

CRCP Performance Patterns Gleaned from Texas Pavement Management Data

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Abstract

Performance management is increasingly emphasized at the state and national levels. This is evident in the Moving Ahead for Progress in the 21st Century Act (MAP-21) and performance targets set by individual state Departments of Transportation (DOTs). This management approach requires the establishment of performance goals, measures, and metrics for pavement networks, and systematic measurement of progress towards achieving the goals. This paper evaluates the performance of continuously reinforced concrete pavement (CRCP) in the Houston, Texas area based on the performance management criteria outlined in MAP-21 and the Texas Department of Transportation (TxDOT) statewide pavement performance goal. The performance metrics used in this analysis are the International Roughness Index (IRI), punchouts per mile, and TxDOT's Condition Score (CS). The data for conducting this analysis was obtained from TxDOT's Pavement Management Information System (PMIS) database. Despite approaching or exceeding the end of its design life, the performance of CRCP in the Houston District has been consistently successful over the past nine years based on the performance management criteria outlined in MAP-21 and TxDOT's statewide pavement performance target.

Introduction

Performance management is increasingly emphasized at the state and national levels. This is evident in the notices of proposed rulemaking (NPRMs) of The Moving Ahead for Progress in the 21st Century Act (MAP-21) and performance targets set by individual state Departments of Transportation (DOTs). (A MAP-21 NPRM is a public notice published in the federal registrar to obtain comments from the public regarding the MAP-21 processes and requirements.) This management approach requires the establishment of performance goals, measures, and metrics for pavement networks.

In January 2015, the Federal Highway Administration (FHWA) issued an NPRM that addresses MAP-21 rules for assessing pavement and bridge conditions for the national highway performance program (FHWA 2015). The NPRM includes proposed performance goals, measures, and metrics for pavement conditions. Each state DOT is required to report to the FHWA on progress towards achieving its targets every two years.

In addition to MAP-21, individual state DOTs have established their own performance goals for their pavement networks. For example, in August 2001, the Texas Department of Transportation (TxDOT) adopted the goal of 90 percent

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of the state-maintained pavement lane-miles would be in “good or better” condition by 2012. TxDOT measures progress towards achieving this goal on an annual basis. This goal is incorporated in TxDOT’s 2015-2019 Strategic Plan.

In this paper, we evaluate the performance of continuously reinforced concrete pavement (CRCP) in Texas based on the performance management criteria outlined in MAP-21 and TxDOT’s statewide pavement performance goal.

The paper begins with a review of CRCP design and management practices in Texas. Then, the performance of CRCP in the Houston District (a major adopter of CRCP in Texas) is analyzed to determine how well these pavements meet the performance requirements set by MAP-21 and TxDOT. Finally, the study summary and conclusions are presented.

CRCP Design and Management Practices in Texas

Currently, about six percent of TxDOT’s roadway lane-miles is CRCP, about one percent is jointed concrete pavement (JCP), and about 93 percent is asphalt-surfaced pavement (see Table 1). The asphalt-surfaced pavement category includes both asphalt concrete pavement (ACP) and old portland cement concrete (PCC) pavement that has been overlaid with hot-mix asphalt. As shown in Figure 1, most of Texas CRCP is located in large urban areas (e.g., Houston and Dallas-Fort Worth).

**Table 1. Current Composition of TxDOT’s Roadway Pavement Network
(not including frontage roads)**

Pavement Type	Lane-Miles	Percent of Total Lane-Miles
JCP	2,554	1%
CRCP	10,309	6%
Asphalt-surfaced	162,603	93%

