



# Continuously Reinforced Concrete Pavement (CRCP) Performance Curves

Prepared by  
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# Objectives

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To present the new recalibrated PMIS Continuously Reinforced Concrete Pavement (CRCP) performance models to TxDOT personnel in order to obtain feedback.

# Acknowledgment

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Bryan Stampley, Project Director

Jenny Li, CRCP Project Advisor

## **CRCP Panel of Experts**

Abbas Mehdibeigi

David Wagner

Mike Alford

Ron Baker

Andrew Wimsatt

Darlene Goehl

Elizabeth Lukefahr

Stacey Young

Tomas Saenz

Won Moon

# Outline

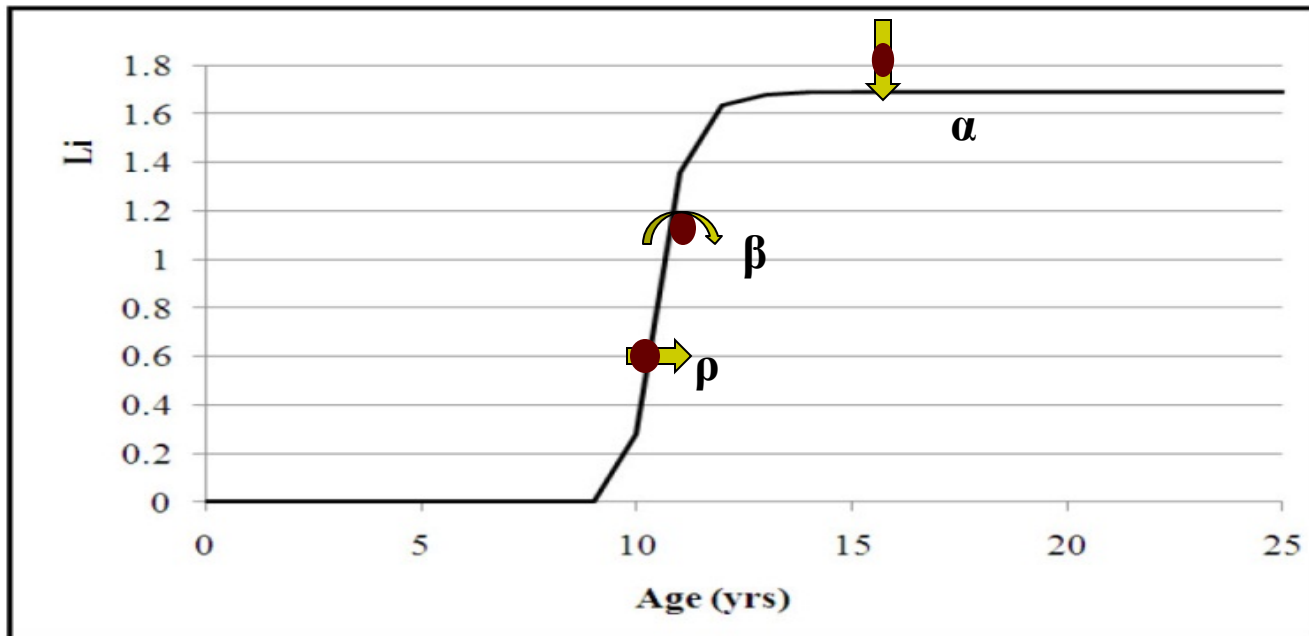
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1. Overview of CRCP Performance Models
2. Recalibration Procedure
3. Recalibrated Models
  - Spalled Cracks
  - Punchouts
  - ACP Patches
  - PCC Patches
  - Ride Score
4. Conclusions

# Overview of CRCP Performance Models

# Performance Curve Parameters

$$L_i = \alpha e^{-\left(\frac{\rho\chi\sigma\varepsilon}{Age}\right)^\beta}$$

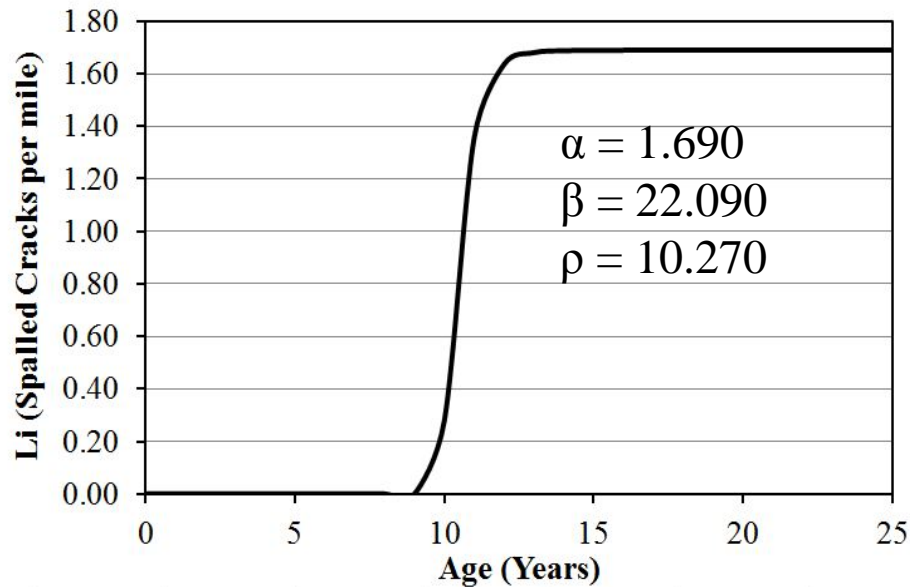


# Performance Curve Parameters

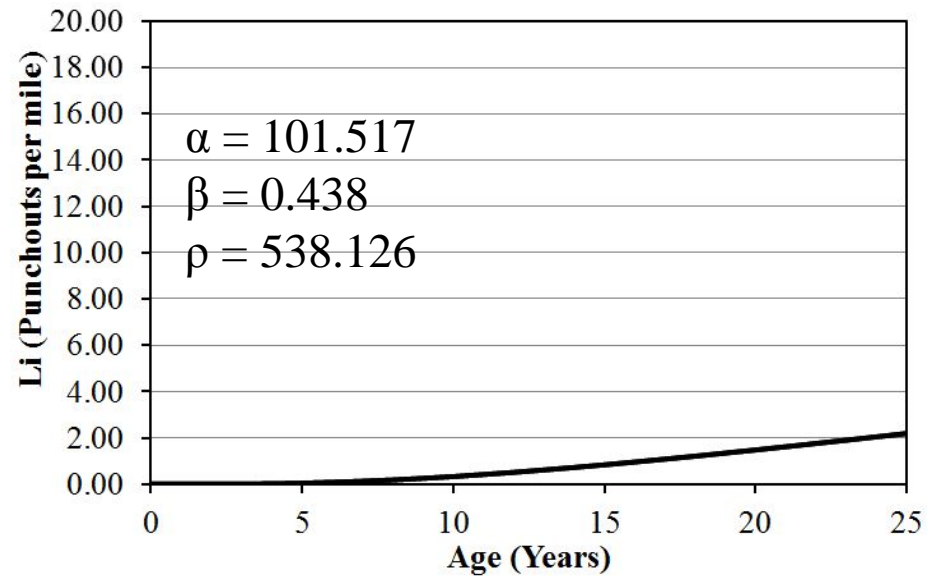
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- $\alpha$ : Alpha is a horizontal asymptote factor and represents the maximum amount that can be lost.
- $\beta$ : Beta is a slope factor and represents the slope of the performance curve at its inflection point.
- $\rho$ : Rho is a prolongation factor and describes how long the pavement will last.
- X: chi coefficient is a truck traffic factor for 18-k ESAL.
- $\epsilon$ : Epsilon is a climatic factor that controls the effect of rainfall and freeze-thaw cycles on performance.
- $\sigma$ : Sigma is a subgrade support factor.

