Project No. 01-59

PROPOSED ENHANCEMENTS TO PAVEMENT ME DESIGN: IMPROVED CONSIDERATION OF THE INFLUENCE OF SUBGRADE SOILS SUSCEPTIBLE TO SHRINK/SWELL AND/OR FROST HEAVE ON PAVEMENT PERFORMANCE

APPENDIX 11

INCORPORATION OF DISTRESS CAUSED BY THE EXPANSIVE SOIL VOLUME CHANGE INTO PAVEMENT DESIGN PROCEDURES

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11.1. Abstract

The Mechanistic-Empirical Pavement Design Guide (MEPDG) developed by the American Association of State Highway and Transportation Officials (AASHTO), also most recently known as AASHTOWare Pavement ME Design, considers the volume change of the road due to environmental effects in the international roughness index (IRI) equation through a variable known as Site Factor, SF. Despite the significant effort that the pavement research community underwent to improve the environmental related distresses, the AASHTOWare PMED guide does not incorporate a mechanistic procedure to evaluate the distress caused by the soil volume change associated with expansive soils and/or frost conditions. Instead, the Site Factor is a parameter that is empirical in nature that serves to incorporate the subgrade swell/shrink, for high-volume change soils in arid regions, and the frost heave for cold regions.

Data collected from the Long-Term Pavement Performance (LTPP) program were used to develop the IRI equations in the MEPDG manual for the four major pavement categories, 1), hot-mix asphalt (HMA) or flexible pavement, 2) Portland cement concrete (PCC) covered with asphalt concrete (AC) pavement, 3) Jointed Plain Concrete Pavement (JPCP), and 4) Continuously Reinforced Concrete Pavement (CRCP). Those equations were imbedded in the AASHTOWare PMED program to predict the IRI change over time.

The objective of this study was to introduce an improved prediction of the distress caused by the expansive soil behavior to replace the SF in the IRI equations. The improved shrink swell model is based on a mechanistic-empirical procedure. This research focused on the application of implementing a calibrated stochastic solution that considered the variance of the soil properties and environmental factors into the roughness index. The solution to the volume change due to the presence of expansive soils in the subgrade layers is presented. The implementation of the model was based on a limited number of sections gathered from the LTPP database that have a weighted plasticity index, *w*PI, greater than or equal to 10. Sections located in freezing zones were preliminarily excluded to investigate the effects in a separate manner. Results showed that the IRI predictions can be improved over the current equations used in the AASHTOWare PMED methodology.

11.2. Objective

The objective of this chapter was to incorporate the calibrated volume change, shrink/swell, variance (V_{ss}) developed based on the soil properties and environmental effect changes into the IRI roughness equations using field data gathered from LTPP.

11.3. Introduction

The Mechanistic-Empirical Pavement Design Guide (MEPDG) is being used for the design and analysis of new and rehabilitated pavement structures based on mechanistic-empirical principles. This design is an update of the 1993 AASHTO Guide for Design of Pavement Structures, which was based on empirical observations from the AASHO Road Test performed in late 1950s in Ottawa, Illinois (MEPDG, 2008, and Haung, 2004). On the other hand, the Long-Term Pavement Performance (LTPP) database was used to create a calibrated mechanistic procedure for MEPDG. The way the Pavement ME Design works is first designing pavement based on trial basis. Next is calculating the cumulative damage over time based on the stresses, strains, and deflections due to climatic and traffic effects and then empirically relates the cumulative damage to pavement distresses and estimate the roughness, IRI. If the predicted performance satisfies the design standards, such as pavement lifetime, then alternatives can be considered that could decrease life cycle costs or generate better performance. Figure 11.1 represents the flow chart of the Mechanistic-Empirical ME procedure (MEPDG, 2020).

Although MEPDG uses mechanistic distress models calibrated and verified to create better agreement between predicted and actual IRI values, the overall statistical accuracy of the models for the four major pavement categories is considered between poor and fair (AC R^2 = 56%, PCC overlays with AC R^2 = 51%, JPCP R^2 = 70%, CRCP R^2 = 68%), Figure 11.2 (MEPDG, 2020). Also, the calibration was created without considering separating sections contain expansive soil subgrades. The performance of those sections may be different because of the expansive/shrink soil behavior.

The properties that affect the current site factor equation, which is considered as the environmental effect representative in the IRI equation, were divided based on the pavement category as summarized in Table 11.1. P_{200} is percent passing #200 sieve (0.075 mm) and P_{02} is percent of fines smaller than 20 microns. In the MEPDG manual, P_{02} is defined as percent passing 0.02 mm sieve.

Table 11.1 Summary of the Properties That Environmentally Affect Each Pavement Category

Pavement Category			
1 and 2		3	4
Frost Heave	Swelling/Shrinkage		
Age	Age	Age	Age
Average Annual Precipitation	Average Annual Precipitation	Average Annual Freezing Index	Average Annual Freezing Index
Average Annual Freezing Index	Plasticity Index	P_{200}	P_{200}
P_{02}	P_{200}		

For high volume change due to swelling/shrinkage, the SF parameter exclude key variables that are widely known and used in practice such as temperature, potential evapotranspiration (PE), Thornthwaite moisture index (TMI), soil water characteristic curve properties (SWCC), groundwater table (GWT), etc. Those missing variables are critical since they greatly control the soil suction, or swelling and shrinkage behavior, which would target the degree of distress at a particular site.

In the NCHRP 1-59 project, a new parameter known as the shrink/swell variance (V_{ss}), which is a comprehensive stochastic solution, was developed using Monte Carlo simulation to predict elevation change magnitude of expansive soils. In his paper, Olaiz explained the details of the stochastic solution that was developed to estimate volume change (Olaiz et al., 2021). The V_{ss} is a function of climate change effect and soil properties, which will replace the site factor.