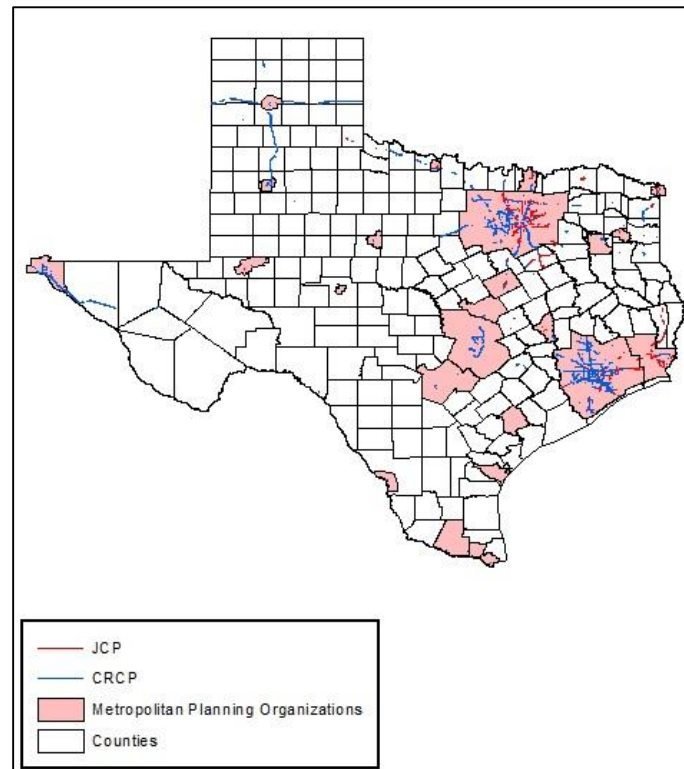


Figure 1. Locations of Concrete Pavement (CRCP and JCP) in Texas

Currently, the only officially approved design method for CRCP by TxDOT is the 1993 AASHTO Guide for Design of Pavement Structures. Typical input values used by TxDOT for this design method are shown in Table 2.

Previously, the concrete slab thickness required by TxDOT had a range between 8 inches and 15 inches. Currently, the design standard used by TxDOT specifies that the thickness of CRCP slab should be 6 inches to 13 inches. Thickness values outside this range need to be submitted to the District Engineer for approval along with justification.

TxDOT requires one of the following base layer combinations for concrete slab support:

- 4-inch asphalt concrete pavement or asphalt stabilized base, or
- A minimum 1-inch asphalt concrete bond breaker over 6-inch cement stabilized base.

Tied PCC shoulders are normally used with CRCP. The width of shoulders varies from 2 to 10 feet, depending on the functional classification of the roadway under design. The PCC shoulder should have the same thickness and the same base layers as the main-lane pavement.

Table 2. Input Variables and Design Values Used in TxDOT CRCP Design

Input Variable	TxDOT Design Value
28-day concrete modulus of rupture, psi	620
28-day concrete elastic modulus, psi	5,000,000
Effective modulus of subgrade reaction, psi/in	300 – 700
Serviceability indices	4.5 (initial) – 2.5 (terminal)
Drainage coefficient	• 0.91 – 0.95 for annual rainfall 58 – 50 in. • 0.96 – 1.00 for annual rainfall 49 – 40 in. • 1.01 – 1.05 for annual rainfall 39 – 30 in. • 1.06 – 1.10 for annual rainfall 29 – 20 in. • 1.11 – 1.16 for annual rainfall 19 – 8 in.
Overall standard deviation	0.39
Reliability, %	95% for > 5 million design ESALs 90% for ≤ 5 million design ESALs
18-kip equivalent single axle load (ESAL)	Based on the traffic analysis report provided by the Transportation Planning and Programming Division

Figure 2 shows a typical CRCP pavement layout and Table 3 shows the longitudinal steel design for CRCP in Texas.