# Current Performance Curves



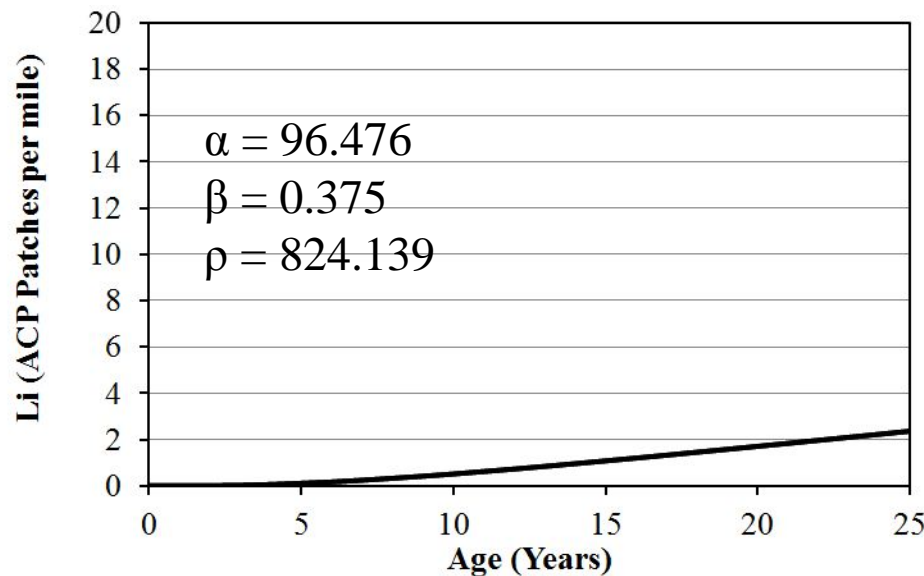
Spalled Cracks



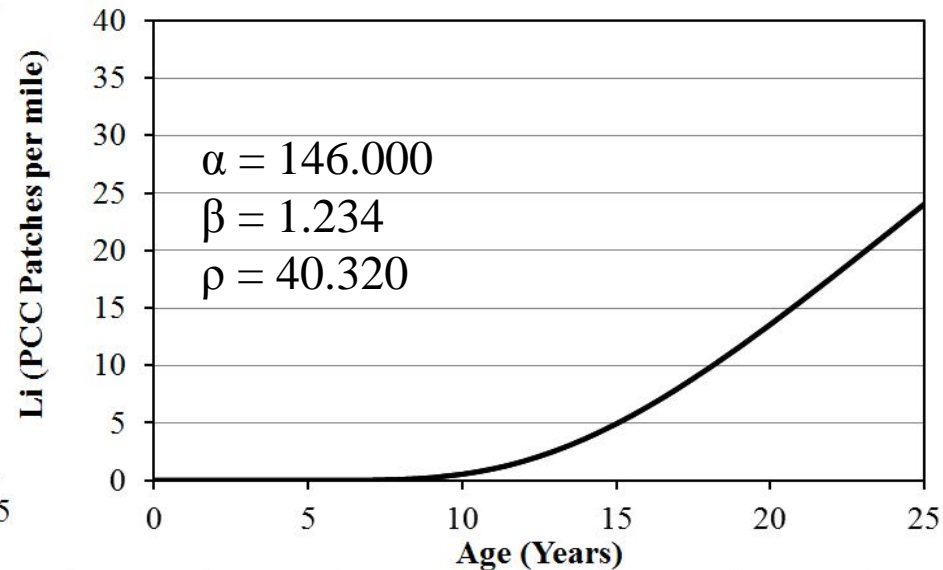
Punchouts



# Current Performance Curves



ACP Patches



PCC Patches

# Recalibration Procedure

# PMIS Data

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Performance curves were re-calibrated for CRCP distress types and ride score using PMIS data from years 1993-2010.

Expert opinion was used to refine the re-calibrated models.

# Recalibration Procedure

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1. Extract pavement distress information from PMIS
2. Perform statistical analysis of the observed level of distress (Li) for each CRCP distress:
  - Spalled Cracks
  - Punchouts
  - ACP Patches
  - PCC Patches

# Recalibration Procedure

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5. Review the results and receive feedback from experienced District personnel to identify critical distress deterioration stages.
6. Filter outliers prior to regression analysis.
7. Perform calibrations using non-linear multi-regression analysis.

# Statistical Analysis for Distress Score and Ride Score

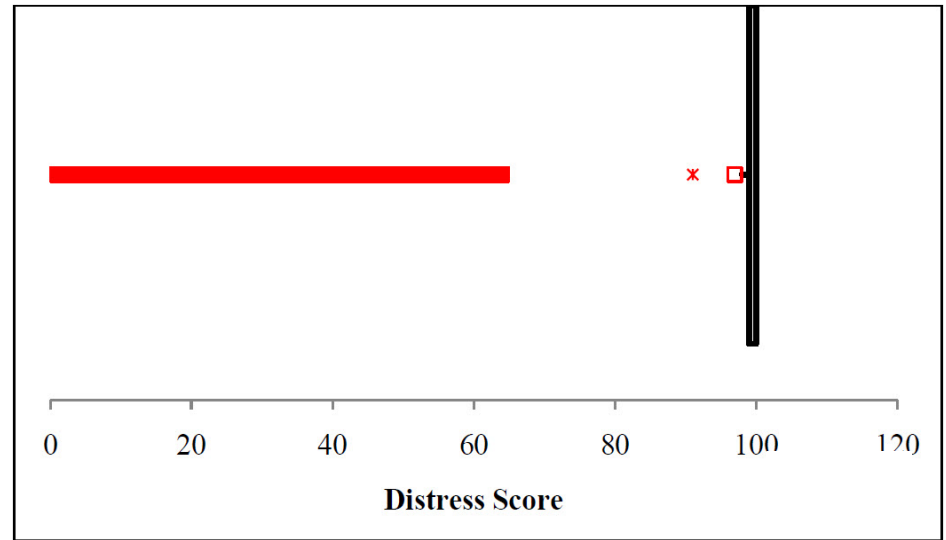
# Statistical Analysis

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- PMIS data were extracted for 25 TxDOT Districts from 1993 to 2010.
- 12,449 sections Statewide were included in the distress statistical analysis
- Box plots and Histograms were generated to study distress characteristics.

# Distress Score Statistical Analysis

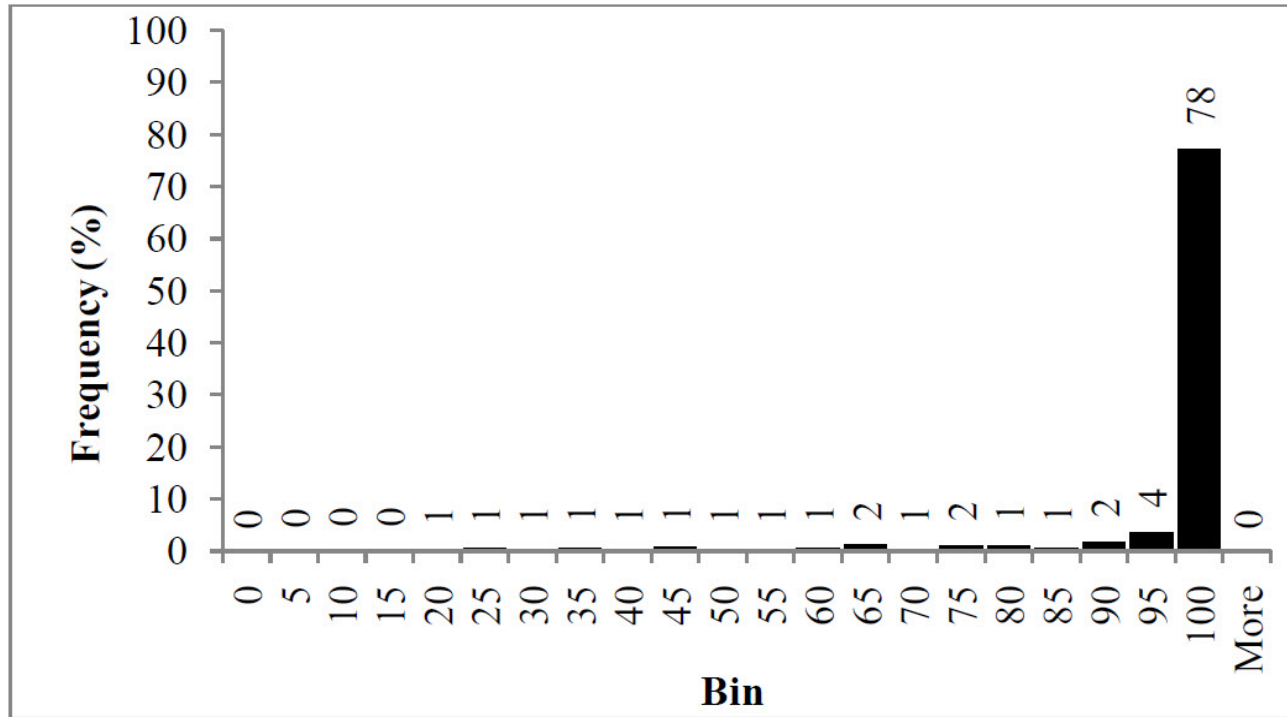
Statistical Parameter	Li
Mean	91.37
Standard Deviation	20.07
Median	100
Minimum	1
Maximum	100
1st Quartile	99
3rd Quartile	100
Frequency of Maximum	83,936



Statistical Parameter and Box Plot for CRCP Distress Score, Statewide. 75% of the data have a score of 99 or higher.