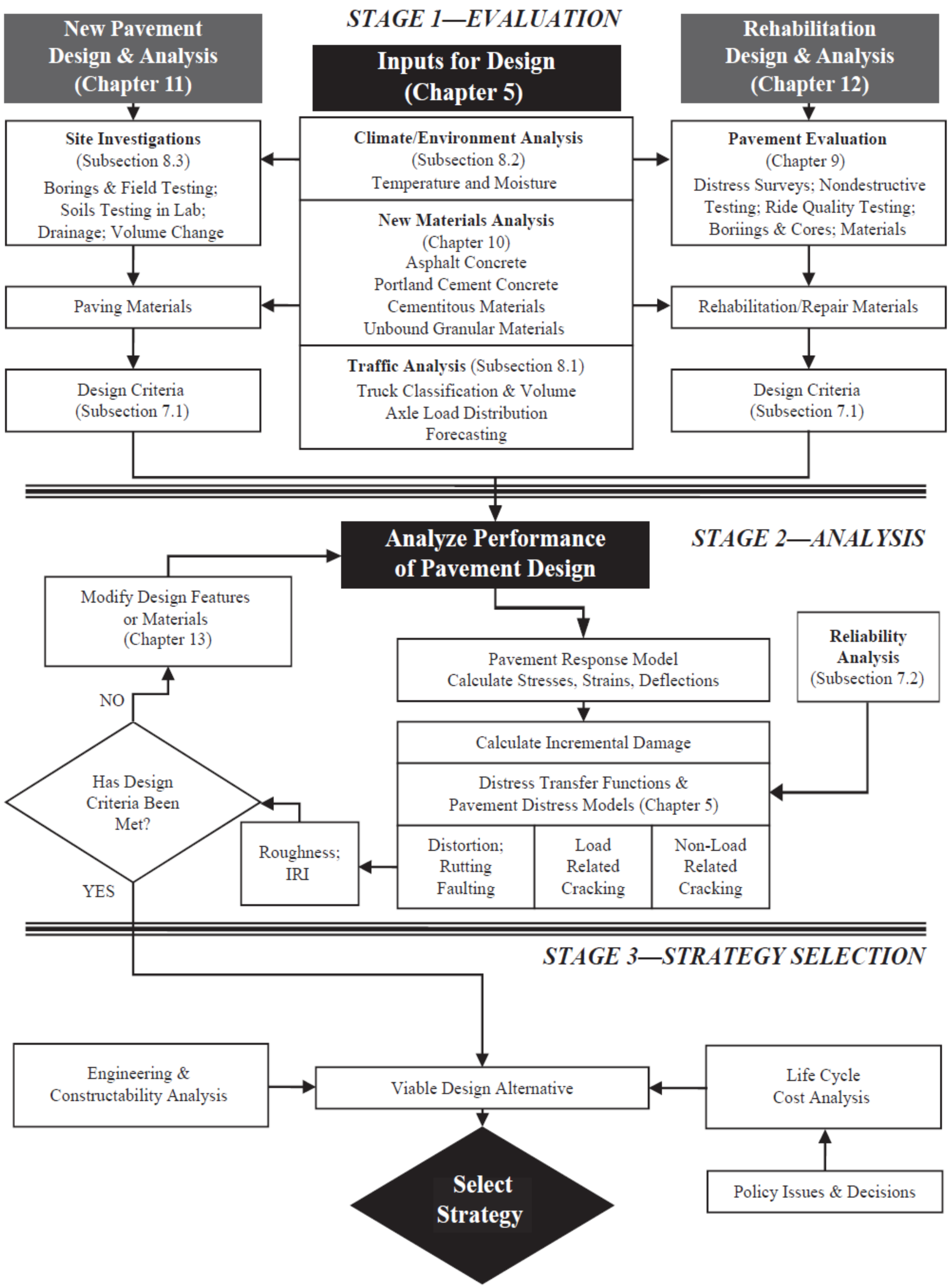

STAGE 1—EVALUATION
New Pavement Design & Analysis (Chapter 11)
Inputs for Design (Chapter 5)
Rehabilitation Design & Analysis (Chapter 12)
Site Investigations (Subsection 8.3)
Borings & Field Testing; Soils Testing in Lab; Drainage; Volume Change
Climate/Environment Analysis (Subsection 8.2)
Temperature and Moisture
Pavement Evaluation (Chapter 9)
Distress Surveys; Nondestructive Testing; Ride Quality Testing; Boriings & Cores; Materials
New Materials Analysis (Chapter 10)
Asphalt Concrete
Portland Cement Concrete
Cementitous Materials
Unbound Granular Materials
Paving Materials
Rehabilitation/Repair Materials
Traffic Analysis (Subsection 8.1)
Truck Classification & Volume
Axle Load Distribution
Forecasting
Design Criteria (Subsection 7.1)
Design Criteria (Subsection 7.1)
Analyze Performance of Pavement Design
STAGE 2—ANALYSIS
Modify Design Features or Materials (Chapter 13)
Pavement Response Model
Calculate Stresses, Strains, Deflections
Reliability Analysis (Subsection 7.2)
NO
Calculate Incremental Damage
Has Design Criteria Been Met?
Distress Transfer Functions & Pavement Distress Models (Chapter 5)
Roughness; IRI
Distortion; Rutting Faulting
Load Related Cracking
Non-Load Related Cracking
YES
STAGE 3—STRATEGY SELECTION
Engineering & Constructability Analysis
Viable Design Alternative
Life Cycle Cost Analysis
Select Strategy
Policy Issues & Decisions

Figure 11.1 Conceptual Flow Chart of the Three-Stage Design/Analysis Process for AASHTOWare PMED (MEPDG, 2020)

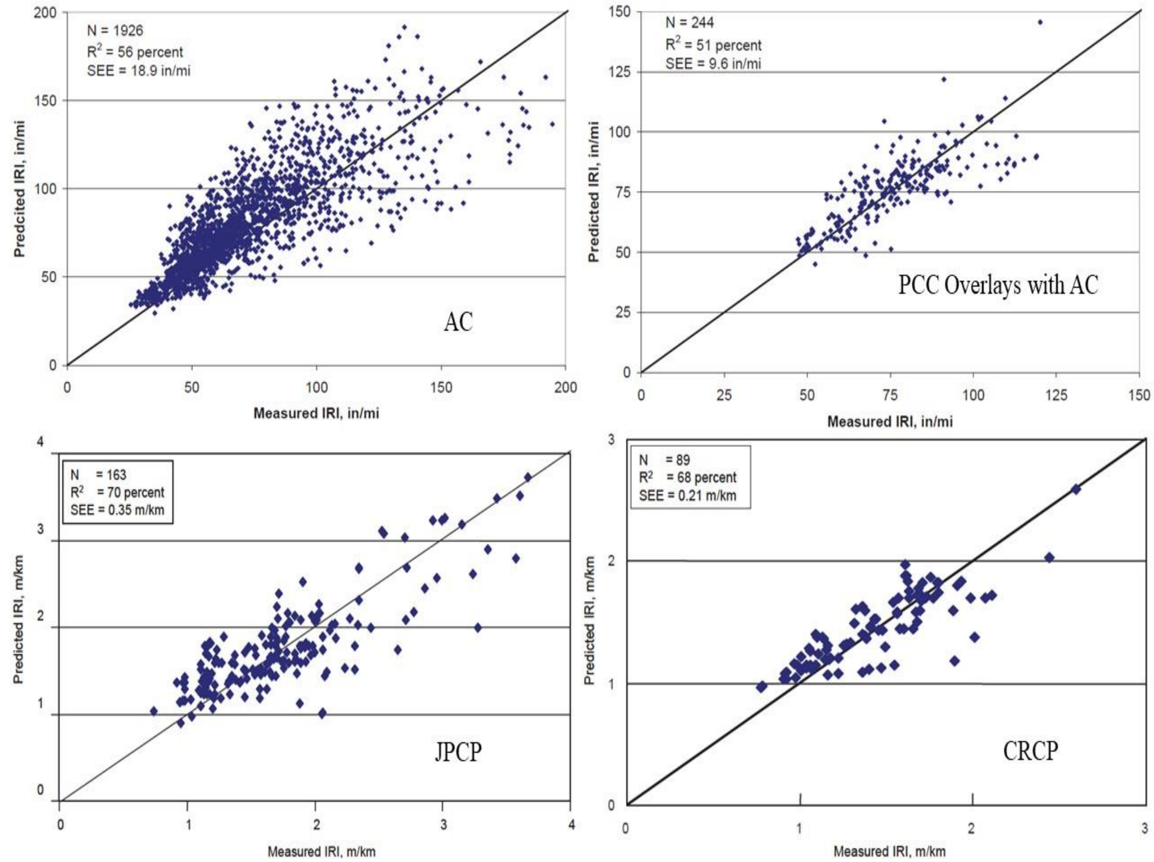


Figure 11.2 Statistical Analysis Results of the Four Pavement Categories from Global Calibration Process (MEPDG, 2020)

In this study, LTPP sections with expansive soils subgrades, wPI $\geq$ 10, were identified and their data, including soil properties, climatic data, pavement information and distresses over time, etc. were collected for three of the pavement categories, 1) AC, 2) PCC overlays with AC, 3) CRCP. A comparison of measured and predicted IRI values was developed for each category using SF and replacing SF with the swell/shrink variance (V_{ss}). JPCP was not included because some of the distresses parameters used in the IRI equation were not located in LTPP database, as it will be explained further later in this chapter.

11.4. Literature Review

11.4.1. The International Roughness Index (IRI) Used in the Mechanistic-Empirical Pavement Design Guide (MEPDG)

The MEPDG design guide is an update of AASHTO Guide 1993. Historically, the Mechanistic-Empirical Pavement Design Guide, MEPDG, was released in 2004 under the NCHRP 1-37A project (Li et al., 2011, and Haung, 2004) with many updates, such as Interim Edition 2008 and MEPDG 2020, ever since. Instead of being only an empirical based design, MEPDG is based on mechanistic-empirical (ME) principles.

Scientifically, mechanistic approach uses only the physical causes to clarify a phenomenon. In pavement design, the physical causes can be defined as the loads, environmental effect, soil properties, pavement material properties, etc., and stresses, strains and deflections are considered the phenomena. The major update of this design guide compared with the previous one, AASHTO Guide for Design of Pavement Structures 1993, is finding mathematical relationship between the phenomena and the physical causes. In addition, with a big database, such as LTPP, empirical models can be created to relate the pavement failure to the stresses, strains, and deflections, and hence failure can be derived using loading cycles to failure (Li et al., 2011).

The LTPP database is the product of a large research program of data gathered from 3,000 pavement test sections over approximately a 20-year period. Data includes 1) subgrade material properties such as soil gradation from sieve analysis and hydrometer tests, Atterberg limits, water content, maximum dry density and optimum moisture content, 2) climatic parameters such as annual average precipitation, temperature, freezing index, and relative humidity, 3) type of pavement, 4) pavement layers and thicknesses, 5) pavement distresses, and 6) IRI values measured overtime, among other information (Rada et al. 1994).

MEPDG uses the International Roughness Index, IRI, to summarize surface deformation and deterioration as a reflection of pavement performance. IRI is a roughness scale based on the response computed from a longitudinal profile measurement using a generic motor vehicle (Quarter car model). It is the cumulative vertical deviations over a section of road per unit length, inches/mile for example (MEPDG, 2020, and Haung, 2004). The following are the IRI equations for the **four popular pavement categories**, 1) AC, 2) PCC overlays with AC, 3) JPCP, and 4) CRCP (MEPDG, 2020),

1. Equation for New HMA Pavements and HMA Overlays of Flexible Pavements:

$$IRI = IRI_0 + 0.0150(SF) + 0.400(FC_{Total}) + 0.0080(TC) + 40.0(RD) \qquad (11-1)$$

Where,

IRI_0 is the Initial IRI after construction (in/mi), SF is the Site factor, FC_{Total} is the Area of fatigue cracking (combined alligator, longitudinal, and reflection cracking in the wheel path) (% of the total lane area). All load related cracks are combined on an area basis. That is, the length of the cracks is multiplied by 1 ft to convert length into an area basis. TC is the Length of transverse cracking (including the reflection of transverse cracks in existing HMA pavements) (ft/mi), and RD is the Average rut depth (in).

$$SF = Age^{1.5}\left[ln\big((Precip+1)(FI+1)p_{02}\big) + ln\big((Precip+1)(PI+1)p_{200}\big)\right] \qquad (11-2)$$

Where,

Age is the pavement age (in years), PI is the Plasticity Index of the soil (%), FI is the Average annual freezing index (ºF days), $Precip$ is the Average annual precipitation or rainfall (in), P_{02} is the percent of 2 micron and P_{200} is the percent passing the 0.075 mm sieve.