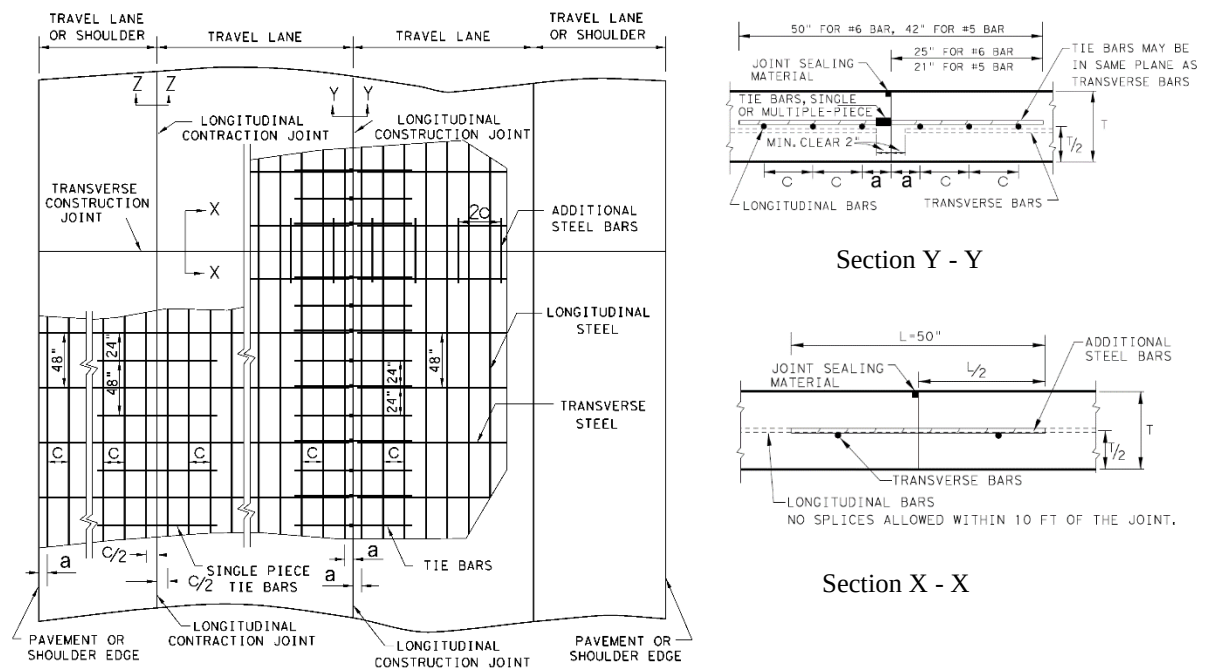


Figure 2 Typical CRCP Slab and Construction Joint Layout

Table 3 Longitudinal Steel Design

Slab Thickness, in.	Steel Bar Size	Steel Bar Spacing, in.	First Spacing at Edge or Joint, in.	Additional Steel Bars at Transverse Construction Joint	
				Spacing, in.	Length, in.
7.0	#5	6.5	3 to 4	13	50
7.5	#5	6.0	3 to 4	12	50
8.0	#6	9.0	3 to 4	18	50
8.5	#6	8.5	3 to 4	17	50
9.0	#6	8.0	3 to 4	16	50
9.5	#6	7.5	3 to 4	15	50
10.0	#6	7.0	3 to 4	14	50
10.5	#6	6.75	3 to 4	13.5	50
11.0	#6	6.5	3 to 4	13	50
11.5	#6	6.25	3 to 4	12.5	50
12.0	#6	6.0	3 to 4	12	50
12.5	#6	5.75	3 to 4	11.5	50
13.0	#6	5.5	3 to 4	11	50

Unit Conversions: 1 inch = 25.4 mm.

Performance of CRCP in the Houston District

The performance of CRCP in the Houston District (a primary adopter of CRCP in Texas) was analyzed from the perspective of MAP-21 and TxDOT's statewide goal. The data for conducting this analysis was obtained from TxDOT's Pavement Management Information System (PMIS) database.

The MAP-21 pavement performance measures for the national highway performance program (as outlined in the January 2015 NPRM) are as follows:

- Percentage of Pavement Lane-Miles in Good Condition
- Percentage of Pavement Lane-Miles in Poor Condition

State DOTs can specify separate targets for the National Highway System (NHS) and non-NHS for these performance measures. For CRCP, the metrics for defining these performance measures are the International Roughness Index (IRI) and Cracking Percent. Each performance metric is rated as Good, Fair, or Poor based on the threshold values shown in Table 4. The January 2015 NPRM of MAP-21 defines cracking percent as “the percentage of pavement surface with longitudinal cracking and/or punchouts, spalling or other visible defects.” However, to be consistent with TxDOT’s pavement management practices (TxDOT 2014), this study uses the metric “number of punchouts per mile” in lieu of cracking percent. According to TxDOT’s pavement condition rating manual (TxDOT 2014), a punchout must be greater than 12 inches long or wide to be rated as a punchout. If a punchout is observed to be longer than 10 feet, then one punchout for each 10 feet of length should be recorded. Also, each of the boundaries of a punchout (except the slab edge, if present) must exhibit either severe spalling or faulting.

