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TPF-5(291) FINAL REPORT:

ANALYSIS OF JOINT SCORE AND ALR IMPACTS ON PAVEMENT PERFORMANCE

Prepared On Behalf Of	Date	Project Number
State Pooled Fund Study TPF-5(291)	October 2021	56A0418-008 (TPF-5(291)) 219.03.10 (NCE)

Engineering & Environmental Services

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1.0 BACKGROUND

The NCE team was awarded the Transportation Pooled Fund (TPF) Study 5(291) to investigate data from the Long-Term Pavement Performance (LTPP) Specific Pavement Study (SPS)-2 experiment for concrete pavement design factors, with the Washington State Department of Transportation as the Lead State. This pooled fund study included the investigation and proposal of a pavement preservation experiment utilizing existing test site conditions. Upon completion of the initial phase of the study, several SPS-2 Tech Days were conducted to broaden the pavement community's knowledge of the SPS-2 experiment and to garner input on analyses the community would find useful. The Pooled Fund Technical Advisory Committee (TAC) also provided recommendations for additional analyses.

As a result, five additional tasks were focused on SPS-2 test sections:

- Conducting a deterioration rate analysis
- Analyzing performance data
- Investigating sources of non-LTPP data
- Analyzing joint score and area of localized roughness (ALR) impacts on performance
- Updating previous SPS-2 analyses

Upon completion of these tasks, an additional 11 tasks were proposed. The purpose of this supplementary extension of TPF-5(291) was to conduct further analyses of existing data from the LTPP SPS-2 concrete pavement experiment. The focus of this set of tasks was to investigate the impact of non-experimental factors on pavement performance. The following tasks were completed:

- Identifying agency-specific trends
- Analyzing the impact of construction and materials issues
- Reviewing early SPS-2 failures
- Identifying lessons learned from state supplemental sections
- Analyzing the impacts of climate, traffic, and overall condition on deterioration rate
- Comparing SPS-8 and SPS-2 performance
- Assessing diurnal changes in roughness
- Evaluating service life
- Comparing mix-design performance
- Conducting Mechanistic Empirical Pavement Design Guide (MEPDG) sensitivity analysis of portland cement concrete/lean concrete base (PCC/LCB) bond
- Evaluating transverse joint opening width

This report leverages and expands upon the SPS-2 section data from two existing LTPP research reports to assess the potential correlation of joint score number and ALR with pavement performance.

2.0 OVERVIEW

The purpose of this study was to review the SPS-2 data from two existing LTPP research reports that include SPS-2 test sections (currently in draft), add data from additional monitoring events for those sections, and provide an expanded analysis of the correlation between section properties and performance. The report titled Effect of Dowel Misalignment on Concrete Pavement Performance (Rao, S. and Premkumar, L. [2018]) compared the joint score number (from MIT Scan measurements) to pavement performance. The report titled Advancement of Profile-Based Curl and Warp Analysis Using LTPP Profile (Karamihas, S., and NCE [2018]) examined changes in ALR over time on each section and compared these changes to distress development. The Federal Highway Administration gave permission to utilize the draft reports in conducting this task, for which the authors are greatly appreciative.

Table 1 provides the total number of SPS-2 sections analyzed in the current study (General Pavement Studies-3 [GPS-3]) test sections were not included); the number of sections that overlap with those in the two draft reports are also listed. It should be noted that to study to effect of ALR on pavement performance, ALR was estimated for all SPS-2 test sections based on a simplification of the method for calculating ALR that was detailed in the draft report. On the other hand, joint score number could only be evaluated for the test sections for which the MIT Scan measurements were taken.

Table 1: Total Number of SPS-2 Sections Studied by Report and State

States	Current Study	Rao and Premkumar (Joint Score)	Karamihas and NCE (ALR)
Arizona	19	12	19
Arkansas	12	11	-
California	12	12	-
Colorado	13	12	-
Delaware	14	-	-
Iowa	13	12	-
Kansas	13	12	13
Michigan	13	-	-
Nevada	12	-	-
North Carolina	14	8	14
North Dakota	18	12	-
Ohio	19	-	19
Washington	13	-	13
Wisconsin	20	11	-
Total	205	102	78

Most of the sections have a performance history of 18-22 years. Some test sections went out-of-study earlier, typically due to construction or materials issues. Various performance parameters such as length of transverse cracking, length of longitudinal cracking, crack propagation rate, percent cracked slabs, MEPDG % cracking index, faulting, and IRI were analyzed based on each sections' base type, strength, and thickness.

3.0 REVIEW OF DRAFT REPORTS

The report Effect of Dowel Misalignment on Concrete Pavement Performance was studied to inform the analysis of joint score on pavement performance. The draft report presented results of MIT Scan data collected on selected LTPP test sections and used the data to assess the effects of dowel misalignment on JPCP performance. MIT Scan testing was performed on 121 Specific Pavement Studies-2 (SPS-2), and 3 GPS-3 test sections. GPS-3 experiments are studies on in-service (existing) jointed, plain concrete pavements. Unlike SPS-2 experiments, GPS-3 projects do not consist of multiple test sections at a single location.

Dowel bar alignment parameters, joint scores, and effective dowel diameters were calculated as part of the analysis. The analysis did not indicate any definitive relationship between joint score and cracking or spalling within the analysis range in most states, although some effect was observed in 3 states. This is not to say that severely misaligned dowel bars do not affect pavement performance, particularly localized distresses. However, more thorough studies were recommended to understand the correlation between pavement performance and joint score.

The report noted that one of the earliest methods to categorize dowel misalignment and consider the combined effects of all bars at a joint was done by Yu and Khazanovich (2005). A methodology was proposed for combining dowel rotational misalignment of all bars within a joint into a joint score, where a higher score corresponds to more bars with higher levels of rotational misalignment. A typical specification requires the joint score to be less than 10, above which corrective action is often specified. In this report, the joint score data were divided into three categories for analysis, as shown in the Table 2.

Table 2: Joint Score Category.

Joint Score	Category
Joint Score <=12	Low
12< Joint Score <=30	Medium
Joint Score >30	High

The second report, Advancement of Profile-Based Curl and Warp Analysis Using LTPP Profile, explained the derivation of ALR, the impacts of ALR on IRI measurements, and the association of ALR with curl and warp of concrete pavement. ALR was described as a segment of the longitudinal profile where IRI exceeded a designated threshold. Severity of ALR was summarized by the total length of segments, the number of segments, or the peak value of segments.

Like IRI, the extent and severity of ALR was noted to be linked to diurnal and seasonal cyclic changes in curl and warp. In addition to short-term changes, the long-term behavior of ALR was found to vary by test section. In some cases, ALR was shown to increase with age. In other cases, ALR was too little to determine growth or the ALR did not show growth (was stable). In other cases, ALR growth was confounded by diurnal and seasonal factors (i.e., the degree of growth could not be determined).

Since the longitudinal profile surveys consisted of several passes, the repeatability of ALR was assessed. It was found that ALR extent and excess roughness deviated more than overall IRI relative to the average of multiple passes. However, sections with high-severity ALR were found to be more consistent than sections with low-severity ALR.

4.0 JOINT SCORE ANALYSIS

For this study, the analysis was performed in several steps to understand a pattern of pavement performance based on joint score or to incorporate a combined effect of joint score and base type (pavement structure).

Since pavement structure has an impact on the pavement performance, the SPS-2 sections were grouped into three categories according to base type:

- Portland Cement Concrete/Lean Concrete Base (PCC/LCB)
- Portland Cement Concrete/Dense Graded Aggregate Base (PCC/DGAB)
- Portland Cement Concrete/Permeable Asphalt Treated Base/ Dense Graded Aggregate Base (PCC/PATB/DGAB)

Of the 205 SPS-2 sections in Table 3, 179 sections fell within these three categories of base types. There were some state supplemental sections where other base types were present. Joint score data were available for 102 sections. Table 3 below summarizes total number of sections in each state with available information used for the analysis in this report.