2. Equation for HMA Overlays of Rigid Pavements:

$$IRI = IRI_0 + 0.00825(SF) + 0.575(FC_{Total}) + 0.0014(TC) + 40.8(RD) \qquad (11-3)$$

Note that the site factor equation was **not** provided for this category in MEPDG 2008, 2015 or 2020 manual. It is stated in the MEPDG 2008 and 2020 manuals that the IRI equations for pavement category 1 and 2, and the site factor equation were developed from the same data collected from LTPP program. Thus, it was assumed that the same SF equation is used for both category 1 and 2.

3. Equation for Jointed Plain Concrete Pavements (JPCP):

$$IRI = IRI_0 + 0.8203 \cdot CRK + 0.4417 \cdot SPALL + 1.4929 \ \cdot TFAULT + 25.24 \cdot SF \qquad (11-4)$$

Where,

CRK is the Percent slabs with transverse cracks (all severities), *SPALL* is the Percentage of joints with spalling (medium and high severities), *TFAULT* is the total joint faulting accumulated per mile (in), and *SF* is the Site factor, which is calculated in accordance with the following equation:

$$SF = AGE\ (1 + 0.5556\ FI)(1 + P_{200}) \times 10^{-6} \qquad (11-5)$$

Where,

Age is the pavement age (yr), *FI* is the Average annual freezing index (°F days), and P_{200} is the Percent passing the 0.075 mm sieve.

4. Equation for Continuous Reinforced Concrete Pavements (CRCP):

$$IRI = IRI_0 + 3.15 \cdot PO + 28.35 \cdot SF \qquad (11-6)$$

Where,

PO is the Number of medium- and high-severity punchouts/mi, and *SF* is the Site factor, which is calculated in accordance with the following equation:

$$SF = AGE\ (1 + 0.556\ FI)(1 + P_{200}) \times 10^{-6} \qquad (11-7)$$

Those IRI equations were empirically developed as a function of “common” pavement distresses, site factors, and measured initial IRI at the time of construction for pavements built on all different soil types. In fact, MEPDG procedures use empirical equations without including enough mechanistic background. It was believed that for expansive soils, different IRI equations, which were developed by the team, should be used.

11.5. Methodology

The following steps were used to pursue the objectives of this study:

a. Validate the current IRI equations by comparing Measured vs. Predicted IRI using sections with only expansive soils subgrades for pavement categories 1) AC, 2) PCC overlays with AC, and 3) CRCP.
b. Replace Site Factor, SF, in the IRI equations for the three categories with the best statistical measurement that represent the environmental parameter developed in NCHRP 1-59 project.
c. Run a correlation to find out new predicted factors for all parameters in the IRI equation using the shrink/swell variance (V_{ss}) and create Measured vs. Predicted IRI.
d. Compare the results to find the best ME-IRI equation for each category.

11.6. Data Collection: LTPP Database

Road sections available in the LTPP database that were used in the analysis were identified using the following steps:

1. Soil Properties

Using LTPP database website, https://infopave.fhwa.dot.gov/, more than 18,000 soil properties test results of subgrade layers can be found for more than 3000 road sections. Each section can be defined using two columns available in all Excel sheets, 1) STATE_CODE_EXP, which is the state name, and 2) SHRP_ID, which is the test section identification number assigned by LTPP program. Of course, not all required properties for the analysis can be found in one Excel sheet. Thus, the following are the names of the Excel sheets that were used and what properties each contained,

1) TST_SS02_UG03: this sheet contains more than 7800 results of sieve analysis and hydrometer tests for subgrade layers only. In all the soil properties sheets, a column named LAYER_NO defines the pavement layer with a unique sequential number assigned to pavement layers, starting with layer 1 as the deepest layer, subgrade.
2) TST_UG04_SS03: this sheet contains more than 5400 Atterberg limits results, liquid limit, plastic limit, and plasticity index.

The results of both sheets were combined and the weighted plasticity index, which is a product of Plasticity Index, PI, and percent passing No. 200 sieve, P_{200}, was calculated to define sections with expansive soils potential, wPI ≥ 10, using the following formula,

$$wPI = \frac{PI \times P_{200}\%}{100} \qquad (11-8)$$

For a specific road section, it was very common to find more than one soil test results, either sieve analysis and hydrometer, Atterberg limits, or both. For the sections used in the analysis, if two or more complete set of the tests results is available, the average value for the parameters was used for that specific road section. If a complete set of data is available for one soil sample while another sample contained some of the results but not all, only the complete set was used. As an example, Table 11.2 shows a modified soil properties table, since the original is very large and contains so many columns, of section AR 05-0804. This table has two complete sets, or results, for sieve analysis but only one set, Sample_No BS05, has the Atterberg limits results. Thus, the results of Sample_No BS06, which do not include Atterberg limits, were ignored and

Sample_No BS05 was used.

2. Freezing zones

As mentioned earlier, sections in freezing zones were eliminated so frost heave effect does not overlap with the swell/shrink effect.

3. Pavement Type

For each road section, a section summary, which is an Excel file includes basic section overview, history and pavement structure, climate, traffic, distresses, IRI data, etc., can be downloaded from the LTPP website. The pavement layers were found in the History & Pavement Structure sheet. Also, in the history, it shows if a new pavement layer was constructed and when it was constructed. As an example, Table 11.3 shows the history of a CRCP section in Mississippi, MS 28-3099. Note that after November 1992, this section became PCC overlays with AC since an AC layer was added. One of so many purposes of using those files was to define the pavement type for each section.

4. Initial IRI and IRI Change with Time

As an example, Table 11.4 provides a summary of the IRI profile for Section TX 48-5154. Note that IRI values, which are available for every road section in its summary spreadsheet, are the average of IRI calculated for the left and right wheels. Also, the IRI is originally measured in m/km but converted to in/mile in this analysis. Road section TX 48-5154 was constructed on July 1st, 1971, as a continuously reinforced concrete pavement (CRCP) type. In 2001, the pavement was overlayed with a hot mixed asphalt concrete (AC) layer. Another AC layer was added in 2013. By looking at the history of this road section, two questions were raised,

1. Should it be used as CRCP, or PCC overlays with AC pavement?
2. What is the initial IRI record that should be used in the IRI equation?

To answer those questions, it was important to understand the reflection of IRI equation or, in other words, what it represented. No matter which IRI record was used as an initial, the final IRI represented the change in IRI from that initial point whether the initial point was the date of construction or the date with the first IRI record. As a result, the initial IRI record can be chosen at any time since the outcome was always the change in IRI.

Referring to Table 11.4, and based on what was explained in the previous paragraph, the IRI data can be divided into three groups,

i. Starting on 04/09/1991 with initial IRI value of 97.7 in/mile and ending on 07/14/2000. Logically, the pavement was used as CRCP, Pavement Category 4, during this time since no AC was yet constructed.
ii. Starting on 10/22/2001 with initial IRI value of 59.5 in/mile and ending on 01/27/2010. During this time, the section was treated as PCC overlays with AC, Pavement Category 2.

iii. Starting on 05/20/2014 with initial IRI value of 25.7 in/mile and ending on 02/23/2016. This was also defined as PCC overlays with AC, Pavement Category 2.

Table 11.2 Soil Properties Modified Table for Section AR 05-0804

SHRP_ID	STATE_CODE	STATE_CODE_EXP	LAYER_NO	LOC_NO	SAMPLE_NO	TST_SS02_UG03_TEST_DATE	NO_4_PASSING	NO_200_PASSING	HYDRO_02	HYDRO_002	LIQUID_LIMIT	PLASTIC_LIMIT	PLASTICITY_INDEX	wPI
0804	5	Arkansas	1	B6	BS06	4/8/1998	88	35.6	11.8	5.5			NP	
0804	5	Arkansas	1	B5	BS05	4/8/1998	96	80.1	56.1	30.6	34	15	19	15.2

Table 11.3 History and Pavement Structure for Road Section MS 28-3099

LTPP Section M&R History				Layer Information			
Experiment Number	**Construction Number (CN) and Max Layer Number**	**CN Event (M&R) Date**	**CN Event (Code and Description)**	**Layer Number**	**Layer Type**	**Thickness (in.)**	**Material Code Description**
GPS-5	CN1(Layer Max = 5)	Jan-1987	Date test section initially accepted for study into LTPP program.	1	Subgrade (untreated)		103-Fine-Grained Soils: Fat Inorganic Clay
GPS-7B	CN2(Layer Max = 7)	Nov-1992	19-Asphalt Concrete Overlay	2	Bound (treated) subbase	8.2	338-Lime-Treated Soil
				3	Unbound (granular) subbase	2.3	306-Sand
				4	Bound (treated) base	5.4	339-Soil Cement
				5	Portland cement concrete layer	7.9	6-Portland Cement Concrete (CRCP)
				6	Asphalt concrete layer	3.1	1-Hot Mixed, Hot Laid AC, Dense Graded
				7	Asphalt concrete layer	1.4	1-Hot Mixed, Hot Laid AC, Dense Graded