The ratings of these metrics are then combined based on the decision tree shown in Figure 3 to determine the overall performance rating for the pavement section.

Table 4. MAP-21 Performance Metrics for CRCP

Metric	Metric Range	Metric Rating
IRI	<95 in/mi	Good
	95-170 in/mi (rural and small urban areas)	Fair
	95-220 in/mi (urbanized areas)	
	>170 in/mi (rural and small urban areas)	Poor
	>220 in/mi (urbanized areas)	
Cracking Percent*	<5 %	Good
	5–10%	Fair
	> 10%	Poor

* This study uses the metric “number of punchouts per mile” in lieu of cracking percent.

Unit Conversions: 1 in/mi = 0.016 m/km.

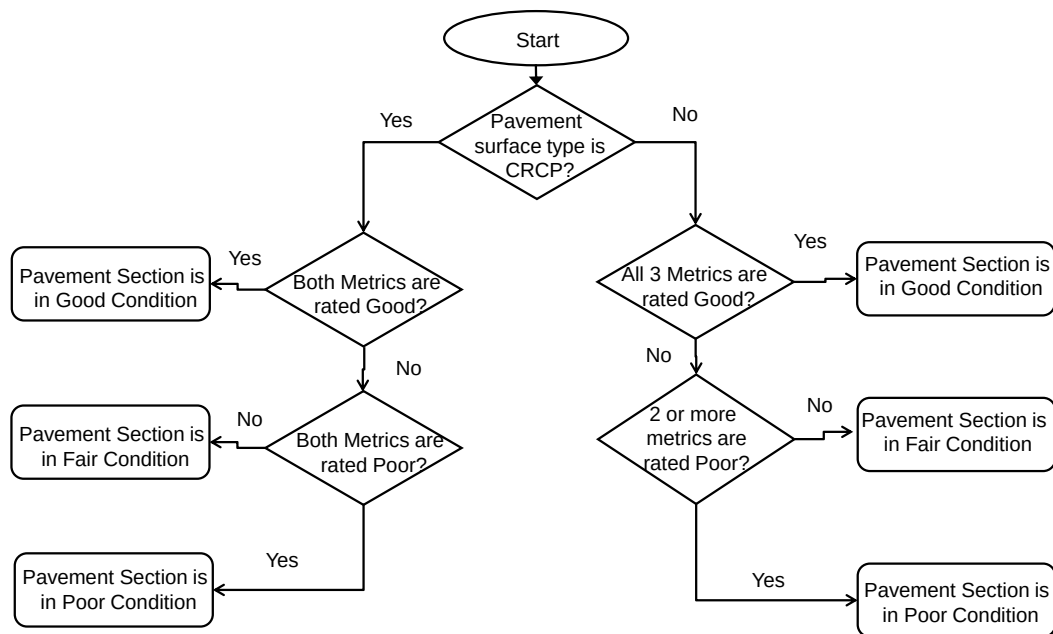
As mentioned earlier, TxDOT has a performance goal of having 90 percent of the state-maintained pavement lane-miles in “good or better.” The term “good or better” is defined based on the Condition Score (CS) metric. CS is a computed index that describes the pavement overall condition in terms of distresses present and ride quality. CS ranges from 1 (worst) to 100 (best). A CS of 70 or higher represents pavement in “good or better” condition. Equations 1 to 3 are used for computing CS. These equations were developed for Texas in the 1990s (Stamply et al. 1995).