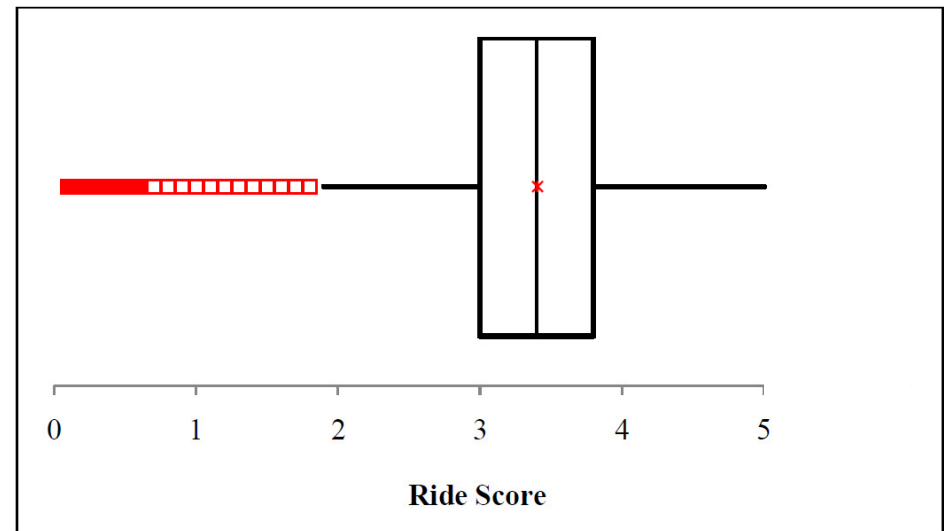
# Distress Score Statistical Analysis



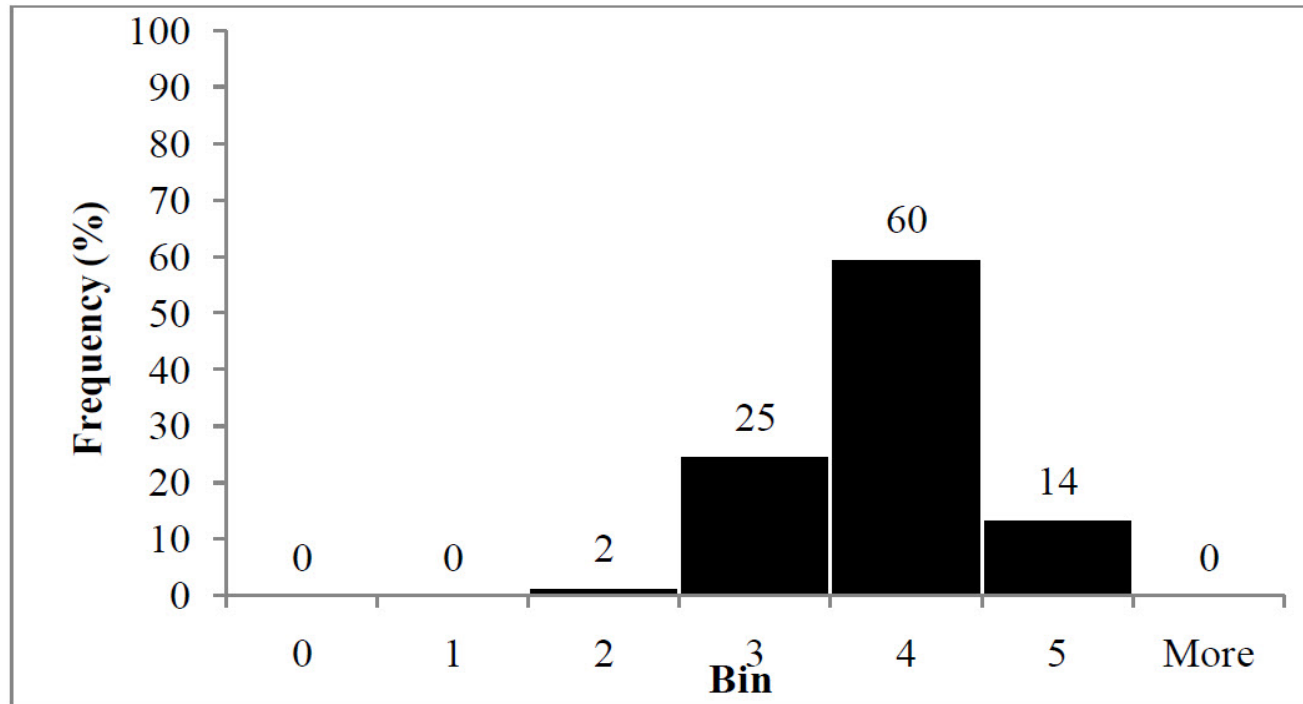
Relative Frequency Plot for CRCP Distress Score, Statewide.  
78% of the Distress Score demonstrate to have a score of 100.

# Ride Score Statistical Analysis

Statistical Parameter	Li
Mean	3.40
Standard Deviation	0.59
Median	3.4
Minimum	0.1
Maximum	5
1st Quartile	3
3rd Quartile	3.8
Frequency of Maximum	8



# Ride Score Statistical Analysis

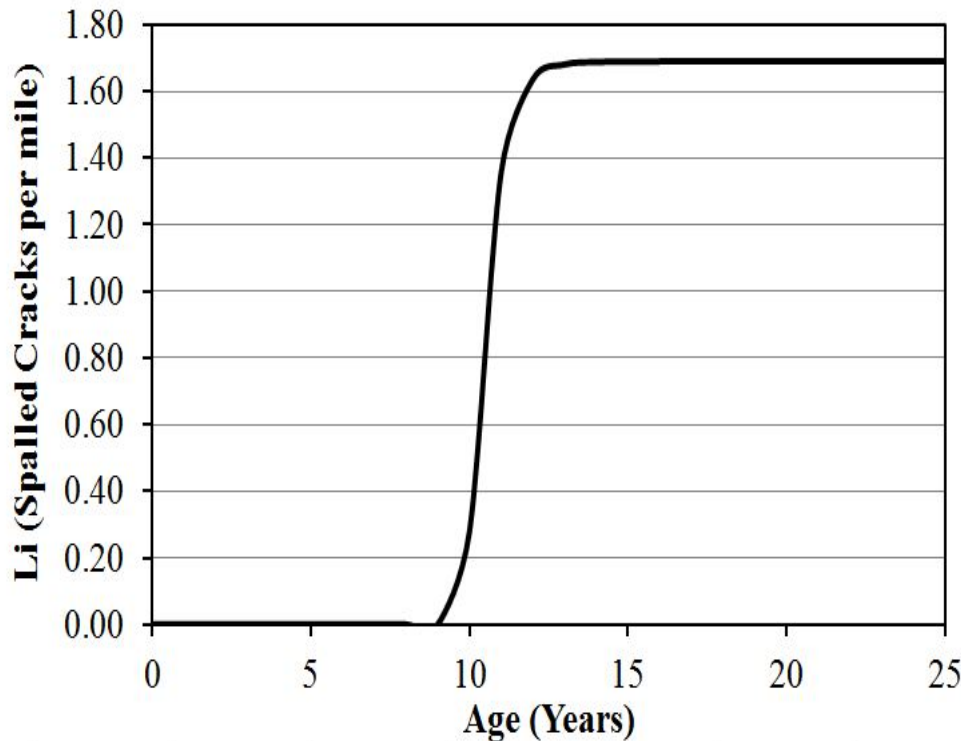


Most of the CRCP sections have ride score between 3 and 4.

# Recalibrated Models

# Spalled Cracks

# Current Spalled Cracks Model



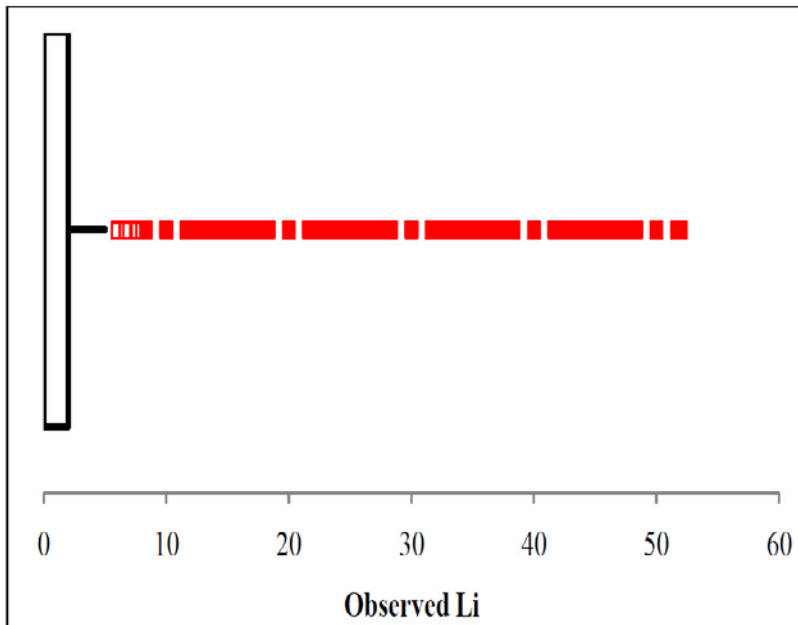
Spalling develops around an age of 9 years.