Table 11.4 Summary of the IRI Profile from LTPP for Section 48-5154

Survey Date and CN Event Date	CN Event Description	International Roughness Index (IRI) Section Average (in/mile)
01/31/1990		
04/04/1990		101.1
07/01/1990	Lane-Shoulder Longitudinal Joint Sealing	
04/09/1991		97.7
12/03/1991		
06/09/1993		97.6
01/30/1995		104.5
03/06/1998		
03/30/1998		96.8
07/14/2000		101.2
06/01/2001	19-Asphalt Concrete Overlay, 31-Aggregate Seal Coat, : Full Depth Patching of PCC Pavement Other Than at Joint	
06/07/2001		100.1
06/08/2001		
10/22/2001		59.5
11/02/2001		
02/19/2003		60.2
08/06/2003		
03/21/2005		63.5
01/27/2010		71.5
06/26/2012		
07/01/2013	Asphalt Concrete Overlay	
05/20/2014		25.7
01/06/2015		26.5
02/23/2016		28.3

Another question can be referred to the IRI value measured on 06/07/2001, which is 100.1 in/mile. This value was found illogical by the author because it was measured a week after a great repair had been conducted on the pavement, yet the measured IRI value is almost equal to the nearest measured IRI value before the repair, 101.2 on 07/14/2000. This would be acceptable, to a certain level, if the values afterward were almost the same or higher. However, this was not the case. On 10/22/2001, only about 4 months later, the IRI was measured to be 59.5 in/mile, which is about 40% less, and it increased to 71.5 in/mile before the next AC was overlayed about 9 years later. As a result, the measured IRI value on 06/07/2001 was eliminated and not used in the analysis. One more question raised was why a third group was used from 2014 when no changes occurred in the pavement type, remained Category 2. Logically, fixing the pavement cancels the previous distresses that may have increased the IRI value. It can obviously be seen when comparing the IRI values between 2010 and 2014. In 2014, after the new AC layer was added, which by default would seal most or maybe even all cracks, the IRI value decreased to about a third of its value in

2010. Thus, as a general rule used in the analysis, ***whenever a repair or rehabilitation was conducted for the pavement, the IRI at that time was set to be the Initial IRI (IRI_0).***

a. Site Factor (SF)

After choosing the useable IRI values of a road section and finalize the divided groups with their initial IRI clearly marked, the next step was calculating the site factor, SF. According to its equations for pavement categories:

- For categories 1 and 2, the SF is a function of age, climate change, represented by freezing index and precipitation, and soil properties, represented by P_{02}, P_{200}, and plasticity index, PI.
- For categories 3 and 4, the SF is a function of age, climate change, represented by freezing index only, and soil properties, represented by P_{200} only.

Climate data used in the SF equations, FI and Precipitation, was found for each road section in its section summary file, specifically in “Climate” sheet. The following unit conversion was required since SI units were used,

1- The Annual Average Freezing Index, FI, was converted from (deg C deg days) to (deg F deg days) by multiplying by a factor of 1.8.
2- The Annual Average Precipitation was converted from mm to inches.

Of course, the FI should be relatively low or even *zero* since no sections in freezing zones was selected for the analysis. In some sections, sometimes for the whole years and other times for some years, FI records were either missing or not recorded. In such cases, FI was assumed to be zero.

For each of the section used, fixed values were used for the soil properties. If more than one test result found for any of the properties, an average value was used. Thus, the soil properties remained constant for a given road section. For freezing index and precipitation, on the other hand, an average annual value was used. Thus, the SF values change annually with one value calculated for each year. Keep in mind, if more than one IRI value was measured at the same year, which can be considered relatively rare, the SF value would be the same for all IRI values in that year.

To explain how the age factor was calculated, let’s start with the following question: since the pavement age is one of the factors that affect the Site Factor (SF) equation, what is the initial year used in the equation? Should it be the construction year, or the year of the initial IRI record?

By referring to the SF equation, it can be concluded that the SF represents the cumulative climate effect that increases with age. Although the SF equation used for categories 1 and 2 is not a function of age only, the *Age* parameter in the equation is raised to the power of 1.5. This indicates that, not always but mostly, SF continuously increases with time. Thus, the SF change increases as time increases. However, calculating SF from the date of construction was not reasonable since IRI equation calculates the change in IRI value from the initial IRI and the change in distresses from the time of the initial IRI. As a result, the SF was calculated from the date of construction, but ***<u>the change in SF</u>*** from the time of the initial IRI was used in the IRI equation. For the previous example, TX 48-5154, the SF values in 1991, 2001, and 2014, since SF was calculated annually, were used as reference points subtracted from the SF calculated afterwards. Again, those were the same years in which IRI values were considered as references, or initial IRI.

b. Distresses

The next parameters in the analysis, as it is notable from the IRI equations, were the change in distresses with time. In LTPP database, the distresses were divided based on the pavement type, AC, JPCP or named JPCC as it appears in the spreadsheets, and CRCP. For each pavement type, all distresses values, either used in IRI equations or not, can be found in one spreadsheet. Those sheets are named MON_DIS_AC_REV, MON_DIS_JPCC_REV, and MON_DIS_CRCP_REV. To make it easier, LTPP gathered some or all distresses required to calculate IRI in different spreadsheets named MON_DIS_AC_CRACK_INDEX for pavement categories 1 and 2, MON_DIS_JPCC_CRACK_INDEX for pavement category 3, and MON_DIS_CRCP_CRACK_INDEX for pavement category 4.

1- Pavement Category 1, AC

For AC sections, MON_DIS_AC_CRACK_INDEX spreadsheet was used. Table 11.5 represents a sample of the values used for Section AL 01-010. It is important to mention that a spreadsheet named "Field Reference" was included in each Excel file to define every column used in any sheet inside the file. So, the definition of each column, as was found in the "Field Reference" spreadsheet is as follows,

- HPMS16_CRACKING_PERCENT_AC: "Percent of section cracked using 2016 HPMS Field Guide definitions. Includes only longitudinal and fatigue cracking in assumed 1m wide wheelpaths", and the unit is in percent.
- MEPDG_CRACKING_PERCENT_AC: "The total area of alligator cracking summed across all levels of severity, divided by the total area of the test section, in accordance with MEPDG definitions. Note that LTPP alligator cracking interpretations are not restricted to the wheel path", and the unit is in percent.
- MEPDG_CRACKING_LENGTH_AC: "Length of transverse cracking per unit length using AASHTO MEPDG definitions. Includes only transverse cracks at least 6 feet long", and the unit is in ft/mi.
- MEPDG_LONG_CRACK_LENGTH_AC: "Total length of sealed and unsealed longitudinal cracks in the wheelpath at all severity levels divided by test section length", and the unit is in ft/mi.

Table 11.5 Distresses Values Measured for Section AL 01-0101 Created from MON_DIS_AC_CRACK_INDEX Spreadsheet

STATE_CODE	STATE_CODE_EXP	SHRP_ID	SURVEY_DATE	HPMS16_CRACKING_PERCENT_AC	MEPDG_CRACKING_PERCENT_AC	MEPDG_CRACKING_LENGTH_AC	MEPDG_LONG_CRACK_LENGTH_AC
1	Alabama	0101	11/17/1998	5.00	1.00	10.00	7.00
1	Alabama	0101	10/30/1997	6.00	0.00	0.00	1299.00
1	Alabama	0101	04/25/1998	12.00	0.00	0.00	2328.00
1	Alabama	0101	10/10/1996	2.00	0.00	0.00	156.00
1	Alabama	0101	02/08/2002	25.00	6.00	121.00	0.00
1	Alabama	0101	04/09/2003	41.00	12.00	506.00	0.00
1	Alabama	0101	08/23/2001	19.00	5.00	28.00	475.00
1	Alabama	0101	04/28/2005	45.00	13.00	506.00	0.00
1	Alabama	0101	05/18/2000	17.00	7.00	21.00	561.00
1	Alabama	0101	08/25/1994	0.00	0.00	0.00	0.00
1	Alabama	0101	07/26/1995	0.00	0.00	0.00	0.00
1	Alabama	0101	02/23/2004	33.00	13.00	544.00	0.00
1	Alabama	0101	02/08/1995	0.00	0.00	0.00	0.00
1	Alabama	0101	04/16/1996	1.00	0.00	0.00	156.00

Referring to the IRI equation of AC-pavement-type, the total area of the fatigue cracking, FC_{Total}, includes alligator, longitudinal, and reflection cracking in the *wheel path*. The first column, HPMS16_CRACKING_PERCENT_AC, is specified in the LTPP spreadsheet that the numbers were measured/calculated using 2016 Highway Performance Monitoring System, HPMS, Field Manual. Cracking percent for AC pavement was defined in the HPMS 2016 as "the percentage of the total area exhibiting visible fatigue type cracking for all severity levels in the wheelpath in each section" (HPMS 2016). Thus, it can be said with confidence that the values in this column represented the FC_{Total} variable in the IRI equation. One may ask, what about the second and fourth columns? The second column, MEPDG_CRACKING_PERCENT_AC, cannot be used in the IRI equation because it is specified that the results of the alligator cracking are ***not*** restricted to the wheel path. Also, the fourth column, MEPDG_LONG_CRACK_LENGTH_AC, cannot be used as well in the IRI equation because it is not converted into an area basis in percent.