$$U_i = \begin{cases} 1.0 & \text{when } L_i = 0 \\ 1 - \alpha e^{-\left(\frac{\rho}{L_i}\right)^\beta} & \text{when } L_i > 0 \end{cases} \quad (1)$$

$$DS = 100 \times \prod_{i=1}^n U_i \quad (2)$$

$$CS = U_{\text{Ride}} \times DS \quad (3)$$

L_i is the density of each distress type in the pavement section. U_i is a utility value (ranging between zero and 1.0) and represents the quality of a pavement in terms of overall usefulness (i.e., a U_i of 1.0 indicates that distress type i is not present and thus is most useful). α (maximum loss factor), β (slope factor), and ρ (prolongation factor) control the location of the utility curve's inflection point and the slope of the curve at that point. DS is the Distress Score, which is a composite index that combines multiple distress types. U_{Ride} is the surface roughness (ride) utility value. These formulas are discussed in details in Stamply et al. (1995) and Gharaibeh et al. (2012).



* For CRCP the metrics are cracking percent and IRI. For jointed concrete pavement, the three metrics are faulting, cracking percent, and IRI.

Figure 3. Decision Tree for Determining Performance Measure Ratings for Pavement*

International Roughness Index

The PMIS database contains separate fields for IRI in the right wheel-path and IRI in the left wheel-path. This paper uses the average of these two fields for the outside lane.

The box and whisker diagram depicted in Figure 4 shows that the IRI of the middle 68 percent of CRCP lane-miles in the Houston District consistently

ranged between about 80 in/mi and 150 in/mi (with a mean value of approximately 120 in/mile) over the past nine years (2007-2015). Using the IRI thresholds proposed in the January 2015 NPRM of MAP-21, the majority of CRCP lane-miles would be classified as Fair and approximately 25 percent would be classified as Good (see Figure 5). Only less than one percent would be classified as Poor.

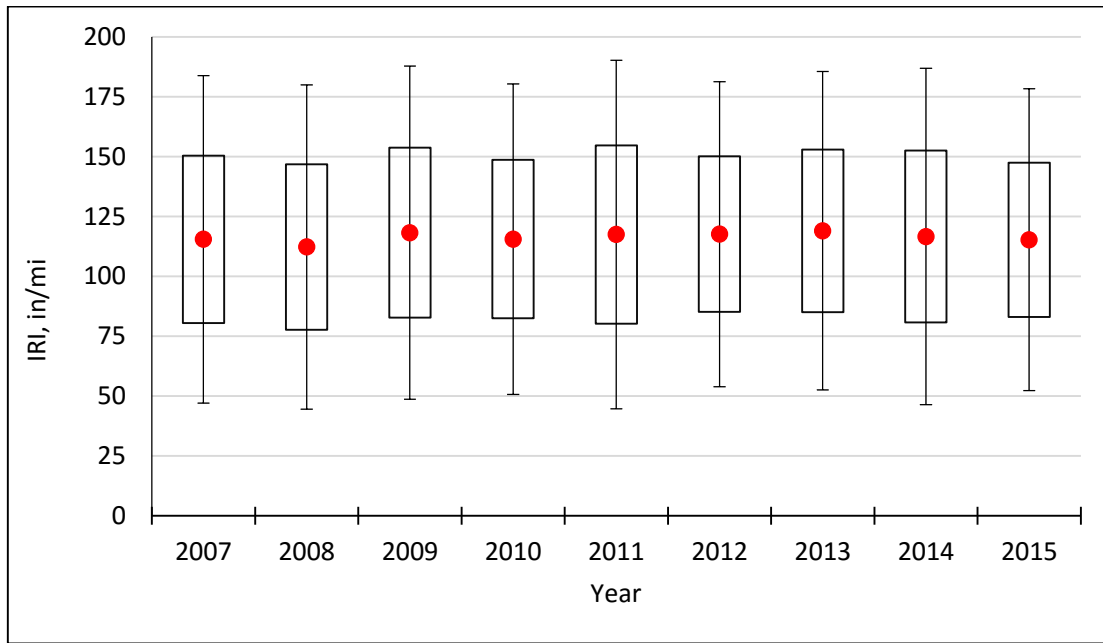


Figure 4. Box and Whisker Diagrams for CRCP IRI in the Houston District (Whiskers = 95% Confidence Interval; Solid Circle=Mean; Box = 68% Confidence Interval)