Table 3. Number of Sections with Available Information

States	Total No. of SPS-2 Sections	No. of Sections with Joint Score	No. of Sections with PCC/LCB*	No. of Sections with PCC/DGAB*	No. of Sections with PCC/PATB/DGAB*
Arizona	19	12	4	6	6
Arkansas	12	11	4	-	-
California	12	12	4	4	4
Colorado	13	12	4	4	4
Delaware	14	-	4	6	4
Iowa	13	12	4	4	4
Kansas	13	12	5	4	4
Michigan	13	-	4	4	4
Nevada	12	-	4	4	3
North Carolina	14	8	4	4	4
North Dakota	18	12	5	6	7
Ohio	19	-	4	6	8
Washington	13	-	4	4	5
Wisconsin	20	11	4	4	4
Grand Total	205	102	58	60	61

*PCC: Portland Cement Concrete; LCB: Lean Concrete Base; DGAB: Dense Graded Aggregate Base; PATB: Permeable Asphalt Treated Base

Based on the 102 sections with joint scores, the average joint scores were calculated for 9 states and are presented in Table 4. Half of the sections were observed to have average joint scores below 12, indicating low risk of joint locking, with only 7 sections above 30. Arizona, Colorado, North Carolina, and North Dakota were observed to have average joint scores in the "Low" category, indicating a lower number of dowel bar misalignments within the slabs, while the average in other states fell in the "Medium" joint score category.

Table 4. Average Joint Score of Sections in Different States

States	Overall			Low Joint Score		Medium Joint Score		High Joint Score	
	No. of Sections	Avg. Joint Score	Standard Deviation	No. of Sections	Avg. Joint Score	No. of Sections	Avg. Joint Score	No. of Sections	Avg. Joint Score
Arizona	12	11	6	9	8	3	20	-	-
Arkansas	11	18	8	4	*10*	6	20	1	33
California	12	27	7	-	-	10	24	2	41
Colorado	12	12	8	9	7	3	24	-	-
Iowa	12	14	8	7	9	4	18	1	31
Kansas	12	18	6	2	9	10	20	-	-
North Carolina	8	11	6	6	9	2	19	-	-
North Dakota	12	11	9	11	8	-	-	1	39
Wisconsin	11	22	14	3	9	6	20	2	46
Total No. of Sections	102	16	2.5	51	9	44	21	7	38

Since severely misaligned dowel bars can affect the pavement performance, the sections were analyzed in terms of transverse cracks, longitudinal cracks, and cracked slabs; the goal was to combine the effect of joint score and cracking in different categories and for different base types. However, since the data on crack lengths, joint score, and base type varied widely or were not available for all 205 sections, a histogram analysis was compiled using available data on cracking performance to understand the distribution of various crack lengths over the total 205 sections (Table 5). This helped choose a range of crack length and assign a qualitative performance level. As can be seen from Table 5, 122 out of 205 sections had no transverse cracks and 113 sections had no longitudinal cracks.

Table 5: Histogram of Section with Various Crack Lengths

	Transverse Cracks		Longitudinal Cracks	
Bin, Crack Length (feet)	**Frequency (no. of sections)**	**Cumulative %**	**Frequency (no. of sections)**	**Cumulative %**
0	122	59.51%	113	55.12%
0-1	0	59.51%	4	57.07%
1.1-25	31	74.63%	38	75.61%
26-50	12	80.49%	8	79.51%
51-75	6	83.41%	9	83.90%
76-100	4	85.37%	2	84.88%
101-200	9	89.76%	14	91.71%
201-300	6	92.68%	3	93.17%
301-400	8	96.59%	1	93.66%
401-500	2	97.56%	5	96.10%
501-600	2	98.54%	3	97.56%
601-700	0	98.54%	3	99.02%
701-800	0	98.54%	1	99.51%
801-900	3	100.00%	1	100.00%

Based on this distribution, cracking performance level was assigned in Table 6. A performance level of "Excellent" was assigned to the sections with no cracking.

Table 6: Cracking Performance Level Criteria

Cracking Performance Level	Crack Length (feet)
Excellent	0
Good	1-100
Fair	101-400
Poor	401-900

Next, the effect of base type on cracking performance level was studied. Figure 1 presents the crack propagation rate for the 179 sections that were grouped into the three base-type categories (Table 3). Figure 1 shows that the crack propagation rate is the highest for the LCB base type. Sections with PATB and DGAB performed better, with a lower rate of crack propagation.

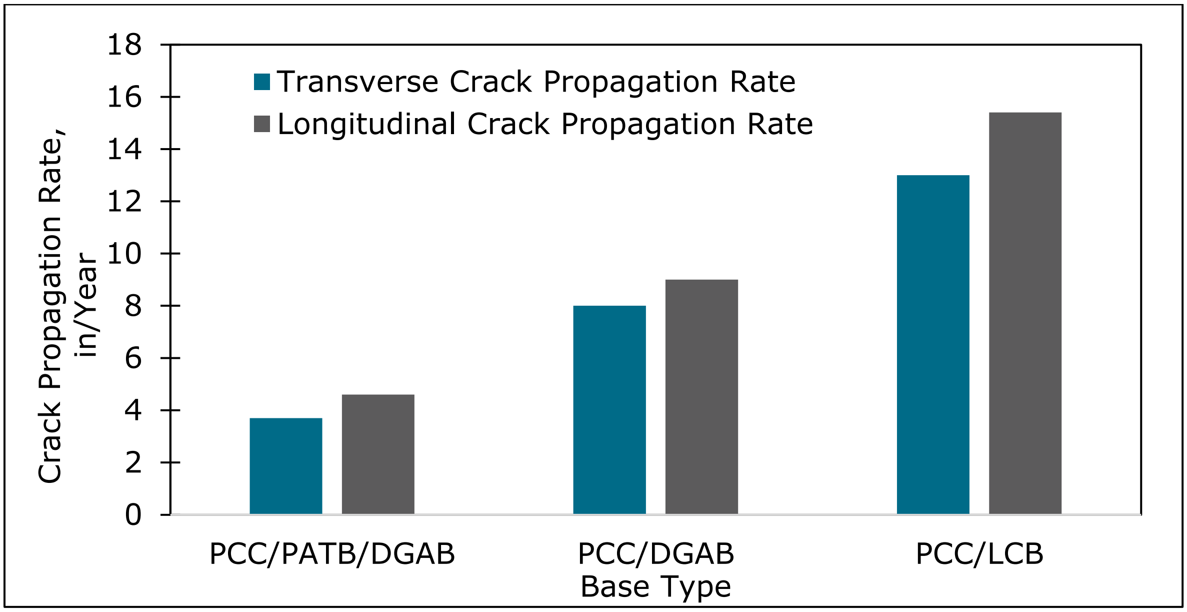


Figure 1: Effect of Base type on Crack Propagation Rate

Further analysis revealed that the pavement structure of 88 sections (out of the 102 sections with a joint score) fall into the three categories mentioned in Figure 1. As a result, for cracking performance, only 88 sections were analyzed. Table 7 presents the number of sections that were used for the cracking performance analysis.

Table 7: Number of Sections Used for Cracking Performance Analysis

States	**No. of Sections with Joint Score**	**No. of Sections with PCC/LCB**	**No. of Sections with PCC/DGAB**	**No. of Sections with PCC/PATB/DGAB**
Arizona	12	4	4	4
Arkansas	4	4	-	-
California	12	4	4	4
Colorado	12	4	4	4
Iowa	12	4	4	4
Kansas	12	4	4	4
North Carolina	6	2	2	2
North Dakota	12	4	4	4
Wisconsin	6	2	2	2
Grand Total	88	32	28	28

Figure 2 presents the average joint score of different states based on different base types.