For the transverse cracking, TC, variable in the IRI equation, the third column, MEPDG_CRACKING_LENGTH_AC, was used. According to the equation, TC was defined as the length of transverse cracking in ft/mi, which matched the definition found in the LTPP. The only variable remained in the IRI equation is Rutting. It can be found for every AC road section in the section summary file, specifically the "Distress" sheet, measured in different times, usually the same time as the other distresses, as shown in

Table 11.6. Note that rutting values were converted from millimeters to inches before using them in the analysis. As a result, all variables in the IRI equation for AC pavement were located and collected in one spreadsheet to be used for calibration.

2- Pavement Category 2, PCC Overlays with AC

The MEPDG IRI equations for PCC, either JPCP or CRCP overlays with AC have the same independent variables as those presented for AC pavements. It was found that whenever an AC layer was added on top of a PCC pavement, the distresses measured were found in the MON_DIS_AC_CRACK_INDEX only. As a result, the same columns used for AC were used for PCC Overlays with AC. Also, for rutting, the "Distress" sheet in the section summary file for each section will be used, as explained previously. Thus, all data available for PCC pavements overlays with AC were collected to be used in the calibration process.

3- Pavement Category 3, JPCP

Only two distresses columns were found in the MON_DIS_JPCC_CRACK_INDEX spreadsheet for joint plain concrete pavement (JPCP) or named joint Portland cement concrete (JPCC) in the spreadsheet.

Table 11.7 is presented as an example for Section AL 01-0601. The definition of each column, as it was found in the "Field Reference" spread sheet is as follows,

1. HPMS16_CRACKING_PERCENT_JPCC: "Percent of section cracked using 2016 HPMS definitions. Includes longitudinal and transverse cracking at least half slab width in length".

Table 11.6 A Summary from the Distress's Spreadsheet for Section AL 01-0101 to Show the Available Rutting Values

Survey Date	AC Distress (Sum of all severity - Low, Medium, High)			Rutting (mm)
	Fatigue (m^2)	Longitudinal Cracking (WP, NWP) (Length, m)	Transverse Cracking (Count)	
04/07/1994	0	0,0	0	4
08/25/1994	0	0,0	0	
02/08/1995	0	0,0	0	
07/26/1995	0	0,0	0	
01/10/1996	0.4	0.7,0	1	5
04/16/1996	0.6	4.5,0	0	
10/10/1996	1.2	4.5,0.8	0	6
10/30/1997	0	37,0	0	5
04/25/1998	0	66.7,0	0	6
11/17/1998	3	0.1,0.9	1	
02/05/2000	0	0,0	1	5
05/18/2000	38.6	16.2,0	1	6
03/07/2001	0	0,0	1	6
08/23/2001	25.3	13.7,0	2	6
01/14/2002	0	0.2,0.5	0	8
02/08/2002	31.1	0,0	10	6
04/04/2003				6
04/09/2003	64.9	0,0	38	
01/20/2004				4
02/23/2004	68	0,0	39	6
04/28/2005	70.4	0,0	35	6

2. MEPDG_CRACKING_PERCENT_JPCC: "Percent of slabs cracked computed from the total number of transverse cracks on a test section divided by the ratio of joint spacing and test section length, times 100. This value is truncated to a maximum value of 100 percent".

Referring to the MEPDG IRI equation for JPCP, the CRK variable is defined as the percent slabs with transverse cracks. It is the author understanding that the second column, MEPDG_CRACKING_PERCENT_JPCC, better represent the CRK variable since no longitudinal cracks are used.

For SPALL and TFAULT variables, no data was found in the LTPP neither in the MON_DIS_JPCC_REV nor MON_DIS_JPCC_CRACK_INDEX spreadsheets. *As a result, it is impossible for the team to conduct a calibration analysis to the MEPDG IRI equation for JPCP.*

Table 11.7 Distresses Values Measured for Section AL 01-0601 Created from MON_DIS_JPCC_CRACK_INDEX Spreadsheet

STATE_CODE	STATE_CODE_EXP	SHRP_ID	SURVEY_DATE	HPMS16_CRACKING_PERCENT_JPCC	MEPDG_CRACKING_PERCENT_JPCC
1	Alabama	0601	02/05/1998	0.00	0.00
1	Alabama	0601	07/01/1998	0.00	0.00
1	Alabama	0601	09/30/1999	4.00	4.00
1	Alabama	0601	09/25/2000	4.00	4.00
1	Alabama	0601	11/13/2001	4.00	4.00
1	Alabama	0601	10/07/2002	4.00	4.00
1	Alabama	0601	10/27/2003	4.00	4.00
1	Alabama	0601	10/04/2004	4.00	4.00
1	Alabama	0601	09/11/2006	4.00	4.00

4- Pavement Category 4, CRCP

Table 11.8 shows an example for Section AZ 04-7079, which is a CRCP pavement type. For the sake of the reporting, some modifications were applied to the original table, such as merging some sells, switching the position of some rows and columns, and mainly use the transpose function to reduce the width of the original table. Referring to the IRI equation for CRCP pavement, the only distress appears in the equation is the punchout, PO, which includes only the number of medium- and high-severity punchouts/mi. Table 11.9 shows the data collected for the same section, AZ 04-7079, from MON_DIS_CRCP_CRACK_INDEX spreadsheet. The following is the definition of the last column, MEPDG_PUNCHOUTS_CRCP, as it appears in the “Field Reference” spreadsheet; “Number of punchouts per unit length using AASHTO MEPDG definitions. Includes medium and high severity punchouts” and the unit is Number/mile. Obviously, this definition matches the one for the PO in the IRI equation. As a result, all variables in the IRI equation for CRCP pavement were located and collected in one spreadsheet to be used in the calibration process.

Table 11.8 Distresses Values Measured for Section AZ 04-7079 Created from MON_DIS_CRCP_REV Spreadsheet

STATE_CODE	4				
STATE_CODE_EXP	Arizona				
SHRP_ID	7079				
CONSTRUCTION_NO	1				
SURVEY_DATE	02/19/2004	11/18/1997	01/21/1999	03/08/1995	02/08/2002
DURAB_CRACK_NO_L	0	0	0	0	0
DURAB_CRACK_NO_M	0	0	0	0	0
DURAB_CRACK_NO_H	0	0	0	0	0
DURAB_CRACK_A_L	0	0	0	0	0
DURAB_CRACK_A_M	0	0	0	0	0
DURAB_CRACK_A_H	0	0	0	0	0
LONG_CRACK_L_L	9.1	2.2	0	0	5.8
LONG_CRACK_L_M	0	0	0	0	0
LONG_CRACK_L_H	0	0	0	0	0
LONG_CRACK_SEAL_L_L	0	0	0	0	0
LONG_CRACK_SEAL_L_M	0	0	0	0	0
LONG_CRACK_SEAL_L_H	0	0	0	0	0
TRANS_CRACK_TOTAL_NO	159	150	151	140	154
TRANS_CRACK_NO_L	159	79	151	140	154
TRANS_CRACK_NO_M	0	71	0	0	0
TRANS_CRACK_NO_H	0	0	0	0	0
TRANS_CRACK_L_L	584.2	292.1	549.3	499.1	566.6
TRANS_CRACK_L_M	0	268	0	0	0
TRANS_CRACK_L_H	0	0	0	0	0
MAP_CRACK_NO	3	0	0	0	0
MAP_CRACK_A	4.9	0	0	0	0
SCALING_NO	0	0	0	0	0
SCALING_A	0	0	0	0	0
POLISH_AGG_A	0	0	0	0	0
BLOWUPS_NO	0	0	0	0	0
CONST_JOINT_NO_L	0	0	0	0	0
CONST_JOINT_NO_M	0	0	0	0	0
CONST_JOINT_NO_H	0	0	0	0	0
PATCH_FLEX_NO_L	0	0	0	0	0
PATCH_FLEX_NO_M	0	0	0	0	0
PATCH_FLEX_NO_H	0	0	0	0	0
PATCH_FLEX_A_L	0	0	0	0	0
PATCH_FLEX_A_M	0	0	0	0	0
PATCH_FLEX_A_H	0	0	0	0	0
PATCH_RIGID_NO_L	0	0	0	0	0
PATCH_RIGID_NO_M	0	0	0	0	0
PATCH_RIGID_NO_H	0	0	0	0	0
PATCH_RIGID_A_L	0	0	0	0	0

PATCH_RIGID_A_M	0	0	0	0	0
PATCH_RIGID_A_H	0	0	0	0	0
PUNCHOUTS_NO_L	0	0	0	0	0
PUNCHOUTS_NO_M	0	0	0	0	0
PUNCHOUTS_NO_H	0	0	0	0	0
LONG_SPALLING_L_L	0	0	0	0	0
LONG_SPALLING_L_M	0	0	0	0	0
LONG_SPALLING_L_H	0	0	0	0	0
PUMPING_NO	0	0	0	0	0
PUMPING_L	0	0	0	0	0
LONG_JT_SEAL_NO	2	2	2	2	2
LONG_JT_SEAL_DAM_L	0	0	0	0.1	0
OTHER					
SURVEY_WIDTH	3.7	3.8	3.7	3.8	3.7