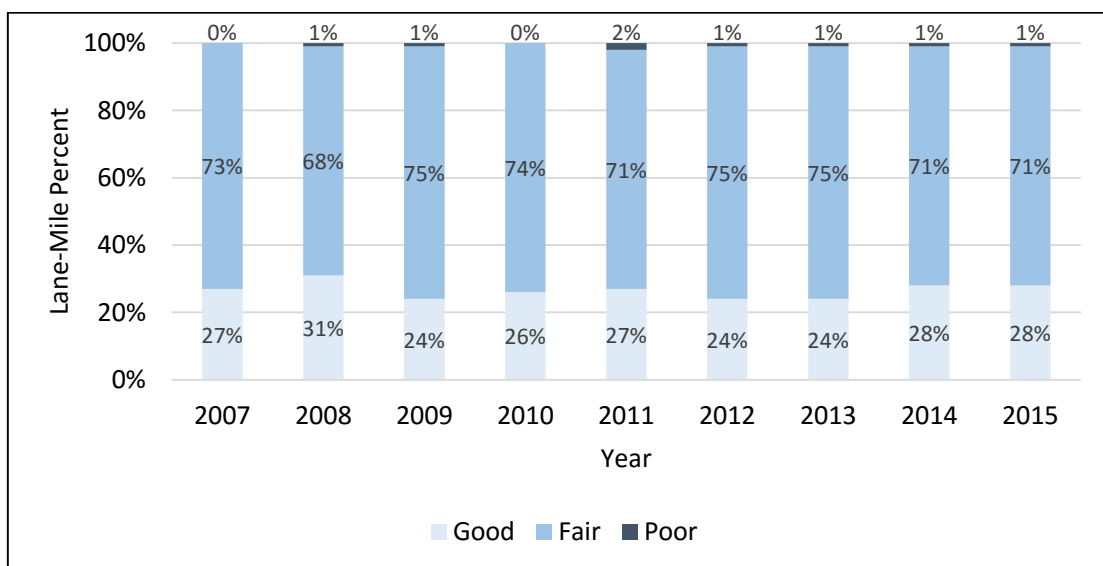


Figure 5. CRCP Performance in the Houston District Based on IRI Thresholds Proposed in the January 2015 NPRM of MAP-21

Condition Score

The CS box and whisker diagram, depicted in Figure 6, shows that the CS of 68 percent of CRCP lane-miles in the Houston District consistently ranged between about 75 and 100 (with a mean value of approximately 90) over the past nine years (2007-2015). Using the CS threshold values specified by TxDOT, the majority (approximately 85 percent) of CRCP lane-miles would be classified as Good or Very Good, approximately seven percent as Fair, and approximately eight percent as Poor (see Figure 7).

