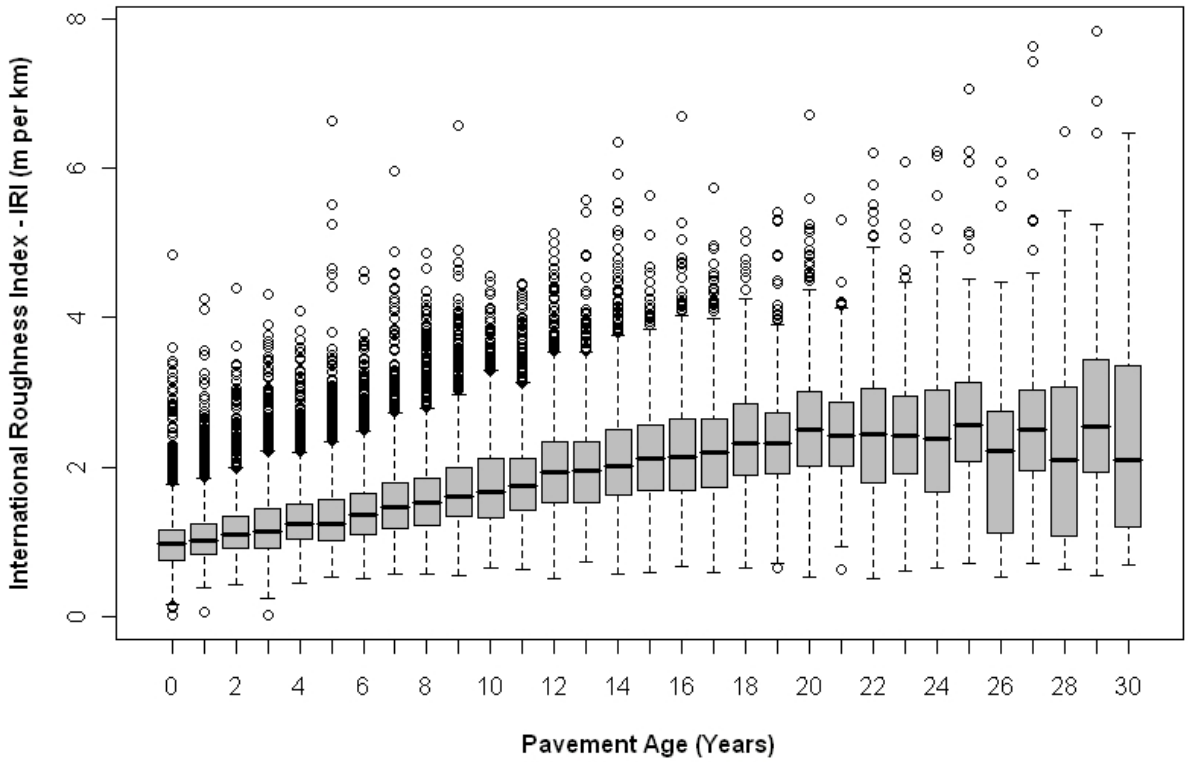

Figure F-2. International Roughness Index (IRI) values for non-warranted Type 3 pavements with an age of thirty years or less. 39,098 records.