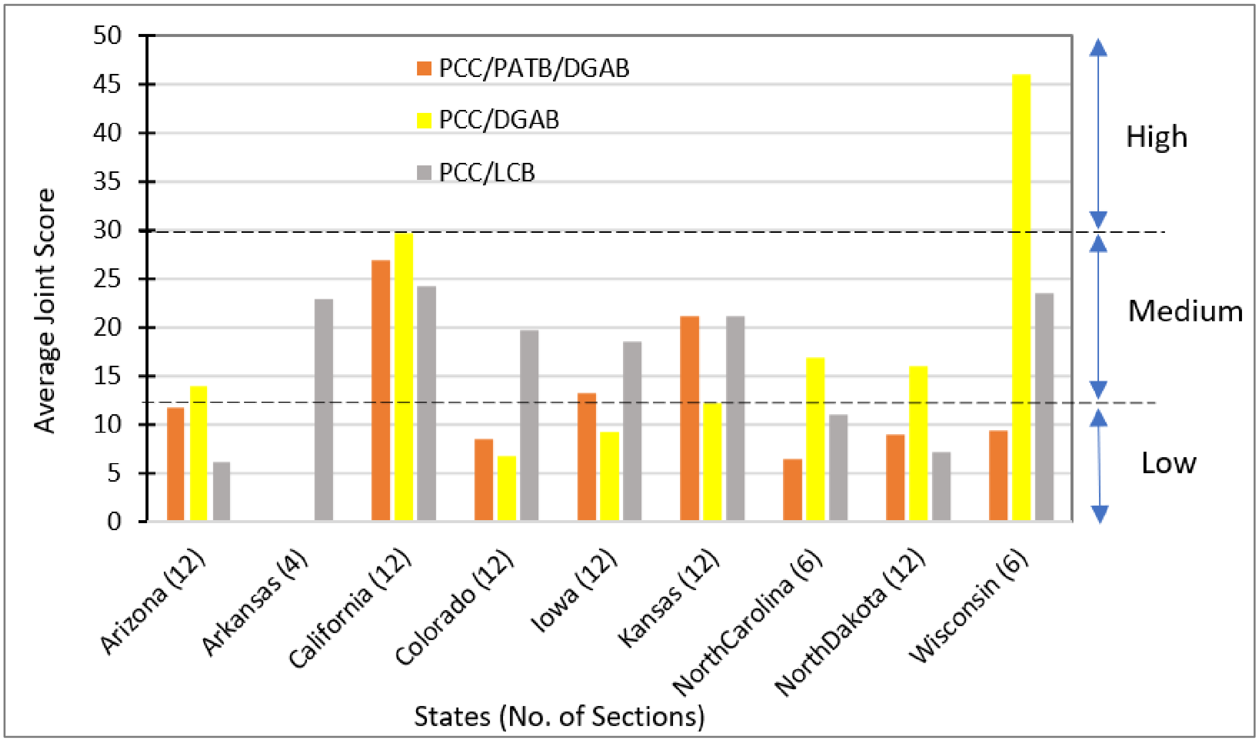


Figure 2. Average Joint Score of Different States based on Different Base-Types

Figure 3 attempts to illustrate potential relationships between average joint score and crack propagation rate among different states.

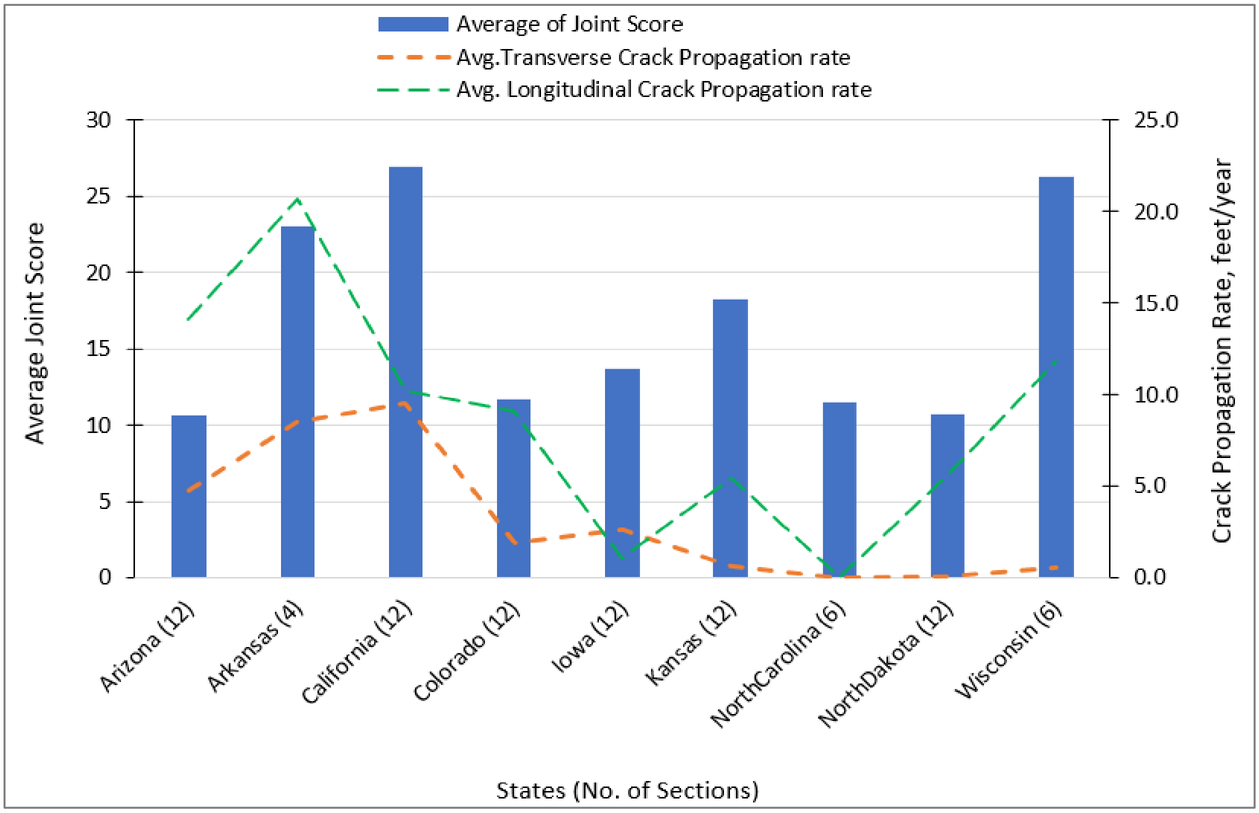


Figure 3. Relationship between Joint Score and Crack Propagation Rate for Different States

While no definite patterns were found from Figure 2 or Figure 3 for different states, analyzing all 88 sections showed sections with lower joint scores (thus lower dowel bar misalignment) tend to have lower transverse and longitudinal crack propagation rates as well as lower crack lengths (Tables 8 and 9). Sections with higher joint scores experienced both high transverse and longitudinal crack lengths, which indicates the expected negative impact of dowel misalignment on pavement performance.

Table 8: Joint Score vs. Transverse Cracking Properties

Joint Score Severity (no. of sections; average joint score)	Average of Transverse Crack Propagation Rate (feet/year)	Average Length of Transverse Cracks (all sections, feet)
Low (45 sections; 8)	1.8	18
Medium (36 sections; 22)	4.2	50
High (7 sections; 39)	5.6	69

Table 9: Joint Score vs. Longitudinal Cracking Properties

Joint Score Severity (no. of sections; average joint score)	Average of Longitudinal Crack Propagation Rate (feet/year)	Average Length of Longitudinal Crack for all sections (feet)
Low (45 sections; 8)	6.7	87
Medium (36 sections; 22)	7.3	82
High (7 sections; 39)	19.1	117

Figure 4 below presents the overall effect of various base types on cracking performance and joint score. Since the sample size was similar for all three base types (varying between 28 and 32), the percent of the sections in each performance category was used for comparison. Most (85%) of the sections with PATB and DGAB had “Excellent/Good” performance (Figure 4). LCB base types showed higher joint scores, indicating that there is a higher propensity for the dowel bars to be misaligned if installed within the PCC pavement with LCB. Sections with LCB also showed a have higher cracking potential. Sections with PATB and DGAB had good performance with lowest cracking potential and comparatively lower potential for dowel bar misalignment.