$\text{Alpha} = 1.69$

$\text{Beta} = 22.09$

$\text{Rho} = 10.27$

# Statistical Analysis for Spalled Cracks

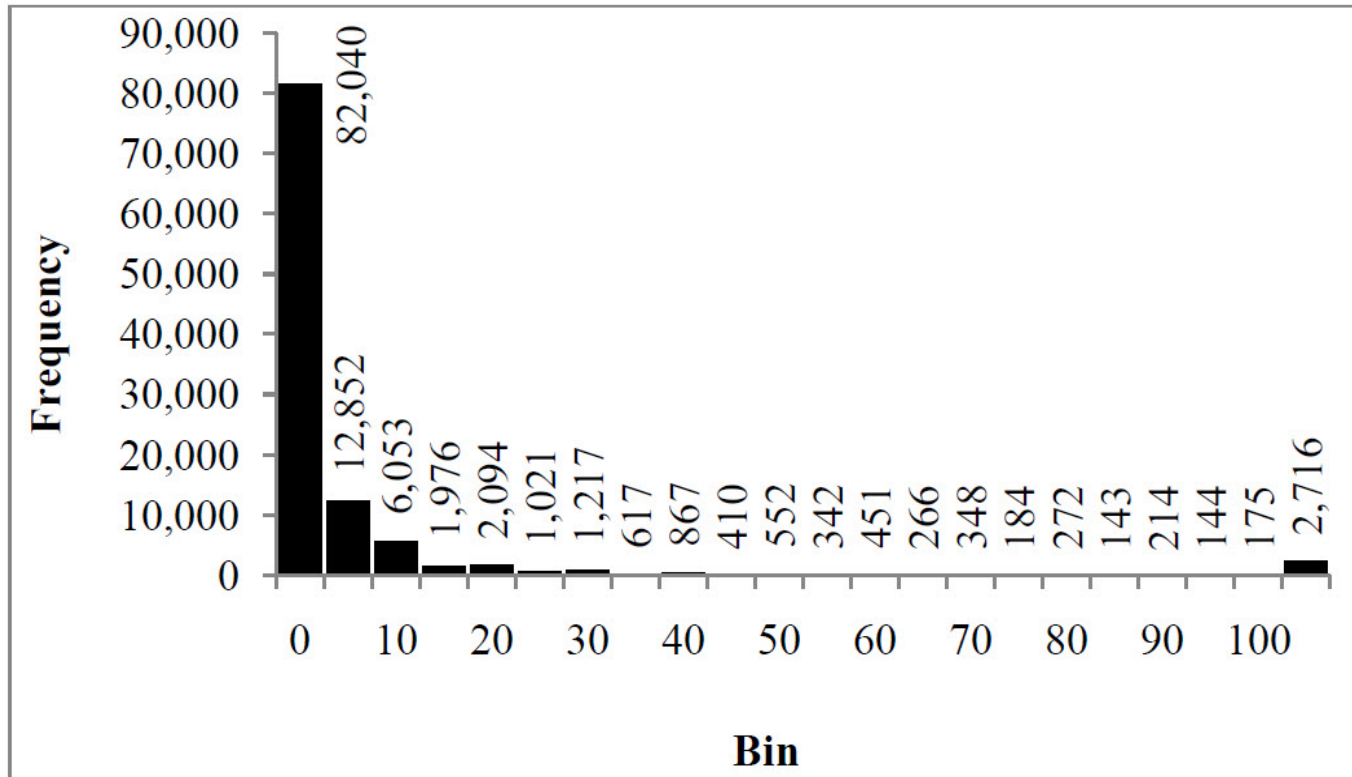


**Observed Li**  
(Spalled Cracks per Mile)

Statistical Parameter	Li
Mean	9.73
Standard Deviation	45.73
Median	0
Minimum	0
Maximum	1980
1st Quartile	0
3rd Quartile	2
Frequency of Maximum	1

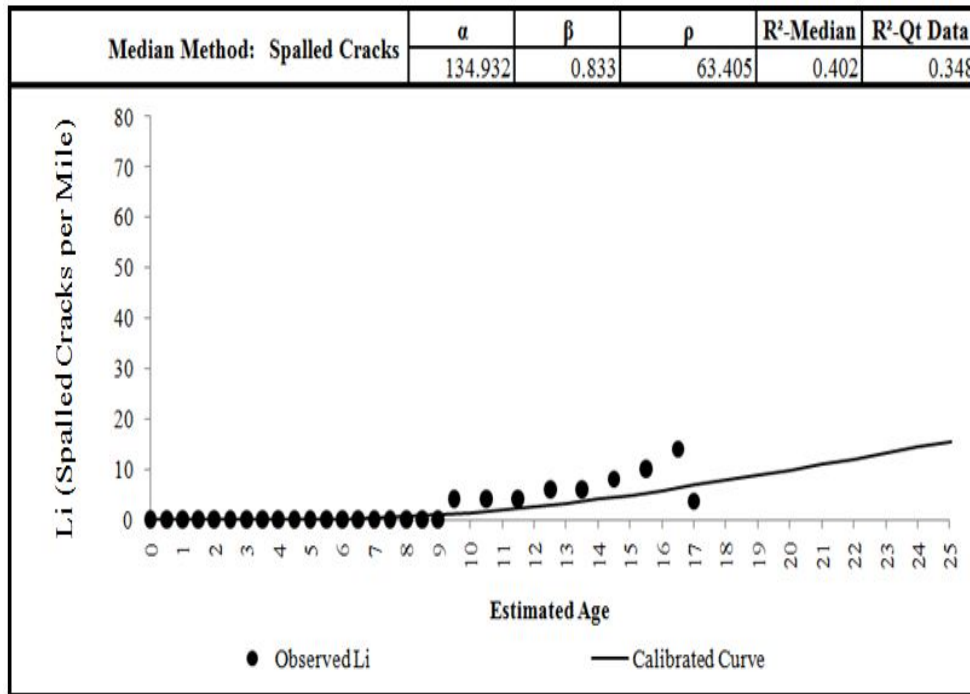
**Li Statistical Parameters**

# Histogram for Spalled Cracks Li





# Recalibrated CRCP Spalled Cracks Performance Model



In the recalibrated model, spalled cracks develop around an age of 9 years.

Alpha = 134.932

Beta = 0.833

Rho = 63.405

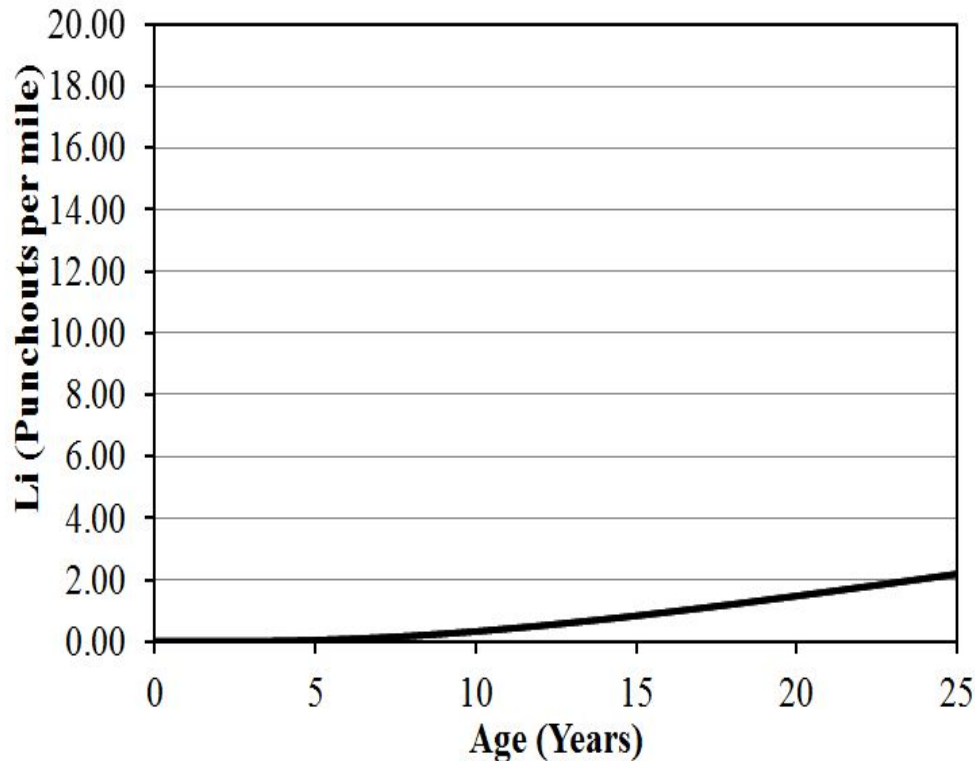
# Expert's Feedback

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According to expert's feedback, the recalibrated spalled cracks curve is the most representative model and shows the slow appearance of this distress.