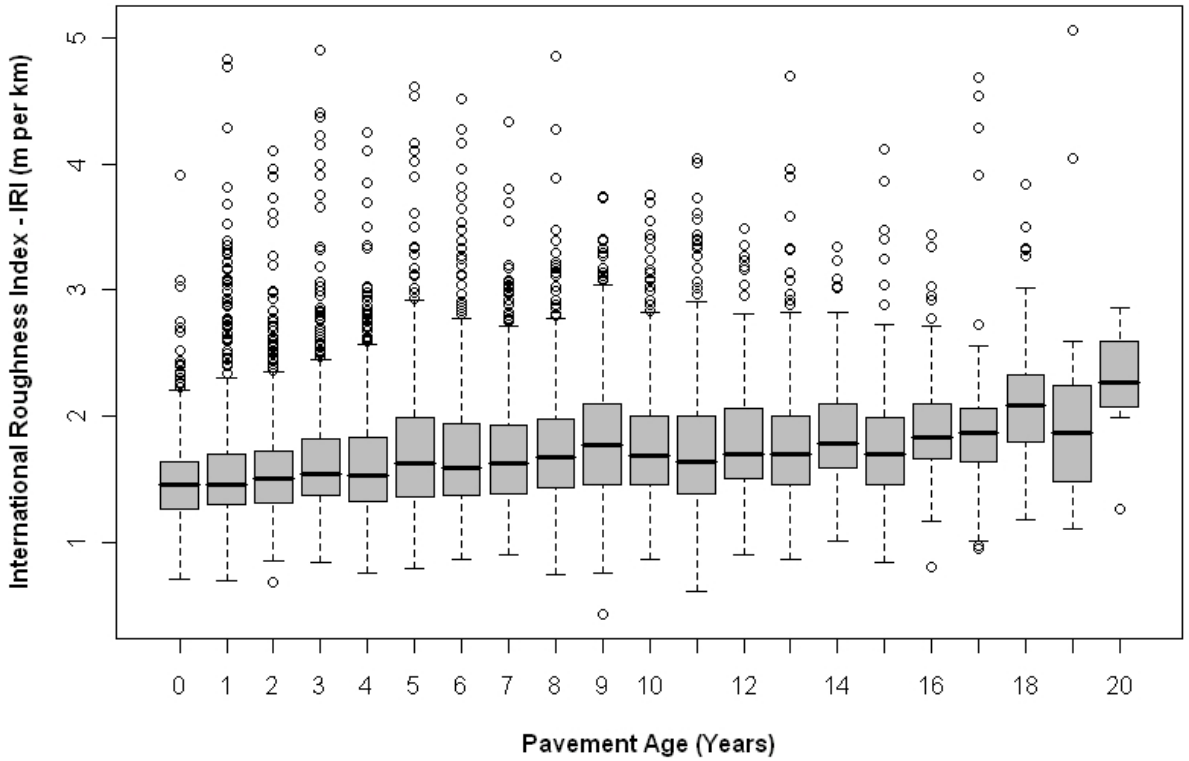

Figure F-3. International Roughness Index (IRI) values for non-warranted Type 8 pavements with an age of twenty years or less. 10,141 records.

Appendix G

Values for Boxplot Features

Table G-1 Information for Figure 3 (Non-warranted, Type 1, PDI)

Pavement Age (Years)	0	1	2	3	4	5	6	7	8	9	10	11	12	
Bottom whisker	0	0	0	0	0	0	0	0	0	0	0	0	6	
25th quartile	0	0	0	0	0	6	7	7	13	13	16	18	27	
50th quartile (median)	0	0	0	7	7	13	13	18	19.5	25	30.5	29.5	43	
75th quartile	0	0	13	13	18	22	27.5	28	32	41	47	46.5	59	
Top whisker	0	0	32	32	44	46	57	59	59	83	92	82	92	Total
Number of records	1545	3312	1368	1497	1105	1255	912	918	572	530	358	240	167	13779
Number of outliers	44	529	71	86	52	78	44	29	36	2	0	1	0	972

Table G-2 Information for Figure 4 (Warranted, Type 1, PDI)

Pavement Age (Years)	0	1	2	3	4	5	6	7	8	9	10	11	12	
Bottom whisker	0	0	0	0	0	0	0	0	0	0	0	6	13	
25th quartile	0	0	0	0	0	0	0	6	0	6	7	13	13	
50th quartile (median)	0	0	0	0	0	7	7	7	7	13	13	13	18	
75th quartile	0	0	6	7	7	13	7	13	13	13	18.5	22	18.5	
Top whisker	0	0	15	16	15	32	15	20	27	21	32	28	19	Total
Number of records	442	541	208	212	136	157	94	84	52	27	27	13	8	2001
Number of outliers	15	72	10	7	7	2	9	6	1	2	0	1	1	133

Table G-3 Information for Figure 6 (Non-warranted, Type 1, IRI)

Pavement Age (Years)	0	1	2	3	4	5	6	7	8	9	10	11	12	
Bottom whisker	0.33	0.44	0.43	0.46	0.51	0.49	0.49	0.57	0.47	0.58	0.49	0.69	0.79	
25th quartile	0.68	0.76	0.74	0.79	0.8	0.84	0.87	0.88	0.98	0.99	1.22	1.12	1.44	
50th quartile (median)	0.77	0.9	0.9	0.93	0.96	0.96	1.03	1.06	1.18	1.23	1.42	1.39	1.7	
75th quartile	0.93	1.14	1.2	1.15	1.23	1.18	1.26	1.29	1.45	1.47	1.74	1.75	2.01	
Top whisker	1.29	1.7	1.89	1.67	1.86	1.69	1.83	1.88	2.15	2.18	2.51	2.57	2.79	
Number of records	2399	1913	1375	1538	1152	1267	925	922	584	531	367	243	167	Total 13383
Number of outliers	161	85	65	82	49	73	48	42	19	23	13	9	10	679

Table G-4 Information for Figure 7 (Warranted, Type 1, IRI)