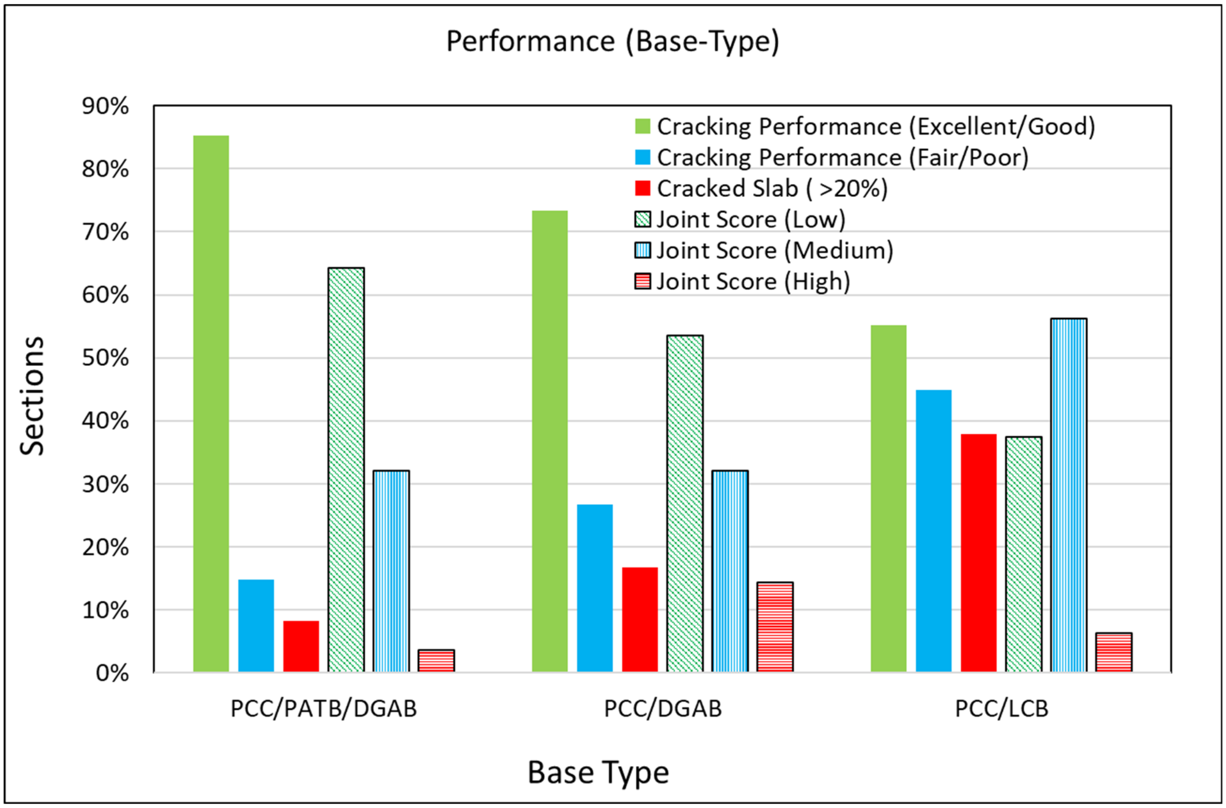
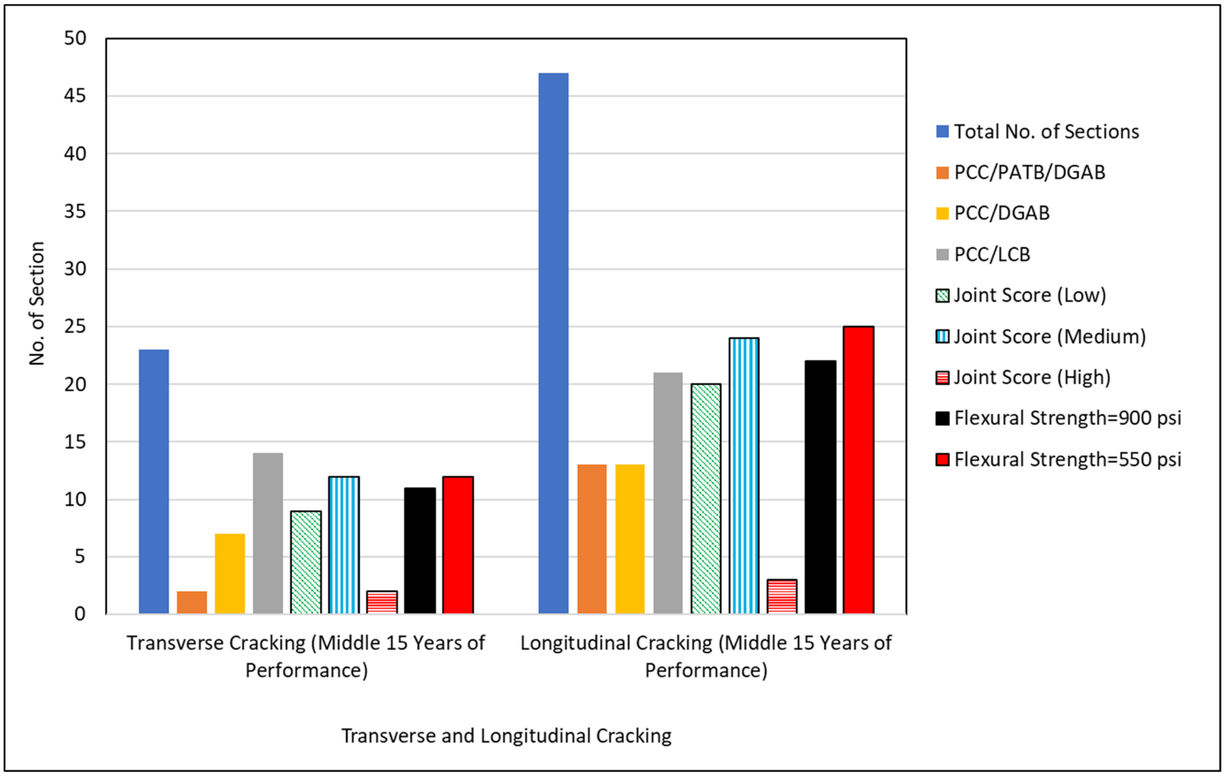
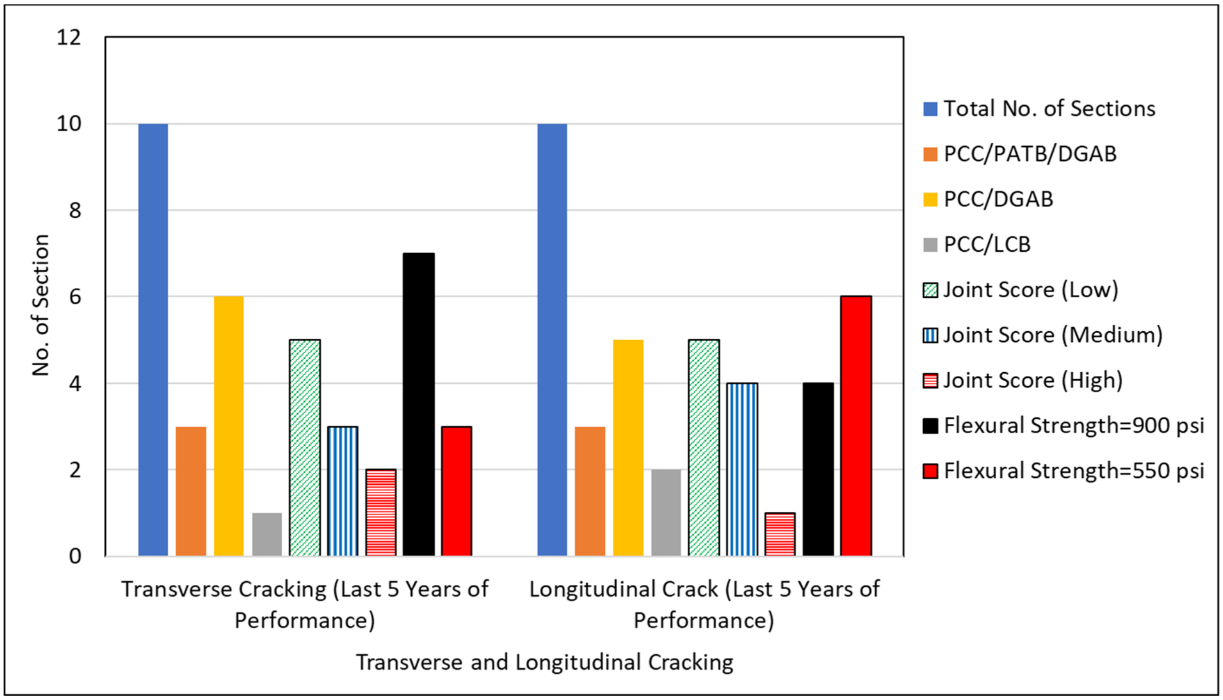