Table 11.9 Distresses Values Measured for Section AZ 04-7079 Created from MON_DIS_CRCP_CRACK_INDEX Spreadsheet

STATE_ CODE	STATE_CODE_ EXP	SHRP _ID	SURVEY_ DATE	HPMS16_CRACKING _PERCENT_CRCP	MEPDG_PUNC HOUTS_CRCP
4	Arizona	7079	02/19/2004	1.00	0.00
4	Arizona	7079	11/18/1997	1.00	0.00
4	Arizona	7079	01/21/1999	0.00	0.00
4	Arizona	7079	03/08/1995	0.00	0.00
4	Arizona	7079	02/08/2002	1.00	0.00

11.7. Summary of the Usable Data

- Table 11.10, Table 11.11, and Table 11.12 summarize the sections used in the analysis for AC, PCC overlays with AC, and CRCP pavements, respectively. The total data points used for each category, which can be found at the bottom of the tables, is 171, 57, and 138, respectively. Note that if a section is highlighted it means that it is the same section as the one before but with a different initial IRI due to one of the reasons explained earlier.
- Table 11.13, Table 11.14, and Table 11.15 contain the required soil properties for the analysis of each section and the year of construction. Note that some sections have a wPI values less than 10. Those were rounded up to 10 since they are 9.5 or greater.
- Table 11.16 and Table 11.17 show samples from the tables developed to calculate SF for the three pavement categories used in the analysis. Note that the same equation was used for pavement category 1 and 2, Table 11.16.
  - The SF equations for pavement category 1 and 2, as mentioned earlier, is

$$SF = Age^{1.5}\left[ln\left((Precip+1)(FI+1)p_{02}\right) + ln\left((Precip+1)(PI+1)p_{200}\right)\right] \qquad (11-9)$$

$\boxed{ln\left((Precip+1)(FI+1)p_{02}\right)}$ represents frost heave, and $\boxed{ln\left((Precip+1)(PI+1)p_{200}\right)}$ represents swelling behavior.

- Average annual freezing index and precipitations were found in the road section summary file using “Climate” sheet.
- The SF Age was calculated from the date of construction.
- The year of the first IRI record was used as a reference point and the change in SF was calculated from that year. If a negative value was shown for the calculated SF, it means that the SF at the given time was less than the SF at the reference point.
- The SF equation for pavement category 3, as mentioned earlier, is

$$SF = AGE\ (1 + 0.556 \cdot FI)(1 + P_{200}) \cdot 10^{-6}$$

- Again, the soil properties, only P_{200} for this category, for each section can be found in Table 11.15.

- Table 11.18 and Table 11.19 show samples from the tables developed to predict IRI and compare it with the measured IRI for the three pavement categories. Note that the same parameters were used for pavement categories 1 and 2 and thus Table 11.18 is a sample for those categories. The difference in procedure was when calculating the Predicted IRI column since different coefficients were used as it will be explained further next.
    - The IRI equations for pavement categories 1 and 2, respectively, as mentioned earlier, are

$$IRI = IRI_0 + 0.0150(SF) + 0.400(FC_{Total}) + 0.0080(TC) + 40.0(RD)$$

$$IRI = IRI_0 + 0.00825(SF) + 0.575(FC_{Total}) + 0.0014(TC) + 40.8(RD)$$

    - For the first parameter, initial IRI, IRI_0, values for each section used in the analysis can be found in Table 11.10 and Table 11.11.
    - The SF values were calculated annually as explained earlier.
    - FC_{Total} and TC, parameters 3 and 4, were collected by matching the same years in which measured IRI values were available.
    - Rutting, the 5th parameter, was found for each section in its section summery file, “Distress” sheet, as mentioned earlier. The year in which a rutting value was recorded should match the year the IRI was measured, as for parameters 3 and 4.
    - Note that, to be able to use a measured IRI value in the analysis for a given year, all parameters should have a record on that year.
        - In some cases, a measured rutting value was not available for a given year while all other parameters are. However, unchanged rutting values were found before and after. So, it was assumed that no change had occurred, and the same value was used.
        - If more than one IRI value was found for a given year while only one distresses records was available, the closest IRI record in time was used while the other was ignored.
    - Then, the predicted IRI was calculated by adding IRI_0 to the parameters after multiplying each one by its corresponded coefficient following the above IRI equations.
    - At the end, a statistical relationship was created, similar to Figure 11.2, between measured and predicted IRI.
    - The IRI equation for pavement category 4, as mentioned earlier, is

$$IRI = IRI_0 + 3.15 \cdot PO + 28.35 \cdot SF$$

- Almost all PO records collected were zero. In some cases, no PO records were found on a given year, but it was zero before and after with no pavement fixing or rehabilitation records. In such cases, it was assumed that PO was zero between any two given years. Values with assumed PO were highlighted in Table 11.19.
  - Section TX 48-5336 contains three records with non-zero PO. Those sections were eliminated because the PO/mile values were unreasonably high, 275, 412, and 348 collected on 2012, 2014, and 2016, respectively.

- Distresses data for the three pavement types can be found in Appendix S.

Table 11.10 The Summary of the Sections Used in the Analysis for Pavement Category 1, AC

Count	STATE_CODE	STATE_CODE_EXP	SHRP_ID	LATITUDE	LONGITUDE	Survey Date and CN Event Date	Initial IRI (in/mile)	No. of Data Points
1	1	Alabama	0101	32.628399	-85.281400	10/30/1995	41.63	8
2	1	Alabama	0102	32.635700	-85.295720	08/25/1994	60.00	7
3	1	Alabama	0102	32.635700	-85.295720	04/27/2004	188.05	1
4	1	Alabama	0103	32.625130	-85.278270	01/10/1996	50.31	5
5	1	Alabama	0106	32.620870	-85.272250	08/25/1994	47.33	6
6	1	Alabama	0109	32.608330	-85.254060	01/10/1996	46.38	5
7	5	Arkansas	0804	34.198700	-91.962810	03/23/1998	87.88	8
8	5	Arkansas	3048	34.372330	-91.128080	11/16/1990	103.91	3
9	5	Arkansas	3071	36.267220	-94.150010	08/30/1990	37.38	2
10	5	Arkansas	3071	36.267220	-94.150010	02/10/1997	50.50	3
11	13	Georgia	1001	33.807500	-83.790030	05/22/1992	51.96	2
12	15	Hawaii	1006	20.983800	-156.669220	02/22/1991	153.33	7
13	22	Louisiana	0113	30.366850	-93.200320	10/16/2004	67.03	2
14	28	Mississippi	0806	34.443840	-89.875070	02/03/1997	51.77	7
15	35	New Mexico	0101	32.677959	-107.070140	03/11/1997	37.64	5
16	35	New Mexico	0102	32.677799	-107.072560	03/11/1997	42.51	3
17	35	New Mexico	0103	32.677589	-107.075650	03/11/1997	40.42	5
18	35	New Mexico	0105	32.677319	-107.079850	03/11/1997	35.99	5
19	35	New Mexico	0107	32.677052	-107.084050	03/11/1997	42.20	5
20	35	New Mexico	0506	32.677959	-107.070140	03/09/1997	27.69	6
21	35	New Mexico	0801	32.193150	-108.301110	12/01/1999	73.56	9
22	35	New Mexico	0802	32.193539	-108.298520	03/09/1997	57.85	10
23	47	Tennessee	1028	36.383140	-83.122060	08/20/2001	44.61	2
24	47	Tennessee	3101	35.942230	-86.122250	05/16/1990	67.35	1
25	47	Tennessee	3101	35.942230	-86.122250	07/07/1999	48.66	1
26	47	Tennessee	3108	36.175530	-84.088990	05/10/1990	33.96	2
27	48	Texas	1046	35.207600	-101.345160	06/03/1998	151.68	2
28	48	Texas	1065	35.225800	-102.423170	10/25/1990	132.04	1
29	48	Texas	1068	29.355900	-98.835020	03/09/2010	84.84	2
30	48	Texas	1116	31.892810	-94.681110	05/27/1993	66.27	1
31	48	Texas	1174	27.787720	-97.873590	03/28/1990	75.21	1
32	48	Texas	1174	27.787720	-97.873590	03/08/1995	112.40	1
33	48	Texas	2133	31.075830	-97.315070	04/27/1990	51.45	2
34	48	Texas	2133	31.075830	-97.315070	10/06/2000	70.96	2
35	48	Texas	9005	29.516800	-98.721000	04/06/1990	76.67	1
36	48	Texas	9005	29.516800	-98.721000	10/11/2000	134.01	1
37	48	Texas	9005	29.516800	-98.721000	02/08/2005	142.37	2
38	48	Texas	A503	32.613449	-96.407010	02/15/1993	71.41	8
39	48	Texas	A504	32.613400	-96.404760	01/21/1992	97.83	9
40	48	Texas	A507	32.613400	-96.401860	01/21/1992	91.81	9
41	48	Texas	A509	32.613991	-96.411780	01/20/1992	78.76	9
							Total	171