# Punchouts

# Current Punchouts Model



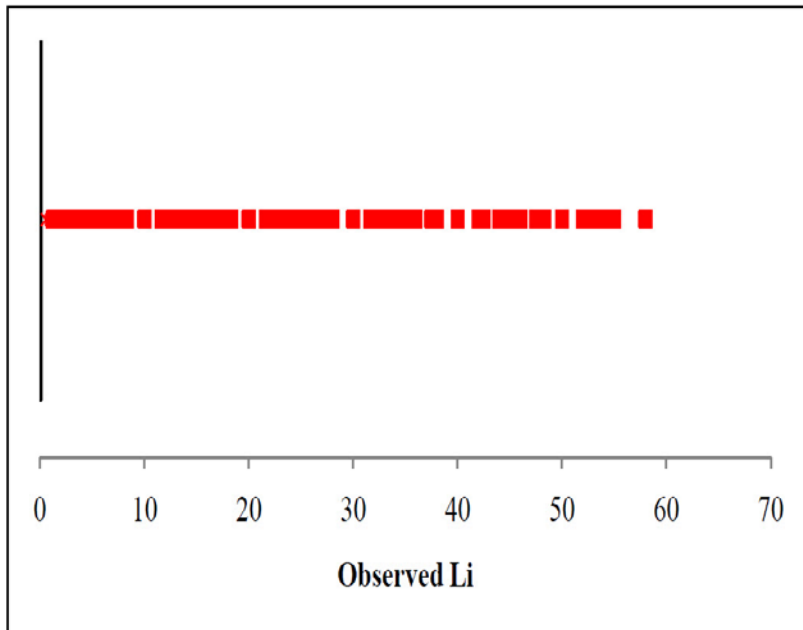
Punchouts develop around an age of 9 years.

$\text{Alpha} = 101.517$

$\text{Beta} = 0.438$

$\text{Rho} = 538.126$

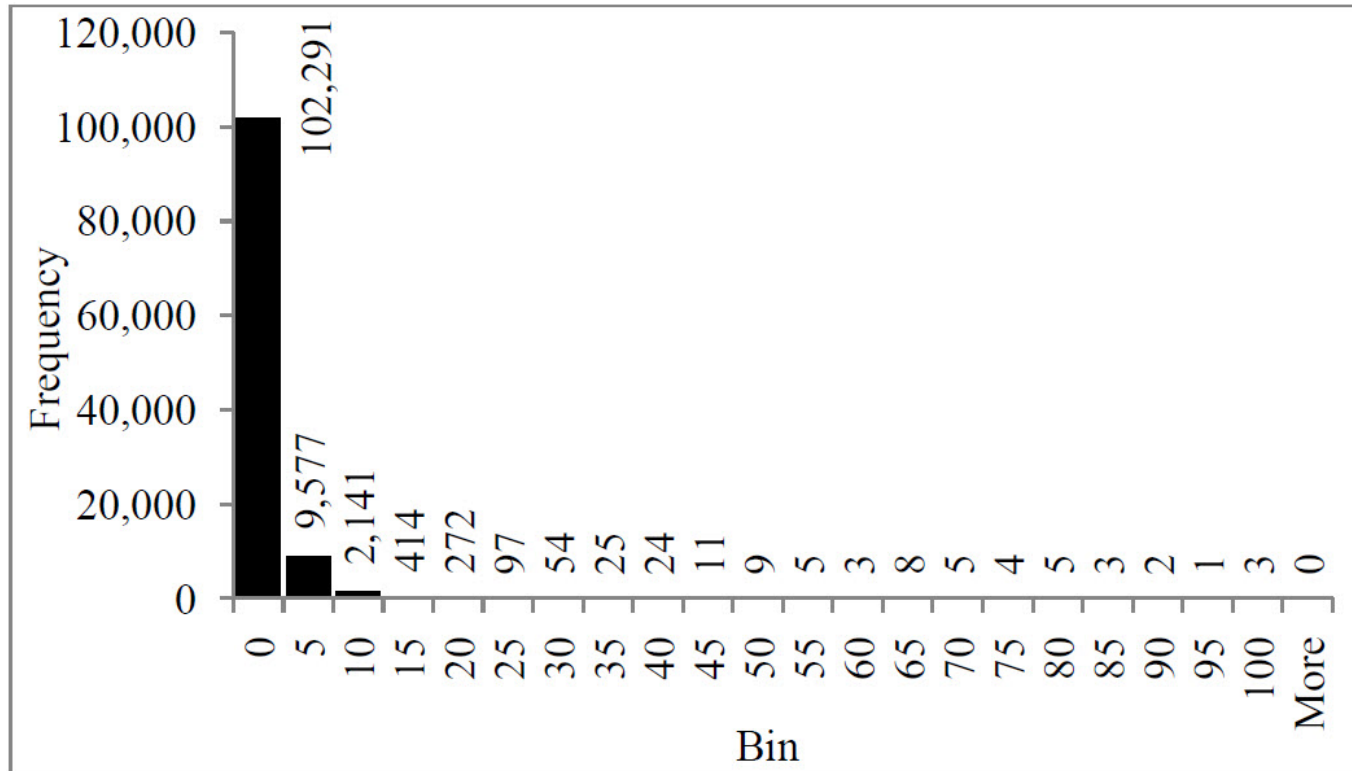
# Statistical Analysis for Punchouts



Statistical Parameter	Li
Mean	0.54
Standard Deviation	2.57
Median	0
Minimum	0
Maximum	100
1st Quartile	0
3rd Quartile	0
Frequency of Maximum	2

**Observed Li**  
(Punchouts per Mile)

# Histogram for Punchouts Li

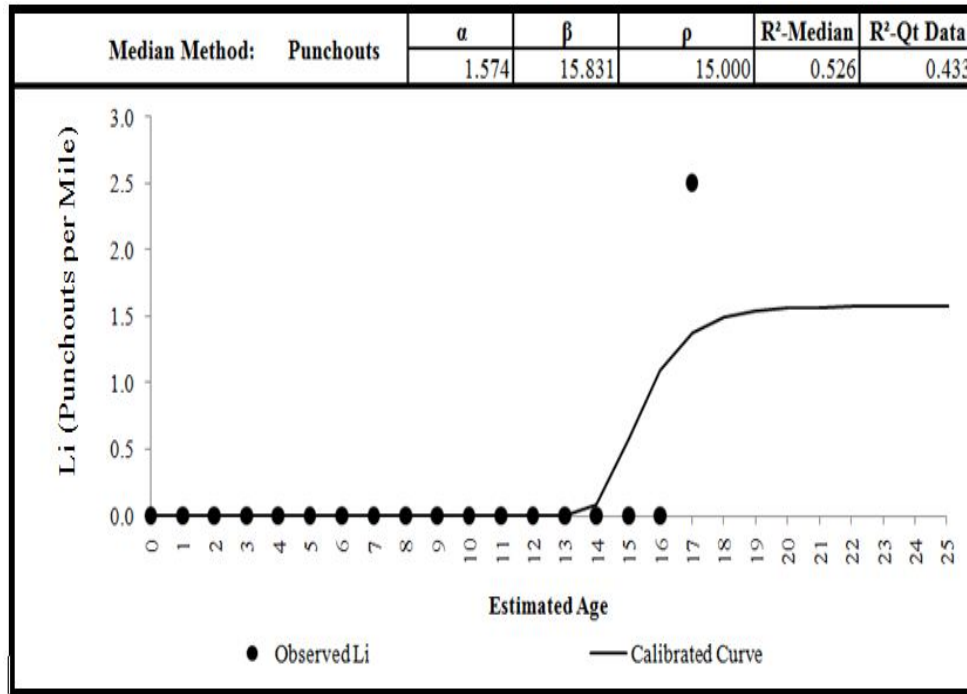


# Constraints

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- The alpha of the punchouts performance curve was constrained to 2. Given that punchouts are a serious structural distress and that they need to be addressed quickly, the performance curve limit the maximum number of acceptable punchouts to 2.
- The beta parameter was constrained to 50.
- The rho parameter was unconstrained.

# Recalibrated CRCP Punchouts Performance Model



In the recalibrated model, punchouts develop around an age of 14 years.