Figure 4: Effect of Base Type on Cracking Performance

The year of crack initiation (if any) for each of the 88 sections was also identified and analyzed. The objective was to see how quickly cracking began for the test sections during the monitoring period to date (Figure 5). The results showed that transverse cracks and longitudinal cracks began to appear within the first 15 years of performance for 23 sections and 47 sections, respectively. Only 10 sections were observed to be without cracks for at least 15 years.


No. of Section
50
45
40
35
30
25
20
15
10
5
0
Transverse Cracking (Middle 15 Years of Performance)
Longitudinal Cracking (Middle 15 Years of Performance)
Transverse and Longitudinal Cracking
Total No. of Sections
PCC/PATB/DGAB
PCC/DGAB
PCC/LCB
Joint Score (Low)
Joint Score (Medium)
Joint Score (High)
Flexural Strength=900 psi
Flexural Strength=550 psi

(a)



(b)

Figure 5: Effect of Base Type and Joint Score on Crack Initiation Year

The final analysis looked at cracked slabs. Figure 6 shows that sections with LCB had a higher likelihood of cracked slabs, similar to the results for transverse and longitudinal cracks discussed above. A total of 57 sections out of 88 were observed to have zero cracked slabs. Sections with PATB and DGAB performed better than the LCB sections.

The results also indicate a possible relationship between joint score and cracked slabs. Sections with zero cracked slabs had a lower average joint score (15) than sections with more than 20% cracked slabs, which had an average joint score of 22.

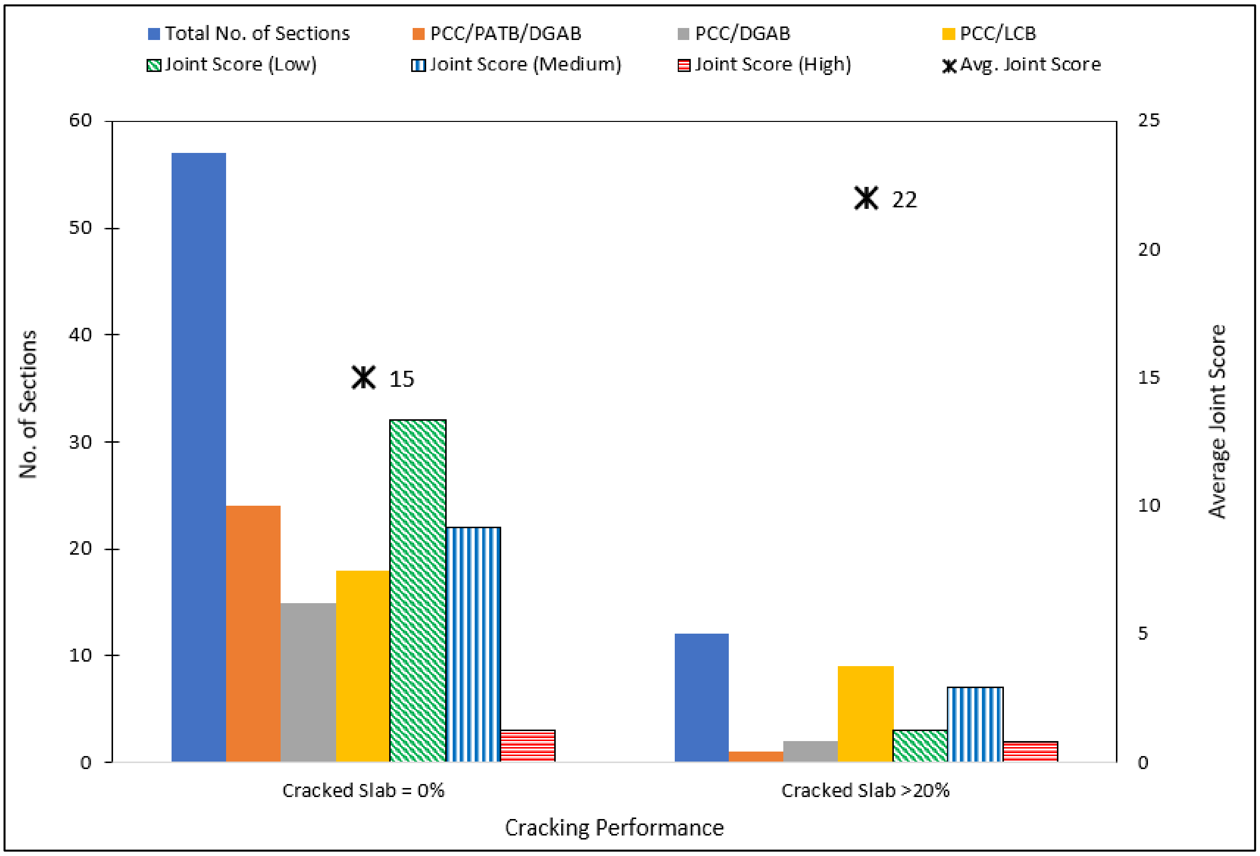


Figure 6: Effect of Base Type and Joint Score on Cracked Slabs

5.0 AREAS OF LOCALIZED ROUGHNESS ANALYSIS

The 2018 report by Karamihas and NCE calculated the ALR from an elevation profile. The elevation profile was filtered using an algorithm for the index of interest. The profile was then smoothed using a moving average with a 9.84-inch base. IRI was calculated as the slope between elevation points in the smoothed profile trace. The IRI was then rectified by calculating its absolute value and a moving average was applied to the rectified trace. The moving average used a segment length of 25 feet with first and last segments being 12.5 feet.

To expand on the 2018 report and draw comparisons between all SPS-2 test sections (not just those included in the original analysis), a simplified method was developed to compute the elevation profile needed for ALR computation. The elevation data used in the simplified method differed from the filtered elevation profile used in the 2018 report by Karamihas and NCE. The simplified method used profile elevation data from high-speed surveys collected at 1-inch intervals (sourced from LTPP table MON_HSS_PROFILE_ELEVATION_25). From this point, the elevation profile was processed in the manner as described in the 2018 report to calculate segmented IRI (at short intervals of 1.641 feet) in the left and right wheel path along the full length of the test section. IRI segments from all survey runs (multiple passes performed during each visit) were averaged for each short-interval segment. Figure 7 and Figure 8 show the IRI calculated using the short-interval roughness profile (averaged over the entire section) versus the section-level IRI computed by LTPP (sourced from LTPP table MON_HSS_PROFILE_SECTION). The average percent error in the short-interval IRI calculated using elevation data was 9% in both the left and right wheel path. This comparison validated that the computed segmented roughness profile was reasonable and could be used to identify ALR in the current analysis.