Table 11.11 The Summary of the Sections Used in the Analysis for Pavement Category 2, PCC Overlays with AC

Count	STATE_ CODE	STATE_CODE _EXP	SHRP_ ID	LATITUDE	LONGITUDE	Survey Date and CN Event Date	Initial IRI (in/mile)	No. of Data Points
1	1	Alabama	0606	34.161812	-85.977230	09/24/1999	89.72	4
2	1	Alabama	0608	34.169811	-85.970180	09/24/1999	55.12	5
3	5	Arkansas	A606	34.429089	-92.193400	02/05/1997	60.95	9
4	5	Arkansas	A607	34.430630	-92.193960	02/05/1997	64.37	9
5	6	California	7455	37.714760	-121.343640	03/22/2001	34.28	2
6	6	California	7455	37.714760	-121.343640	12/13/2010	38.14	2
7	28	Mississippi	3099	32.326778	-89.405860	01/21/1994	36.50	1
8	40	Oklahoma	0603	36.713482	-97.345950	06/09/1999	84.84	4
9	40	Oklahoma	0603	36.713482	-97.345950	04/12/2007	116.71	1
10	40	Oklahoma	0604	36.711281	-97.345970	06/09/1999	87.50	5
11	40	Oklahoma	0606	36.703541	-97.345970	06/09/1999	93.90	5
12	47	Tennessee	0603	35.713089	-88.650900	01/30/1997	44.73	5
13	48	Texas	5154	29.692459	-97.213640	10/22/2001	59.50	2
14	48	Texas	5274	32.669392	-97.212550	03/21/2003	100.24	1
15	48	Texas	5287	32.842491	-97.339120	03/21/2003	91.43	2
							Total	57

Table 11.12 The Summary of the Sections Used in the Analysis for Pavement Category 4, CRCP

Count	STATE _CODE	STATE_CODE _EXP	SHRP_ ID	LATITUDE	LONGITUDE	Survey Date and CN Event Date	Initial IRI (in/mile)	No. of Data Points
1	4	Arizona	7079	33.602299	-112.253410	03/23/1990	65.32	4
2	6	California	7455	37.714760	-121.343640	12/16/1989	78.63	4
3	22	Louisiana	0705	30.186020	-90.907870	01/08/1993	83.38	1
4	22	Louisiana	0708	30.176880	-90.889070	01/08/1993	64.75	1
5	28	Mississippi	5006	34.326481	-88.814400	12/05/1990	91.75	6
6	48	Texas	3569	33.127991	-95.754580	04/25/1990	76.29	8
7	48	Texas	3719	30.015779	-94.048480	04/12/1990	153.96	7
8	48	Texas	3779	31.793051	-106.441340	10/11/1990	142.18	11
9	48	Texas	3845	33.570690	-97.166160	09/28/1990	106.38	11
10	48	Texas	5026	29.041639	-95.471330	04/10/1990	107.90	10
11	48	Texas	5035	32.798340	-96.681220	03/12/1990	112.21	9
12	48	Texas	5154	29.692459	-97.213640	04/09/1991	97.70	4
13	48	Texas	5274	32.669392	-97.212550	03/08/1990	101.06	3
14	48	Texas	5283	32.863411	-97.102480	03/09/1990	72.36	11
15	48	Texas	5287	32.842491	-97.339120	03/08/1990	118.67	5
16	48	Texas	5317	32.589809	-97.140820	03/09/1990	138.19	10
17	48	Texas	5323	35.210701	-101.127970	10/29/1990	112.97	3
18	48	Texas	5328	33.591862	-97.922700	11/01/1990	105.81	12
19	48	Texas	5335	35.194038	-101.071990	10/29/1990	128.62	5
20	48	Texas	5335	35.194038	-101.071990	09/19/2001	127.10	3
21	48	Texas	5336	34.968929	-101.871650	10/26/1990	89.02	10
							Total	138

Table 11.13 The Main Soil Properties and Year of Construction for AC Sections

Count	STATE _CODE	STATE_CODE _EXP	SHRP_ ID	Date of Construction (MM/D/YYYY)	NO_4_P ASSING	NO_200_ PASSING	HYDRO _02	LIQUID _LIMIT	PLASTIC _LIMIT	PLASTICITY _INDEX	*w* PI	Initial IRI Year
1	1	Alabama	0101	3/1/1993	99.1	68	46.1	49	35	14	9.5	1995
2	1	Alabama	0102	3/1/1993	94.8	61.0	46.4	42.0	25.4	16.6	10.0	1994
3	1	Alabama	0102	3/1/1993	94.8	61.0	46.4	42.0	25.4	16.6	10.0	2004
4	1	Alabama	0103	3/1/1993	98.5	68.0	46.6	46.0	28.0	18	12.2	1996
5	1	Alabama	0106	3/1/1993	97.6	72.3	52.3	51.0	34.0	17.0	12.3	1994
6	1	Alabama	0109	3/1/1993	95.5	64.4	51.1	43.0	22.0	21.0	13.5	1996
7	5	Arkansas	0804	12/1/1997	96.0	80.1	56.1	34.0	15.0	19.0	15.2	1998
8	5	Arkansas	3048	12/1/1981	100.0	93.7	61.5	33.0	22.5	10.5	9.9	1990
9	5	Arkansas	3071	7/1/1987	100.0	92.1	63.0	35.0	17.5	17.5	16.1	1990
10	5	Arkansas	3071	7/1/1987	100.0	92.1	63.0	35.0	17.5	17.5	16.1	1997
11	13	Georgia	1001	9/1/1986	93.5	52.9	46.3	50.5	30.5	20.0	10.8	1992
12	15	Hawaii	1006	7/1/1980	88.5	58.1	46.4	38.5	22.5	16.0	9.5	1991
13	22	Louisiana	0113	7/1/1997	99.0	92.1	53.8	37.0	18.0	19.0	17.5	2004
14	28	Mississippi	0806	10/1/1996	82.3	44.6	26.5	33.0	15.7	17.3	9.7	1997
15	35	New Mexico	0101	11/1/1995	92.7	68.6	42.0	40.0	18.0	22.0	15.1	1997
16	35	New Mexico	0102	11/1/1995	93.5	58.9	41.4	44.0	18.5	25.5	15.6	1997
17	35	New Mexico	0103	11/1/1995	99.4	89.6	75.0	70.0	28.0	42.0	37.6	1997
18	35	New Mexico	0105	11/1/1995	98.5	86.4	72.4	58.0	27.0	31.0	26.8	1997
19	35	New Mexico	0107	11/1/1995	96.7	78.6	61.8	67.0	28.0	39.0	30.7	1997
20	35	New Mexico	0506	6/1/1965	90.0	48.5	38.8	41.0	19.0	22.0	10.7	1997

21	35	New Mexico	0801	11/1/1996	96.0	47.3	40.0	38.0	14.5	23.5	11.2	1999
22	35	New Mexico	0802	11/1/1996	91.5	53.2	40.8	43.3	15.0	28.3	16.2	1997
23	47	Tennessee	1028	9/1/1983	87.5	70.8	65.0	60.0	28.5	31.5	22.5	2001
24	47	Tennessee	3101	1/1/1980	95.5	77.6	64.0	52.5	26.0	26.5	20.5	1990
25	47	Tennessee	3101	1/1/1980	95.5	77.6	64.0	52.5	26.0	26.5	20.5	1999
26	47	Tennessee	3108	7/1/1972	88.5	58.8	54.5	46.0	20.0	26.0	15.3	1990
27	48	Texas	1046	9/1/1955	100.0	86.7	61.3	39.0	20.5	18.5	16.2	1998
28	48	Texas	1065	12/1/1969	100.0	93.2	67.8	39.5	18.0	21.5	20.1	1990
29	48	Texas	1068	3/1/1987	100.0	74.0	55.5	38.0	18.0	20.0	15.8	1995
30	48	Texas	1116	7/1/1987	100.0	68.4	48.0	34.0	15.0	19.0	13.0	1993
31	48	Texas	1174	5/1/1975	99.5	63.9	51.0	55.0	21.5	33.5	21.7	1990
32	48	Texas	1174	5/1/1975	99.5	63.9	51.0	55.0	21.5	33.5	21.7	1995
33	48	Texas	2133	10/1/1985	100.0	90.6	82.0	65.0	20.0	45.0	40.8	1990
34	48	Texas	2133	10/1/1985	100.0	90.6	82.0	65.0	20.0	45.0	40.8	2000
35	48	Texas	9005	7/1/1986	80.0	63.7	53.3	57.5	26.5	31.0	20.0	1990
36	48	Texas	9005	7/1/1986	80.0	63.7	53.3	57.5	26.5	31.0	20.0	2000
37	48	Texas	9005	7/1/1986	80.0	63.7	53.3	57.5	26.5	31.0	20.0	2005
38	48	Texas	A503	6/1/1977	96.0	91.8	81.9	90.0	19.0	71.0	65.2	1993
39	48	Texas	A504	6/1/1977	100.0	92.6	75.1	77.0	16.0	61.0	56.5	1992
40	48	Texas	A507	6/1/1977	96.0	89.6	77.4	84.0	23.0	61.0	54.7	1992
41	48	Texas	A509	6/1/1977	100.0	91.0	76.0	83.0	24.0	59.0	53.7	1992