Alpha = 1.574

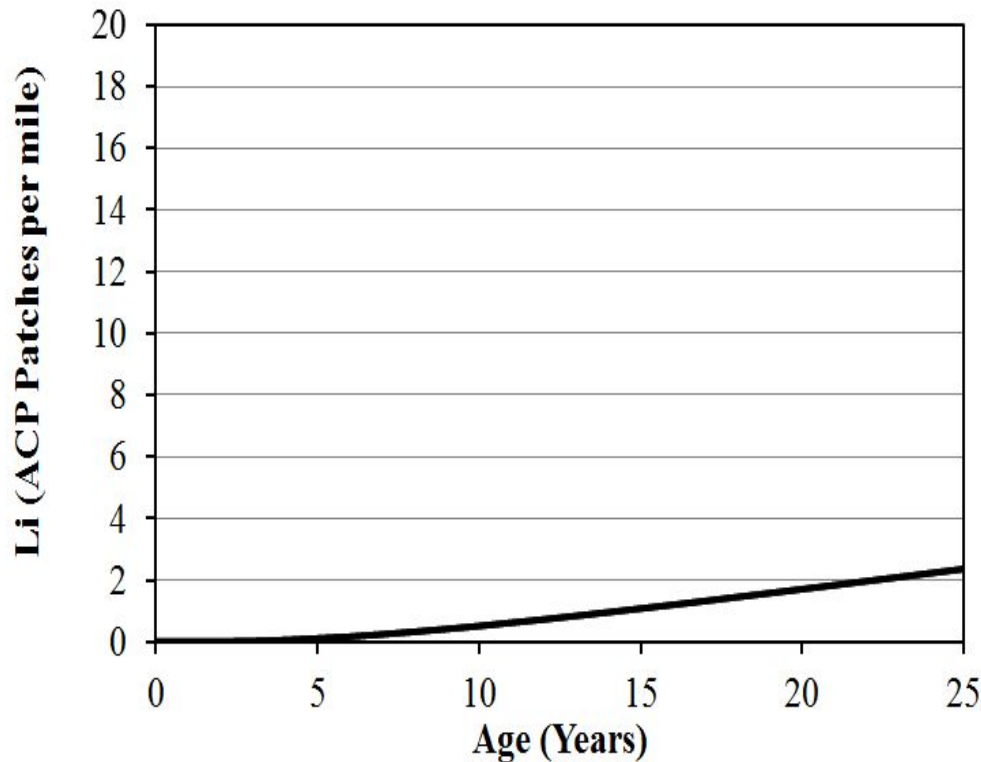
Beta = 15.831

Rho = 15.000



# ACP Patches

# Recalibration of CRCP Distress Performance Models- ACP Patches



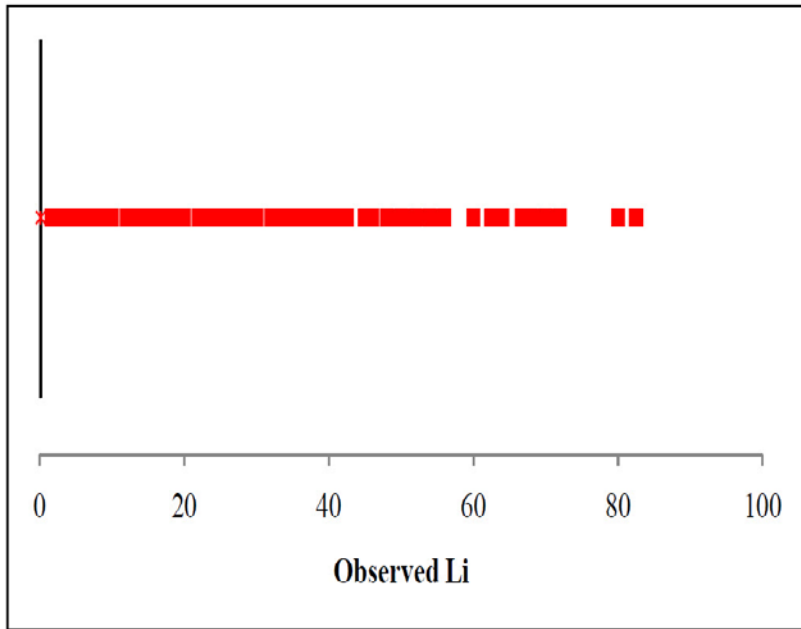
ACP Patches develop around an age of 8 years.

$\text{Alpha} = 94.476$

$\text{Beta} = 0.375$

$\text{Rho} = 824.139$

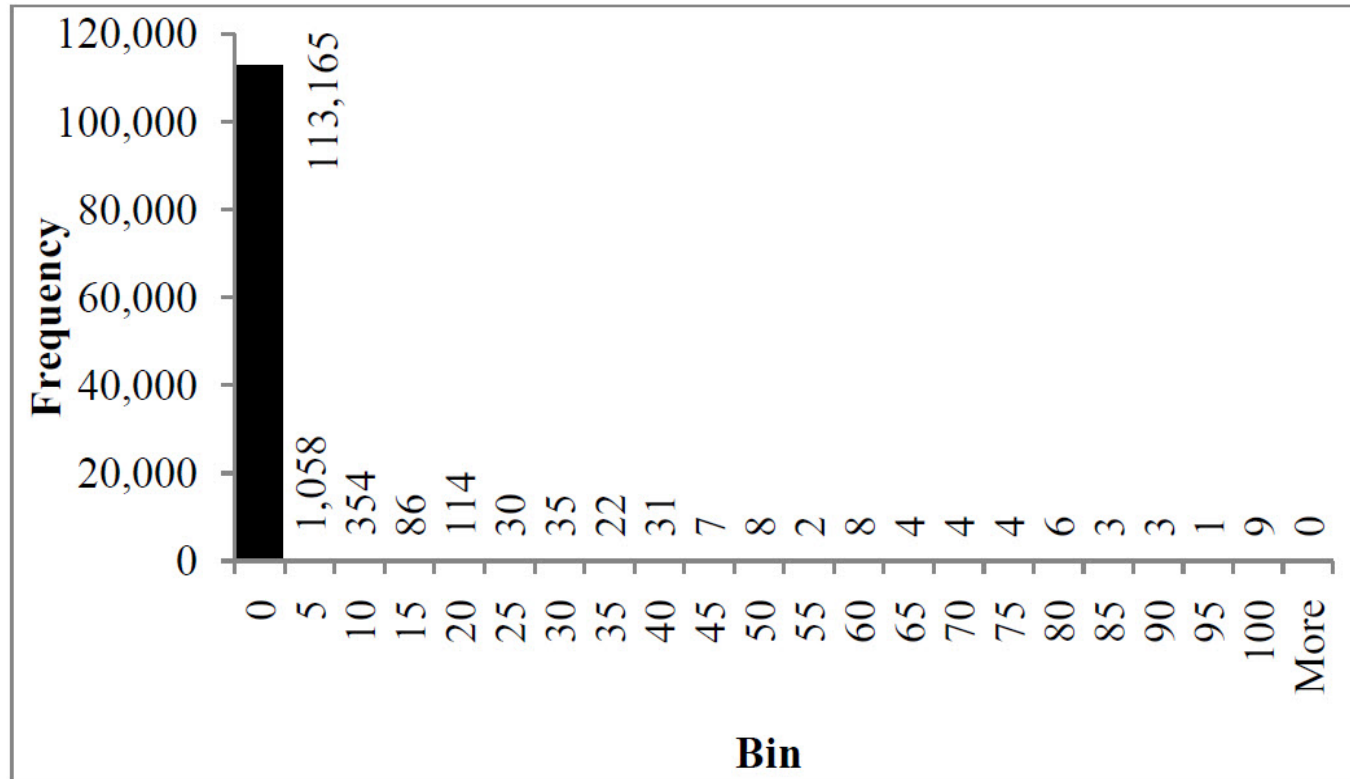
# Statistical Analysis for ACP Patches



Statistical Parameter	Li
Mean	0.14
Standard Deviation	2.08
Median	0
Minimum	0
Maximum	100
1st Quartile	0
3rd Quartile	0
Frequency of Maximum	8

**Observed Li**  
(ACP Patches per Mile)

# Histogram for AC Patches Li

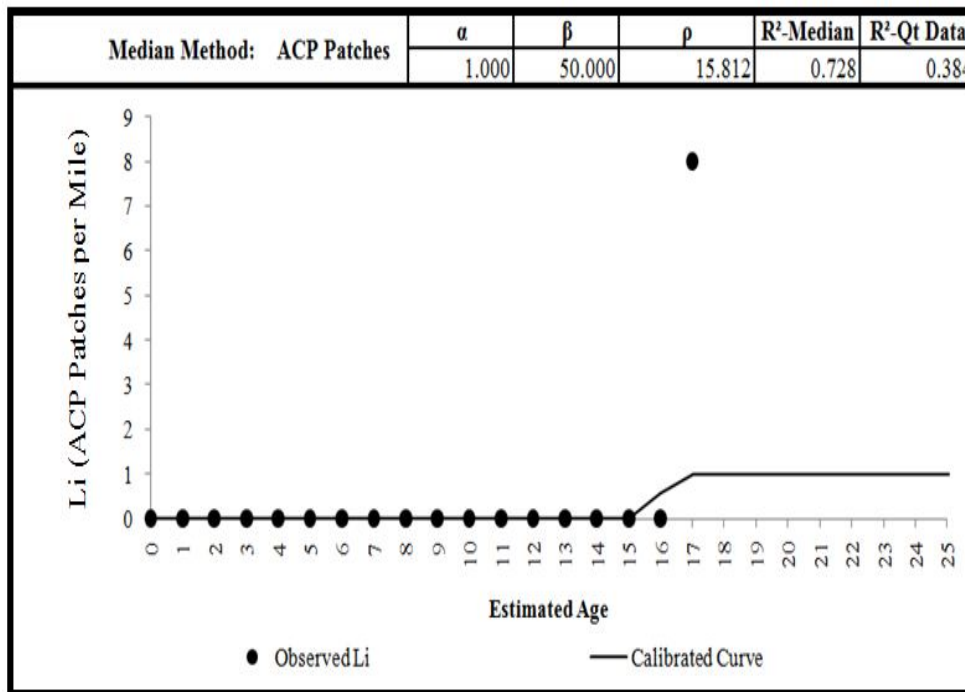


# Constraints

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- The alpha of the ACP patches performance curve was constrained to 1 since according to the statistical analysis performed this distress is not very common in CRC pavements.
- The beta parameter was constrained to 50.
- The rho parameter was unconstrained.