The current study evaluated the relationship between total ALR and several other factors of all SPS-2 core test sections:

- Comparison of total ALR in the left and right wheelpath to the age of the pavement
- Comparison of the deterioration rate of total ALR to SPS-2 design factors
- Change in total ALR after a maintenance treatment
- Comparison of total ALR to the precent of slabs cracked transversely
- Comparison of total ALR to joint score category

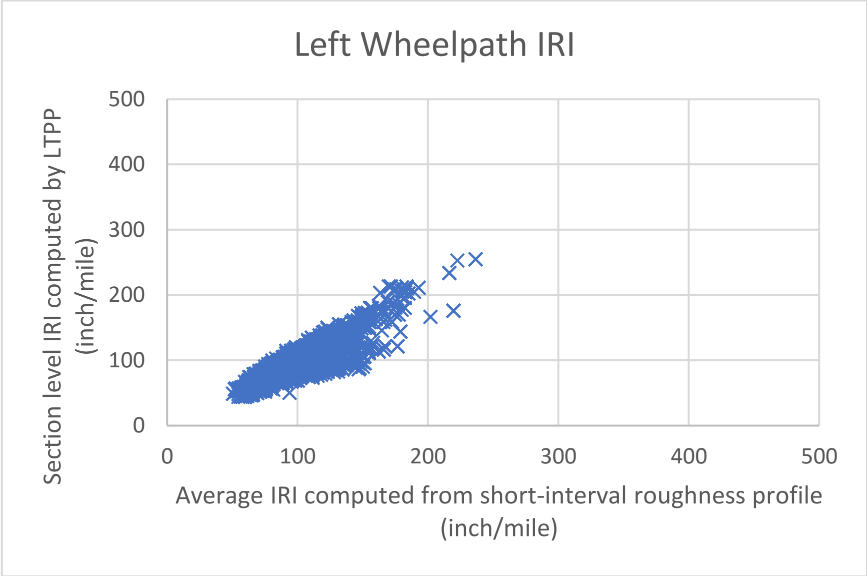


Figure 7: Comparison of Computed IRI in the Left Wheel Path

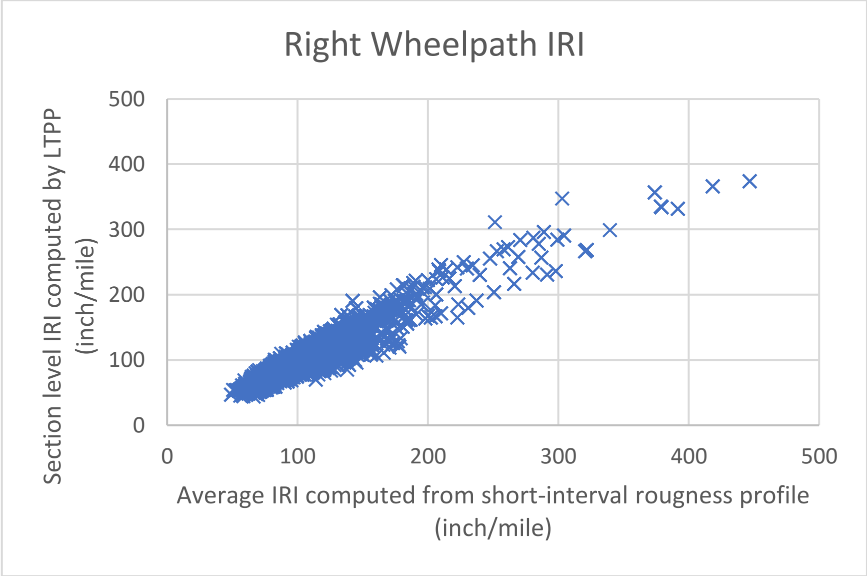
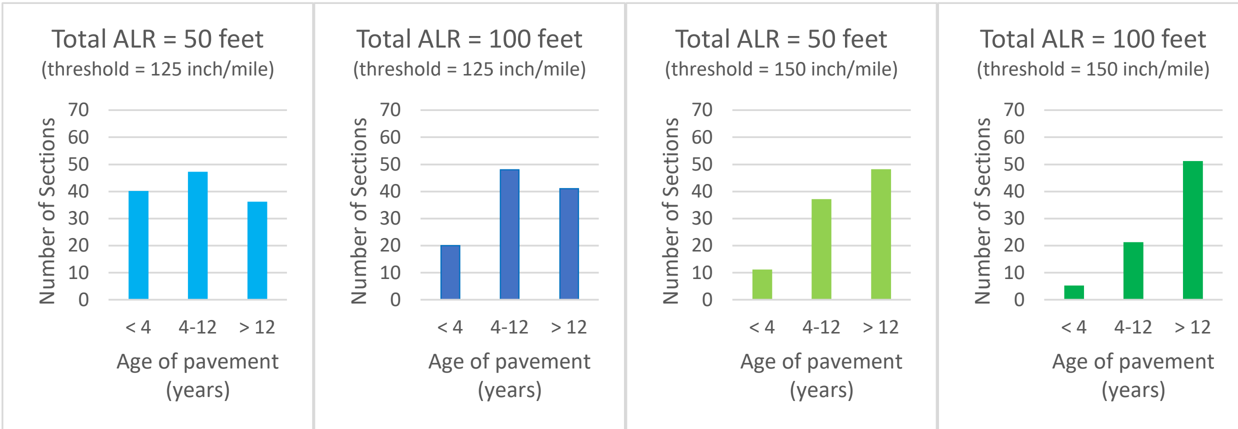


Figure 8: Comparison of Computed IRI in the Right Wheel Path

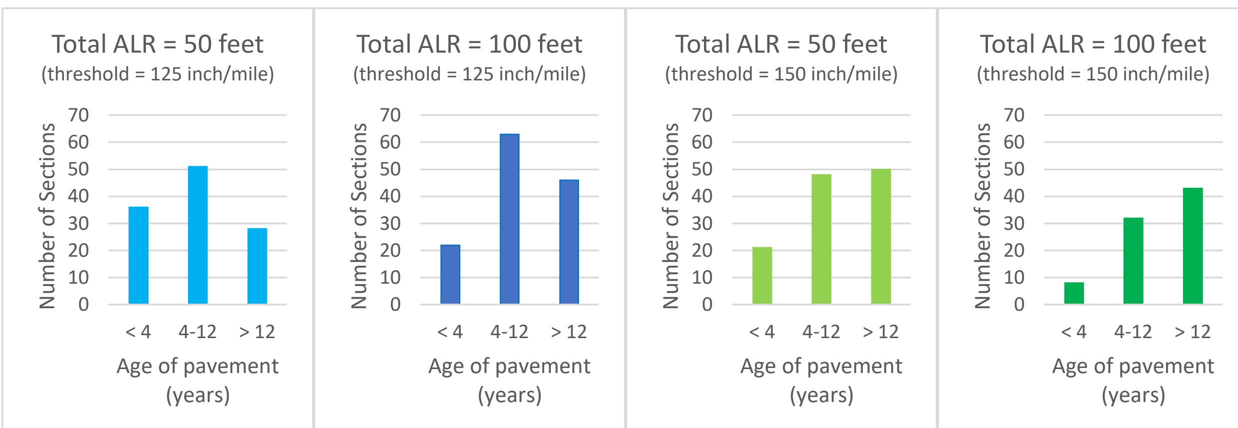
5.1 Comparison of Total ALR to Pavement Age

ALR was identified as any segment of the roughness trace that exceeded a designated threshold. Total ALR was evaluated for 205 SPS-2 test sections and identified when the summed length of all segments with ALR reached 50 feet and 100 feet for the designated thresholds of 125 inch/mile and 150 inch/mile, respectively. The results, shown in Figure 9 and Figure 10, indicate that higher quantities of ALR were found in older pavements (greater than 12 years old). The relationship between pavement age and total ALR was more pronounced when using the threshold of 150 inch/mile – a trend that was consistently demonstrated in both the left and right wheel paths.