Pavement Age (Years)	0	1	2	3	4	5	6	7	8	9	10	11	12	
Bottom whisker	0.38	0.41	0.46	0.43	0.49	0.51	0.44	0.57	0.52	0.66	0.55	0.85	0.79	
25th quartile	0.62	0.63	0.7	0.68	0.685	0.68	0.68	0.68	0.61	0.86	0.75	1.01	0.96	
50th quartile (median)	0.71	0.74	0.79	0.8	0.82	0.79	0.8	0.78	0.79	0.98	0.95	1.07	1.22	
75th quartile	0.8	0.85	0.92	0.93	0.95	1.04	1.01	0.95	1.06	1.08	1.15	1.15	1.57	
Top whisker	1.07	1.18	1.22	1.29	1.29	1.56	1.5	1.29	1.61	1.23	1.42	1.23	1.93	
Number of records	541	344	228	210	147	157	94	90	52	27	27	13	8	Total 1938
Number of outliers	29	18	11	9	6	3	0	2	0	1	1	2	0	82

Table G-5 Information for Figure 9 (Non-warranted, Type 3, PDI)

Pavement Age (Years)	0	1	2	3	4	5	6	7	8	9	10	11	12	
Bottom whisker	0	0	0	0	0	0	0	0	0	0	0	18	0	
25th quartile	0	0	6	6	7	13	13	14	14	20.5	18	28	28	
50th quartile (median)	0	0	7	13	13	18	21	27	26	28	28.5	32	51	
75th quartile	0	0	23	26	31	28	37	42	38	48	47	48	65	
Top whisker	0	0	48	56	66	50	73	83	74	87	74	78	76	
Number of records	731	1797	753	842	696	752	489	455	401	244	216	89	27	Total 7492
Number of outliers	29	431	22	20	11	69	3	0	1	0	0	1	0	587

Table G-6 Information for Figure 10 (Warranted, Type 3, PDI)

Pavement Age (Years)	0	1	2	3	4	5	6	7	8	9	10	
Bottom whisker	0	0	0	0	7	13	7	0	28		55	
25th quartile	0	0	0	0	13	13	15.5	6.5	31		55	
50th quartile (median)	0	0	6	7	20	13	18	13	34		55	
75th quartile	0	0	6	13	27.5	16.5	32	25.5	39.5		58	
Top whisker	0	0	13	18	37	20	32	38	42		60	Total
Number of records	54	66	24	26	7	15	7	4	7	0	7	217
Number of outliers	0	13	1	0	0	4	0	0	1	0	1	20

Table G-7 Information for Figure 12 (Non-warranted, Type 3, IRI)

Pavement Age (Years)	0	1	2	3	4	5	6	7	8	9	10	11	12	
Bottom whisker	0.38	0.44	0.46	0.51	0.46	0.54	0.57	0.71	0.58	0.68	0.69	0.77	0.65	
25th quartile	0.68	0.77	0.85	0.8	0.88	0.87	0.92	0.99	0.95	1.13	1.07	1.25	1.115	
50th quartile (median)	0.82	0.95	0.99	0.98	1.03	1.03	1.12	1.22	1.1	1.28	1.25	1.45	1.5	
75th quartile	1.01	1.15	1.18	1.18	1.28	1.26	1.39	1.5	1.34	1.54	1.48	1.74	1.775	
Top whisker	1.48	1.7	1.67	1.74	1.86	1.82	2.05	2.26	1.89	2.04	2.04	2.46	2.62	Total
Number of records	1101	1196	789	917	680	758	495	458	405	248	217	93	31	7388
Number of outliers	81	68	64	59	40	48	26	13	21	11	7	4	2	444

Table G-8 Information for Figure 13 (Warranted, Type 3, IRI)

Pavement Age (Years)	0	1	2	3	4	5	6	7	8	9	10	
Bottom whisker	0.43	0.46	0.54	0.47	0.99	0.74	0.9	0.68	1.01		1.22	
25th quartile	0.6	0.66	0.64	0.64	1.12	0.85	1.0	0.77	1.18		1.45	
50th quartile (median)	0.68	0.74	0.74	0.76	1.26	0.95	1.37	0.91	1.34		1.64	
75th quartile	0.76	0.85	1.05	0.91	1.46	1.12	1.47	1.03	1.65		1.91	
Top whisker	0.96	1.07	1.42	1.12	1.69	1.25	1.69	1.1	1.91		2.21	Total
Number of records	73	46	24	27	7	15	7	4	7	0	7	217
Number of outliers	2	3	1	0	0	1	0	0	0	0	0	7

Table G-9 Information for Figure 15 (Non-warranted, Type 8, PDI)

Pavement Age (Years)	0	1	2	3	4	5	6	7	8	9	
Bottom whisker	0	0	0	0	3	3	3	0	0	0	
25th quartile	0	0	0	0	3	3	3	0	3	3	
50th quartile (median)	0	0	3	3	3	3	3	3	3	3.5	
75th quartile	0	3	3	3	3	3	3	3	6	20	
Top whisker	0	7	7	7	3	3	3	7	10	38	
Number of records	527	780	466	363	305	220	234	114	109	30	3148
Number of outliers	25	19	26	21	113	80	84	16	18	0	402