# Recalibrated CRCP ACP Patches Performance Model



In the recalibrated model, ACP Patches develop around an age of 15 years.

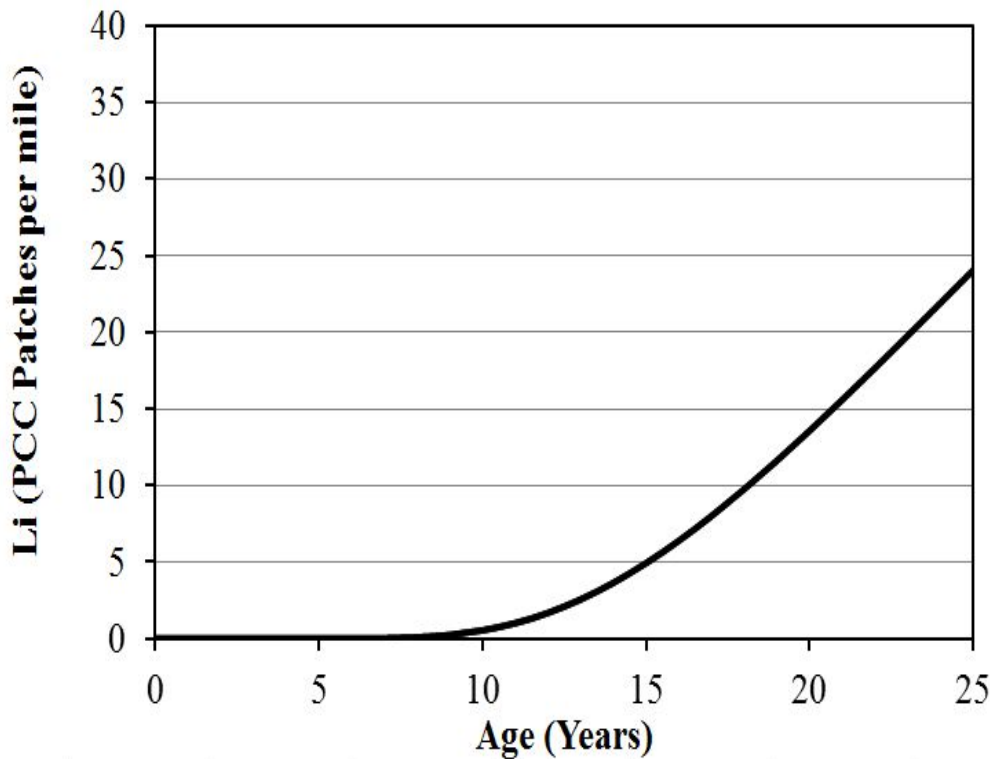
Alpha = 1.000

Beta = 50.000

Rho = 15.812

# PCC Patches

# Recalibration of CRCP Distress Performance Models- PCC Patches



PCC Patches develop around an age of 10 years.

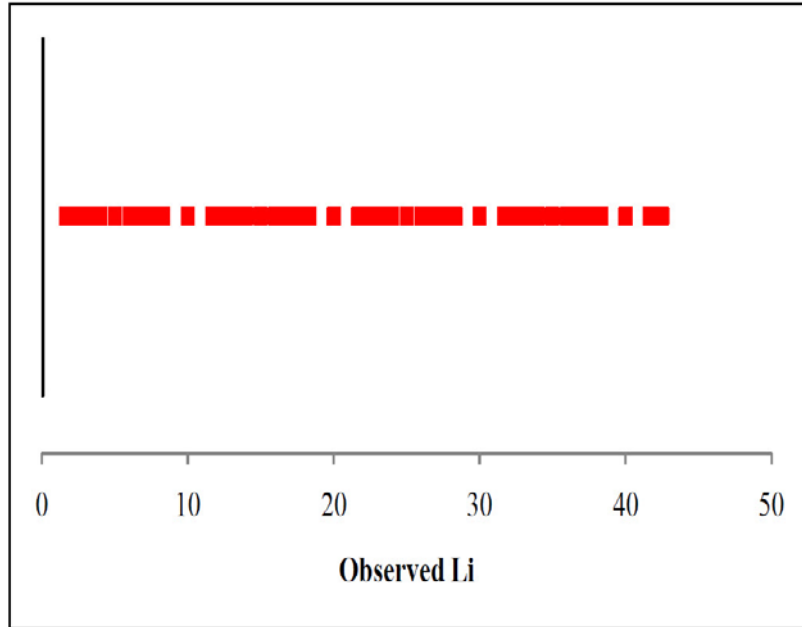
Alpha = 146.000

Beta = 1.234

Rho = 40.320



# Statistical Analysis for PCC Patches

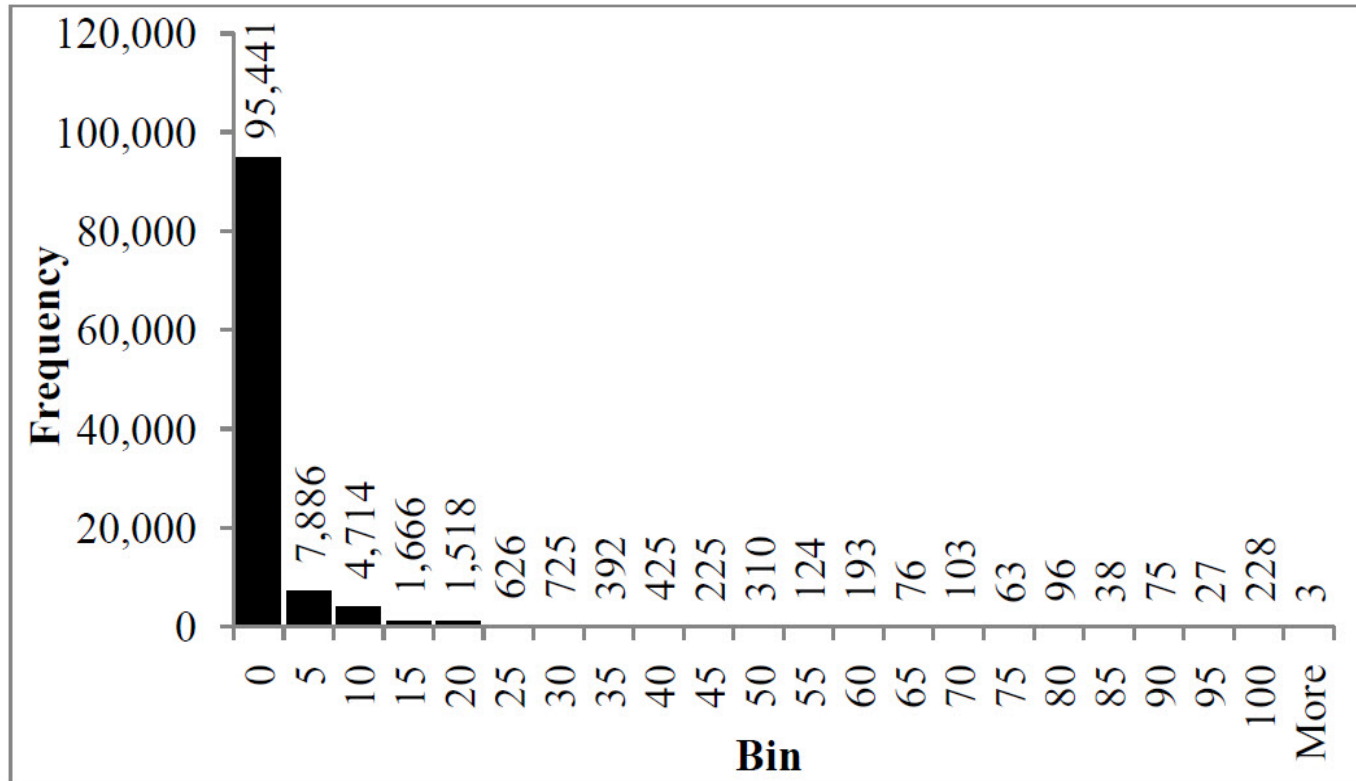


**Observed Li**  
(PCC Patches per Mile)

Statistical Parameter	Li
Mean	2.41
Standard Deviation	9.25
Median	0
Minimum	0
Maximum	205
1st Quartile	0
3rd Quartile	0
Frequency of Maximum	1

Recommended Statewide  
Curve, Median Method.