(a) (b) (c) (d)

Figure 9: Total ALR in the Left Wheel Path Versus Pavement Age



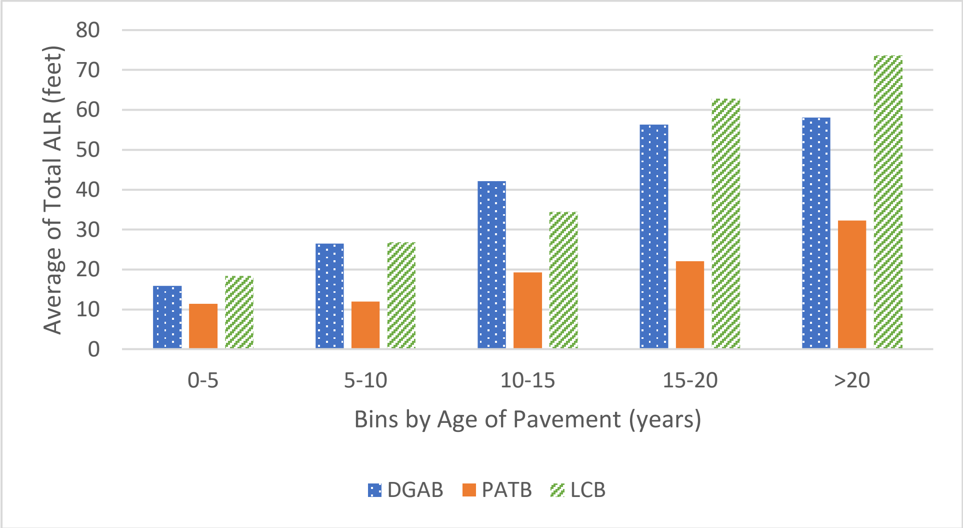
(a) (b) (c) (d)

Figure 10: Total ALR in the Right Wheel Path Versus Pavement Age

5.2 Comparison of Total ALR to Base Type

Next, the average total ALR from SPS-2 core test sections were compared by base type: DGAB, PATB, and LCB. Previous studies on the SPS-2 experiment (including previous analyses in this TPF-5(291) study), have determined that base type was a significant design factor in pavement performance; test sections with PATB base had typically performed better in the IRI and transverse cracking than test sections with LCB bases.

Figure 11 shows the average total ALR subdivided into bins by pavement age in 5-year increments. The results show that ALR was more prevalent in test sections with DGAB and LCB base types. The rate of increase in ALR was also higher in test sections with DGAB and LCB base types. However, this pattern was not consistent for all projects; the standard deviation of the total ALR in Figure 11 ranges from 19 to 86 feet. In some states, test sections with LCB base type had less ALR than DGAB test sections and in other states, the opposite was shown. Occasionally, ALR decreased midway through the pavement's life – possibly due to due to seasonal and diurnal changes in curl and warp – but this should be studied further.

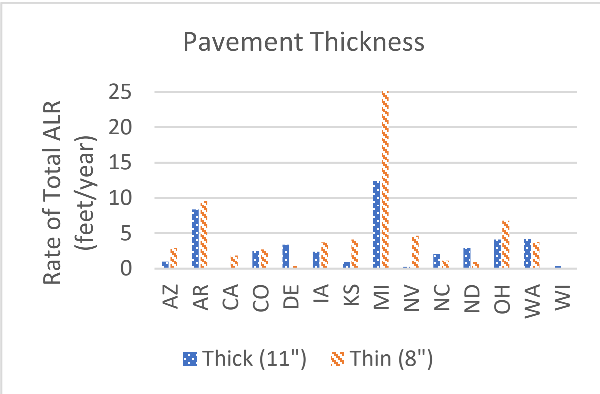


*ALR threshold is 150 inch/mile

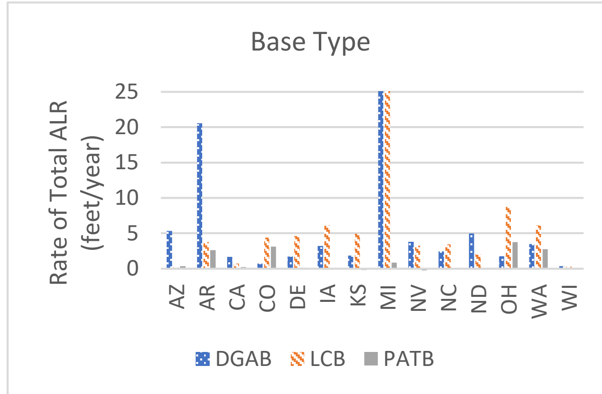
Figure 11: Left Wheel Path, Total ALR by Base Type

5.3 Comparison of Total ALR to SPS-2 Design Factor

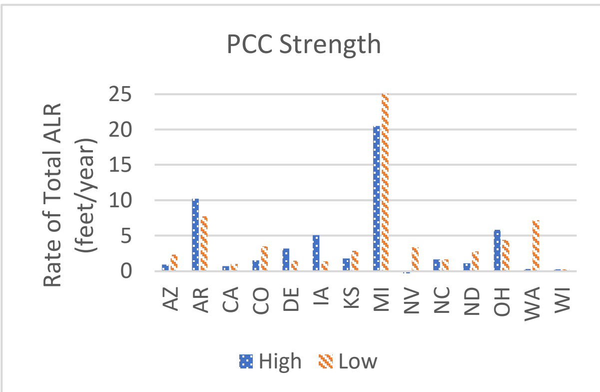
Figure 12 shows the average rate of change in total ALR at each SPS-2 project by the design factor. From these figures, trends within each project can be compared to determine which projects followed a common trend and which projects were outliers. The figures cut off the upper bound of the rate of total ALR at 25 feet per year. Michigan is an outlier in these figures, where there were four test sections where the rate of total ALR exceeded 25 feet per year. These predominantly DGAB test sections (0213, 0214, 0215, and 0217) went out-of-study within 10 years. A relatively higher rate of total ALR was also found in DGAB test sections in the states of Arizona and Arkansas. However, the rate of ALR in Arizona and Arkansas may have been driven by the effects of curl-and-warp and traffic-loading at these sites. In several other states, test sections with LCB base type had a higher rate of ALR, followed by sections with DGAB base type. The other design factors did not contribute as significantly to the rate of total ALR as base type. A very slight trend was apparent in terms of lane width, where widened lanes at several sites had a slower rate of total ALR than 12-foot-wide lanes.



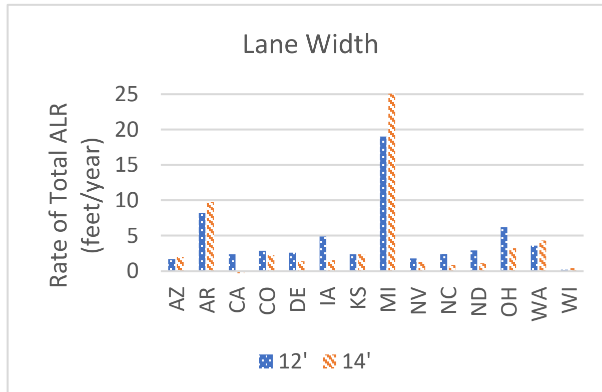
(a)



(b)

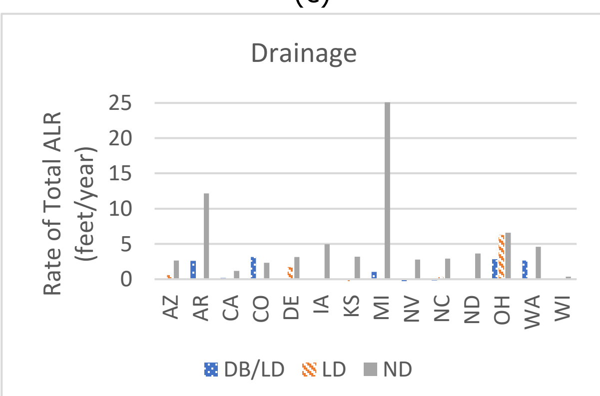


(c)