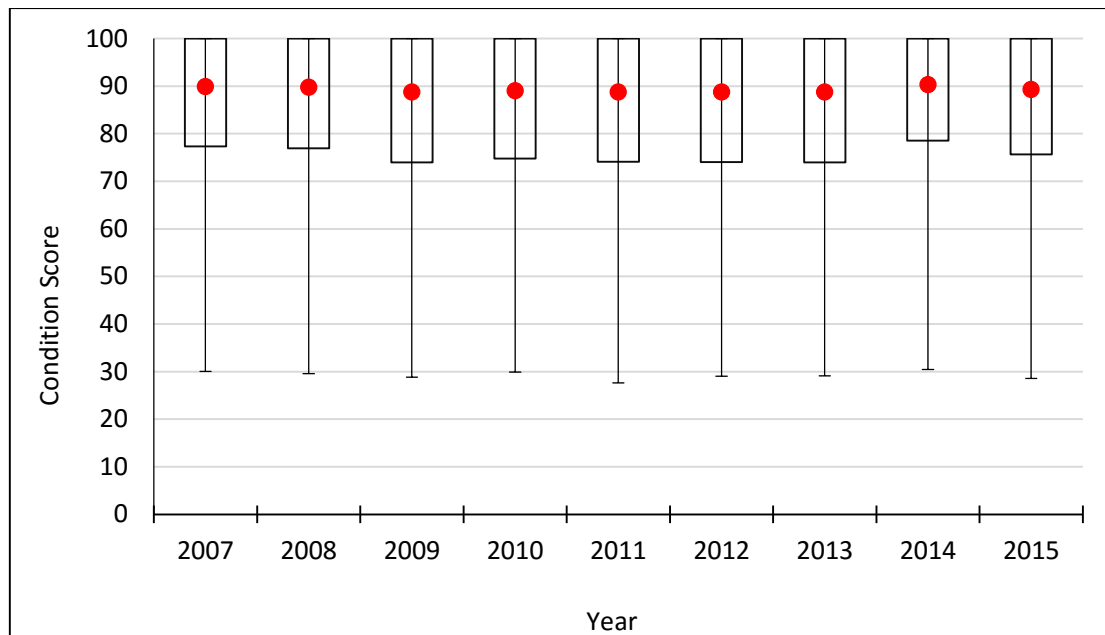


Figure 6. Box and Whisker Diagrams for CRCP CS in the Houston District (Whiskers = 95% Confidence Interval; Solid Circle=Mean; Box = 68% Confidence Interval)

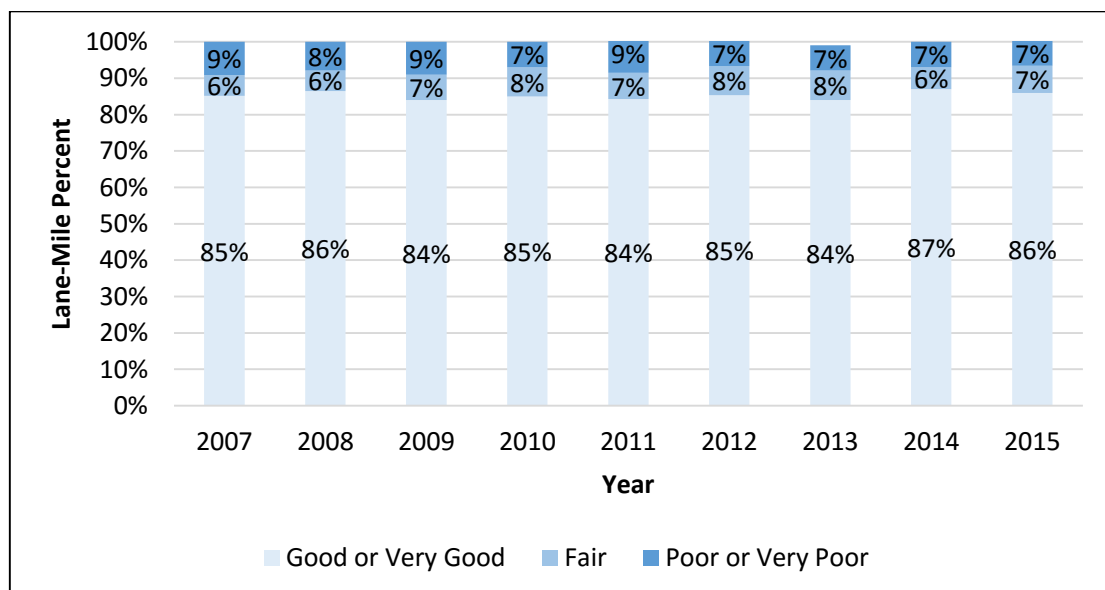


Figure 7. CRCP Performance in the Houston District Based on CS Thresholds Specified by TxDOT

Punchouts

Punchout is a key distress type for CRCP (Gagnon et al. 1998; Won et al. 2008, Roesler and Hiller 2013) and is normally expressed as number of punchouts per mile. The AASHTO Interim Mechanistic-Empirical Pavement Design Guide (MEPDG) (AASHTO 2008) has indicated that the number of medium and high severity punchouts per mile should not exceed ten for interstate highways and freeways, 15 punchouts per mile for primary highways, and 20 punchouts per mile for secondary highways. These threshold values are the maximum number of punchouts per mile for a pavement section at the end of its design life.