Total

Table G-10 Information for Figure 16 (Warranted, Type 8, PDI)

Pavement Age (Years)	0	1	2	3	4	5	6	7	8	9	
Bottom whisker	0	0	0	3	3	0	3	0	0	0	
25th quartile	0	0	0	3	3	0	3	1	1.5	2	
50th quartile (median)	0	0	3	3	3	3	3.5	3	3	3	
75th quartile	0	0	3	3	3	3	10	9	3.5	9	
Top whisker	0	0	5	3	3	3	10	18	4	9	
Number of records	44	54	31	21	8	14	8	14	8	14	216
Number of outliers	0	11	0	3	1	2	0	0	1	1	19

Total

Table G-11 Information for Figure 18 (Non-warranted, Type 8, IRI)

Pavement Age (Years)	0	1	2	3	4	5	6	7	8	9	
Bottom whisker	0.84	0.85	0.68	0.84	0.76	0.87	0.87	0.92	1.01	1.25	
25th quartile	1.28	1.31	1.26	1.29	1.25	1.29	1.33	1.36	1.34	1.39	
50th quartile (median)	1.45	1.47	1.44	1.50	1.44	1.50	1.56	1.52	1.61	1.80	
75th quartile	1.64	1.70	1.67	1.78	1.72	1.83	1.85	1.77	1.88	2.08	
Top whisker	2.13	2.29	2.23	2.48	2.41	2.59	2.60	2.21	2.62	2.84	
Number of records	513	495	488	368	309	230	242	117	110	31	2903
Number of outliers	19	30	19	17	12	10	16	8	5	1	137

Total

Table G-12 Information for Figure 19 (Warranted, Type 8, IRI)

Pavement Age (Years)	0	1	2	3	4	5	6	7	8	9	
Bottom whisker	1.17	1.15	1.10	0.84	0.90	0.96	1.26	1.06	1.29	1.14	
25th quartile	1.41	1.39	1.29	1.15	1.14	1.20	1.37	1.25	1.36	1.23	
50th quartile (median)	1.53	1.55	1.47	1.33	1.25	1.27	1.48	1.33	1.47	1.31	
75th quartile	1.66	1.74	1.78	1.52	1.37	1.42	1.60	1.40	1.56	1.45	
Top whisker	1.97	2.05	2.18	1.93	1.47	1.52	1.69	1.47	1.72	1.67	
Number of records	47	41	29	21	8	14	8	14	8	14	204
Number of outliers	2	0	0	0	0	1	0	2	0	1	6

Total

Table G-13 Information for Figure 21 (Non-warranted, HMA, bid costs)

Construction Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	
Bottom whisker	$17.81	$21.68	$21.00	$21.21	$21.45	$19.12	$24.13	$29.49	$29.13	$38.74	
25th quartile	$21.83	$24.41	$26.69	$24.99	$26.71	$24.88	$30.08	$37.10	$39.26	$46.09	
50th quartile (median)	$24.33	$27.61	$29.35	$27.61	$29.12	$28.76	$33.08	$40.74	$43.99	$56.67	
75th quartile	$30.60	$32.21	$31.89	$32.07	$31.54	$31.62	$37.02	$48.24	$51.60	$63.27	
Top whisker	$37.35	$38.08	$39.44	$38.99	$36.26	$40.25	$46.71	$60.93	$63.79	$82.25	
Number of records	68	68	87	65	60	59	53	51	59	42	612
Number of outliers	0	1	2	5	4	3	3	2	1	1	22

Total

Table G-14 Information for Figure 22 (Warranted, HMA, bid costs)

Construction Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	
Bottom whisker	$22.48	$21.28	$26.51	$28.10	$23.41	$23.13	$23.42	$25.66	$28.59	$25.23	
25th quartile	$22.97	$22.42	$27.03	$28.10	$28.37	$27.48	$26.88	$32.11	$34.33	$38.74	
50th quartile (median)	$25.78	$27.40	$27.99	$29.48	$32.24	$29.66	$28.55	$35.23	$37.15	$49.18	
75th quartile	$28.65	$33.05	$28.96	$30.83	$34.58	$31.32	$30.16	$41.56	$39.33	$62.34	
Top whisker	$29.66	$35.31	$29.60	$31.42	$40.32	$31.71	$30.50	$45.17	$45.69	$77.25	
Number of records	5	6	7	6	9	10	12	24	21	23	123
Number of outliers	0	0	2	1	0	1	2	1	2	0	9

Total