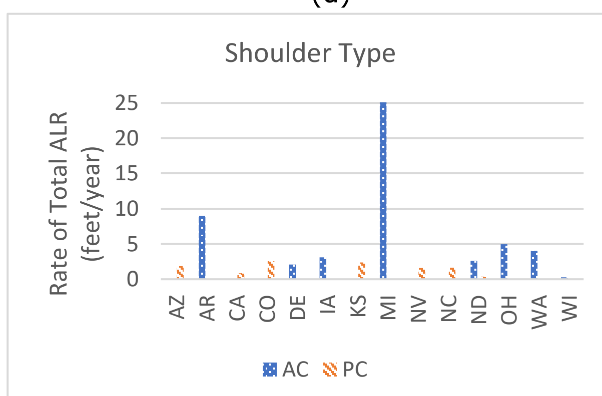
*CA had 13-foot-wide lanes instead of 14-foot-

(d)



* DB/LD – drainage blanket with longitudinal drains,

(e)



(f)

Figure 12: Average Rate of Change in Total ALR by Design Factor and State

5.4 Change in Total ALR after Maintenance Activity

The average rate of total ALR in test sections where certain maintenance treatments were performed was also evaluated. The rate of ALR was based on the entire monitoring period of each test section and not the relative change in ALR due to the maintenance treatment. As a baseline, test sections where no work was performed had an average rate of total ALR of 5.9 feet per year, but this group of test sections also had the highest standard deviation. Test sections that received maintenance treatments, such as crack sealing or surface grinding, had slower rates of ALR than other test sections, but these test sections, post-maintenance, may have been in better condition than test sections that needed patching or slab replacement. Because maintenance was performed for corrective and preventive reasons, and was subject to the agency's decision making, the condition of pavement at time of treatment for SPS-2 test sections may vary. Therefore, the comparison of total ALR to another condition metric (i.e., transverse cracking and joint score in the subsequent analyses) may determine the usefulness of total ALR in complementing these other condition metrics for pavement performance evaluation.

Table 10: Left Wheel Path, Average Rate of Total ALR in Test Sections by Maintenance Work Type

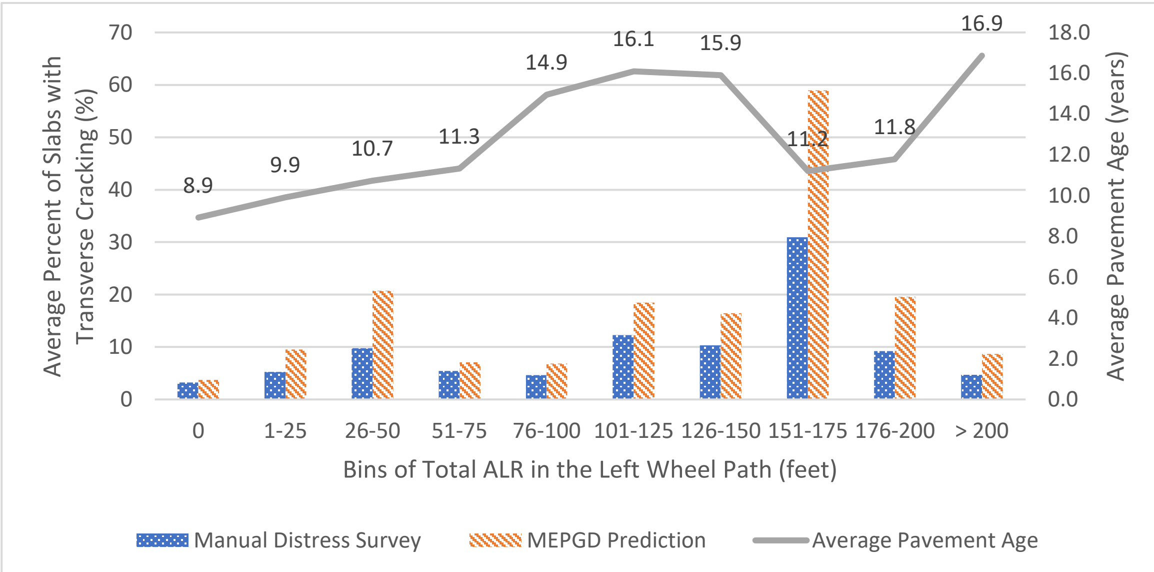
Maintenance Work Type	Average (feet/year)	Standard Deviation (feet/year)
Grinding Surface	1.6	3.9
Transverse Joint Sealing	2.1	3.7
Crack Sealing	3.3	5.8
AC Shoulder Restoration	3.5	8.2
Partial-Depth Patching of PCC Pavements at Joints	3.8	8.6
Skin Patching	3.9	4.3
Lane-Shoulder Longitudinal Joint Sealing	4.0	8.7
Patch Potholes - Hand Spread, Compacted with Truck	5.7	4.2
No Work Performed	5.9	23.3
Partial-Depth Patching of PCC Pavement Other Than at Joint	5.9	7.7
Full-Depth Patching of PCC Pavement Other Than at Joint	6.5	4.2
Full-Depth Transverse Joint Repair Patch	6.7	14.3
PCC Slab Replacement	8.2	16.3

*ALR threshold is 150 inch/mile.

**Negative change in ALR indicates that total ALR decreased after maintenance treatment.

5.5 Comparison of Total ALR to Transverse Cracking

Transverse cracking and joint score were the last two parameters evaluated. Figure 13 shows the relationship between total ALR and transverse cracking. The chart does not show a consistently linear correlation between total ALR and the percent of slabs with transverse cracking. This suggests mechanisms and design factors that contribute to ALR do not necessarily contribute to transverse cracking to the same degree. ALR growth is often confounded by diurnal and seasonal changes associated with curl-and-warp, while transverse cracking relates more to the performance of pavement under traffic-loading. The average pavement age was shown to vary considerably in relation to both ALR and transverse cracking, further suggesting that rate of ALR and the rate of transverse cracking may be different depending on the test section.



*ALR threshold is 150 inch/mile.

Figure 13: Comparison of Total ALR in the Left Wheel Path to Measured and Predicted Percentages of Slabs with Transverse Cracking

5.6 Comparison of Total ALR to Joint Score Category

Table 11 shows the average total ALR of 117 test sections categorized by joint score; as previously described (Table 2), joint score number can be divided into categories of low, medium, and high. The table shows that ALR typically increased with joint score. Although ALR at medium and high joint scores were not significantly different, the low joint score ALR averages4 were smaller. The MIT Scan performed on test sections to calculate joint score was performed on pavements with ages ranging from 14 to 27 years. Within this age range, the correlation between joint score and total ALR seemed to be slightly better for older pavements (19 to 27 years) than younger pavements (14 to 18 years).

Table 11: Average total ALR by joint score category.

Joint Score Category	Average Total ALR (feet)	Standard Deviation (feet)
Low	37	52
Medium	56	75
High	61	44

6.0 KEY FINDINGS

The following summarizes the key findings from the joint score and ALR analyses:

- PCC sections with lower flexural strength exhibited earlier crack initiation (on average).
- Overall, joint score had a correlation with cracking performance.
- The lower the joint score number, the slower the crack propagation rate, and the smaller the overall crack length.
- There was a relative lack of correlation between joint score and other design factors (lane width, PCC strength, layer thickness, drainage).
- Base type was observed to be a strong correlating factor with joint score.
- On average, severity of ALR correlated to the age of the pavement.
- Severity of ALR in the left and right wheel paths were similar – especially when using a higher threshold for ALR.
- SPS-2 core test sections with PATB base type had lower severity and growth of ALR than test sections with DGAB and LCB base types.
- Surface grinding may reduce the severity of ALR, but the degree of improvement in ALR should be studied further.
- The curl-and-warp of the pavement and overall condition may confound the growth of ALR.
- There was not a consistent linear correlation between ALR and transverse cracking.
- Based on the available data, test sections with ALR typically had higher joint scores, but there was significant deviation in the relationship between ALR and joint score.

This study expanded on previous research to understand the correlation (or lack thereof) of joint score number and ALR to pavement performance in conjunction with the design factors of the SPS-2 experiment. In the case of both joint score number and ALR, base type was the strongest correlating factor. However, this strong correlation may be indicative of the similarly strong correlation that base type has to transverse cracking and roughness. Joint score number and ALR do succeed in adding context to pavement evaluations as performance indicators. However, more research is warranted to further understand their mechanisms and uses in performance analyses.