The box and whisker diagram, depicted in Figure 8, shows that the number of punchouts per mile (computed on a roadway-by-roadway basis) extremely rarely exceeded 1.5 punchouts per mile over the past nine years, with the mean value consistently hovering around 0.25 punchouts per mile.

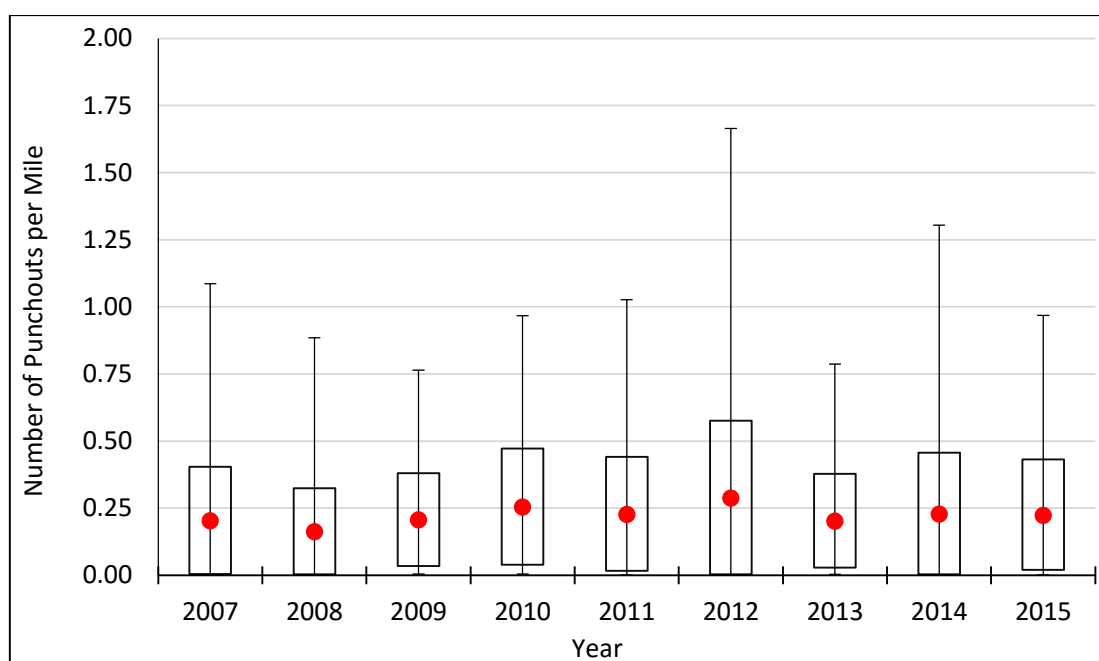


Figure 8. Box and Whisker Diagrams for Road-by-Road CRCP Punchouts per Mile in the Houston District (Whiskers = 95% Confidence Interval; Solid Circle=Mean; Box = 68% Confidence Interval)

Summary and Conclusions

Current CRCP design and performance management practices in Texas are discussed. The performance of CRCP in TxDOT's Houston District was evaluated based on the criteria outlined in MAP-21 and TxDOT's statewide pavement performance target. Three performance metrics were used in this study: IRI, punchout per mile, and TxDOT's Condition Score. Much of CRCP in the Houston District was built in the early 1990s or before and was designed to last for 30 years.

For the majority of CRCP in the Houston District, IRI has consistently ranged between 80 and 150 inch/mile throughout the past nine years (2007-2015), with the mean value of approximately 120 inch/mile. About 85 percent of CRCP lane-miles in the Houston District have a Condition Score of 70 or higher

(described as “good or better” by TxDOT). The number of punchouts per mile (computed on a roadway-by-roadway basis) extremely rarely exceeded 1.5 punchouts per mile over the past nine years, with the mean value consistently hovering around 0.25 punchouts per mile.

A very small proportion of CRCP in the Houston District can be categorized as poor condition (i.e., less than one percent based on IRI, nearly eight percent based on Condition Score, and zero based on punchouts per mile). Despite approaching or exceeding the end of its design life, the performance of CRCP in the Houston District has been consistently successful in the past nine years. In terms of punchouts, however, it appears that this CRCP design is overly conservative.

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