# Histogram for PCC Patches Li



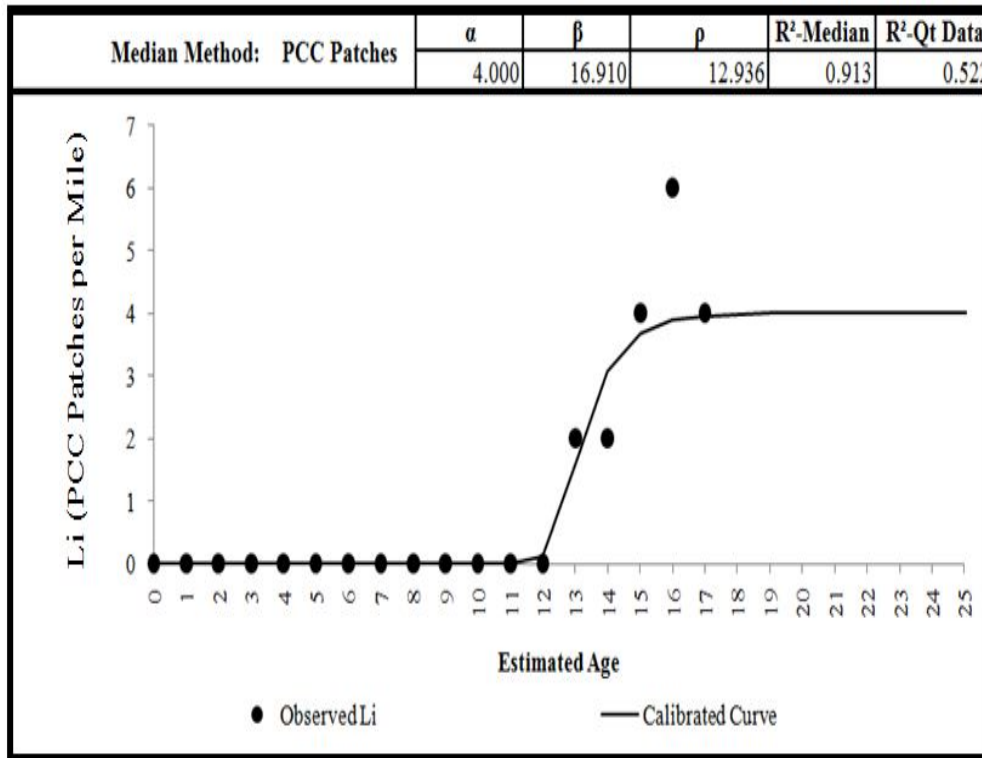
Observed Li for PCC Patches

# Constraints

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- According to expert's feedback, the alpha of the PCC patches performance curve was suggested to be constrained at 4
- The beta parameter was constrained to 50.
- The rho parameter was unconstrained.

# Recalibrated CRCP PCC Patches Performance Model



In the recalibrated model, PCC Patches develop around an age of 12 years.

Alpha = 4.000

Beta = 16.910

Rho = 12.936

# Summary of Recalibrated CRCP Distress Performance Models

CRCP Distress	Re-Calibrated Statewide Performance Curve				
	$\alpha$	$\beta$	$\rho$	R <sup>2</sup> -Median	R <sup>2</sup> -Quartile
Spalled Cracks	134.932	0.833	63.405	0.402	0.348
Punchouts	1.574	15.83	15.000	0.526	0.433
ACP Patches	1.000	50.000	15.812	0.728	0.384
PCC Patches	4.000	16.910	12.936	0.913	0.522

# Ride Score

# Recalibration of Ride Score Performance Curve

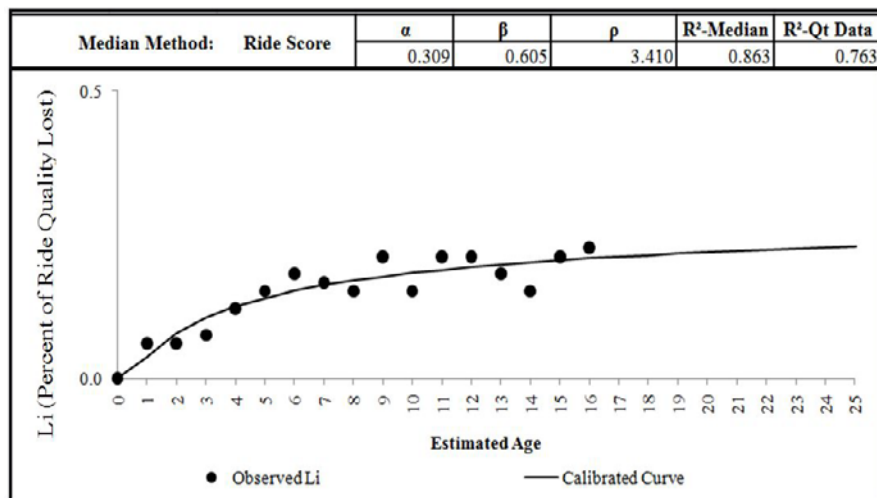
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The following steps outline the process followed to recalibrate the ride score curves:

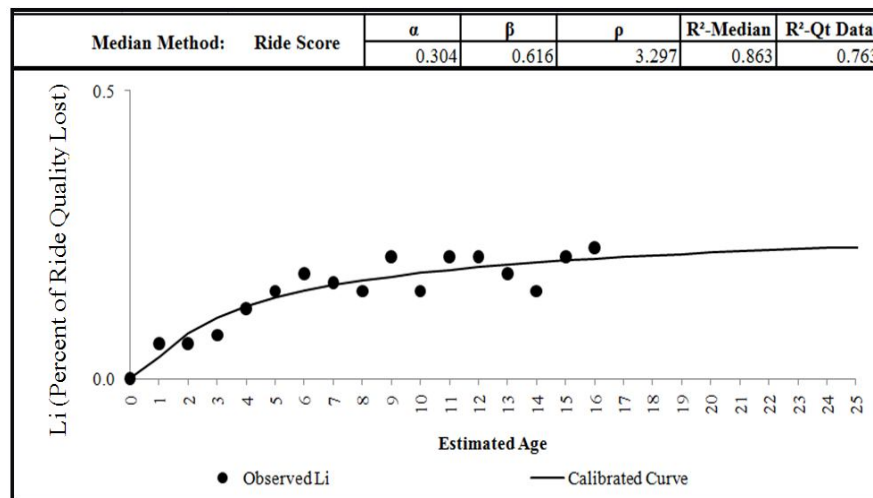
- a) The traffic level was classified into Low, Medium and High.
- b) According to the traffic level, the percent of ride quality lost ( $L_i$ ) was obtained using the following equation.

$$L_i = \frac{4.8 - RS}{4.8 - RS_{\min}}$$

# Recalibration of Ride Score Performance Curve



**Recalibrated Performance Curve  
(Unconstrained)**



**Recalibrated Performance Curve  
(Constrained)**



# Ride Score Performance Curve Parameters

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The coefficients obtained for the recalibrated statewide CRCP ride performance curves are:

Method	$\alpha$	$\beta$	$\rho$	R <sup>2</sup> -Median	R <sup>2</sup> -Quartile
Unconstrained	0.309	0.61	3.41	0.863	0.763
Constrained	0.304	0.62	3.3	0.863	0.763

Unconstrained Ride Li performance curve is proposed to represent the performance of pavement ride quality.

# Conclusions

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1. PMIS raw data from 1993-2010 show a large amount of records with no distresses. This situation reflects the importance of pavement sections where CRCP are located that demands immediate repair from TxDOT.
2. The lack of distress data specially at a later deterioration stage makes it challenging to develop performance curves to forecast distresses.

# Conclusions

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3. The recalibrated distress performance curves represent an improvement when compared to the current distress performance curves.
4. Alpha and Rho values could be further adjusted based on local experience at each District.

CRCP Distress	Re-Calibrated Statewide Performance Curve				
	$\alpha$	$\beta$	$\rho$	R <sup>2</sup> -Median	R <sup>2</sup> -Quartile
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**THANKS !**

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