Table 11.14 The Main Soil Properties and Year of Construction for PCC Overlays with AC Sections

Count	STATE_CODE	STATE_CODE_EXP	SHRP_ID	Date of Construction (MM/D/YYYY)	NO_4_PASSING	NO_200_PASSING	HYDRO_02	LIQUID_LIMIT	PLASTIC_LIMIT	PLASTICITY_INDEX	*w* PI	Initial IRI Year
1	1	Alabama	0606	5/1/1966	71.7	50.6	37.5	49.0	18.7	30.3	15.4	1999
2	1	Alabama	0608	5/1/1966	85.5	64.0	45.3	40.0	15.5	24.5	15.8	1999
3	5	Arkansas	A606	12/1/1978	99.0	64.9	52.1	49.0	17.0	32.0	20.8	1997
4	5	Arkansas	A607	12/1/1978	90.0	73.3	65.9	49.0	31.0	18.0	13.2	1997
5	6	California	7455	5/1/1971	80.0	53.7	43.7	38.5	15.5	23.0	12.4	2001
6	6	California	7455	5/1/1971	80.0	53.7	43.7	38.5	15.5	23.0	12.4	2010
7	28	Mississippi	3099	11/1/1970	100.0	95.9	86.5	66.0	23.5	42.5	40.9	1994
8	40	Oklahoma	0603	11/1/1962	100.0	74.9	47.6	34.0	13.0	21.0	15.7	1999
9	40	Oklahoma	0603	11/1/1962	100.0	74.9	47.6	34.0	13.0	21	15.7	2007
10	40	Oklahoma	0604	11/1/1962	100.0	84.3	58.0	48.5	16.0	32.5	28.0	1999
11	40	Oklahoma	0606	11/1/1962	100.0	86.0	58.0	32.0	17.0	15.0	12.9	1999
12	47	Tennessee	0603	6/1/1964	100.0	92.8	58.9	43.0	22.0	21.0	19.5	1997
13	48	Texas	5154	7/1/1971	100.0	45.1	40.0	46.0	20.5	25.5	11.6	2001
14	48	Texas	5274	3/1/1973	96.5	88.9	70.0	66.5	26.5	40.0	35.8	2003
15	48	Texas	5287	8/1/1973	77.0	57.5	47.5	48.5	28.0	20.5	11.8	2003

Table 11.15 The Main Soil Properties and Year of Construction for CRCP Sections

Count	SHRP_ ID	STATE _CODE	STATE_CODE _EXP	Date of Construction (MM/D/YYYY)	NO_200_ PASSING	*w* PI	Initial IRI Year
1	7079	4	Arizona	3/1/1989	51.0	9.9	1990
2	7455	6	California	5/1/1971	53.7	12.4	1989
3	0705	22	Louisiana	6/1/1979	98.7	38.5	1993
4	0708	22	Louisiana	6/1/1979	92.0	22.1	1993
5	5006	28	Mississippi	4/1/1979	79.7	15.9	1990
6	3569	48	Texas	6/1/1960	83.4	17.2	1990
7	3719	48	Texas	9/1/1964	88.9	23.6	1990
8	3779	48	Texas	6/1/1978	61.5	48.4	1990
9	3845	48	Texas	6/1/1960	91.0	36.9	1990
10	5026	48	Texas	11/1/1985	96.0	29.8	1990
11	5035	48	Texas	9/1/1979	61.7	17.9	1990
12	5154	48	Texas	7/1/1971	45.1	11.6	1991
13	5274	48	Texas	3/1/1973	88.9	35.8	1990
14	5283	48	Texas	11/1/1987	63.5	9.9	1990
15	5287	48	Texas	8/1/1973	57.5	11.8	1990
16	5317	48	Texas	4/1/1982	59.0	12.2	1990
17	5323	48	Texas	9/1/1980	71.5	10.7	1990
18	5328	48	Texas	9/1/1975	68.8	10.0	1990
19	5335	48	Texas	9/1/1980	75.5	13.6	1990
20	5335	48	Texas	9/1/1980	75.5	13.6	2001
21	5336	48	Texas	12/1/1986	75.3	15.1	1990

Table 11.16 A Sample from the Table Developed to Calculate SF for Pavement Categories 1 and 2

STATE _CODE	STATE_CODE _EXP	SHRP_ID	Time (Year)	Annual Average Freeze Index (deg C deg days)	Annual Average Freeze Index (deg F deg days)	Annual Average Precipitation (mm)	Annual Average Precipitation (in)	Age (yrs) Using Initial IRI	Frost (2020)	Swell (2020)	SF (2020)	ΔSF from initial IRI year
1	Alabama	0101	1995	6.6	11.88	1258.2	50	2	10	11	60	0
1	Alabama	0101	1996	27	48.6	1201.5	47	3	12	11	116	57
1	Alabama	0101	1997	5.3	9.54	1475.3	58	4	10	11	170	110
1	Alabama	0101	1998	0	0	1396.7	55	5	8	11	210	150
1	Alabama	0101	1999	6.2	11.16	1145.2	45	6	10	11	307	248
1	Alabama	0101	2000	12	21.6	845.2	33	7	10	10	388	328
1	Alabama	0101	2001	3	5.4	1167.2	46	8	10	11	460	400
1	Alabama	0101	2002	3	5.4	1117.8	44	9	9	11	546	486
1	Alabama	0101	2003	6	10.8	1593.8	63	10	10	11	681	621
1	Alabama	0101	2004	2	3.6	1378.6	54	11	9	11	741	681
1	Alabama	0101	2005	2	3.6	1847.6	73	12	10	11	868	808

Table 11.17 A Sample from the Table Developed to Calculate SF for Pavement Category 4

STATE_ CODE	STATE_CODE _EXP	SHRP _ID	Time (Year)	Annual Average Freeze Index (deg C deg days)	Annual Average Freeze Index (deg F deg days)	Age (yrs)	SF	ΔSF from initial IRI year
48	Texas	5154	1991	0	0	20	0.00092	0.0000000
48	Texas	5154	1992	0	0	21	0.00097	0.0000461
48	Texas	5154	1993	0	0	22	0.00102	0.0000923
48	Texas	5154	1994	0	0	23	0.00106	0.0001384
48	Texas	5154	1995	0	0	24	0.00111	0.0001846
48	Texas	5154	1996	2	3.6	25	0.00346	0.0025401
48	Texas	5154	1997	1.1	1.98	26	0.00252	0.0015978
48	Texas	5154	1998	0.6	1.08	27	0.00199	0.0010713
48	Texas	5154	1999	0	0	28	0.00129	0.0003692
48	Texas	5154	2000	0	0	29	0.00134	0.0004153

Table 11.18 A Sample from the Tables Developed to Predict IRI to Compare It with Measured IRI for Pavement Categories 1 and 2

						2		3 & 4				5		
STATE _CODE	STATE_CODE _EXP	SHRP _ID	Survey Date	Year	Measured IRI (in/mile)	Year	SF (2020)	SURVEY _DATE	Year	HPMS16 FC (%)	TC (ft/mi)	Survey Date	Rutting (in)	Predicted IRI
1	Alabama	0101	10/11/1996	1996	42.96	1996	57	10/10/1996	1996	2	0	10/10/1996	0.24	52.73
1	Alabama	0101	10/15/1997	1997	44.54	1997	110	10/30/1997	1997	6	0	10/30/1997	0.20	53.56
1	Alabama	0101	04/23/1998	1998	44.04	1998	150	4/25/1998	1998	12	0	04/25/1998	0.24	58.13
1	Alabama	0101	03/14/2001	2001	47.08	2001	400	8/23/2001	2001	19	28	03/07/2001	0.24	64.90
1	Alabama	0101	03/10/2002	2002	44.73	2002	486	2/8/2002	2002	25	121	02/08/2002	0.24	69.34
1	Alabama	0101	01/29/2003	2003	46.38	2003	621	4/9/2003	2003	41	506	04/04/2003	0.24	80.84
1	Alabama	0101	04/27/2004	2004	49.17	2004	681	2/23/2004	2004	33	544	02/23/2004	0.24	78.84
1	Alabama	0101	05/04/2005	2005	49.80	2005	808	4/28/2005	2005	45	506	04/28/2005	0.24	85.25

Table 11.19 A Sample from the Table Developed to Predict IRI to Compare It with Measured IRI for Pavement Category 4

						2			3		
STATE _CODE	STATE_CODE _EXP	SHRP _ID	Survey Date	Year	Measured IRI (in/mile)	Date	Year	PO	Year	SF	Predicted IRI (in/mile)
48	Texas	5328	03/01/1991	1991	103.47	6/20/1991	1991	0	1991	-0.026275	105.07
48	Texas	5328	04/21/1993	1993	100.68	8/5/1993	1993	0	1993	-0.015078	105.38
48	Texas	5328	12/06/1994	1994	103.28	12/06/1994	1994	0	1994	-0.016426	105.35
48	Texas	5328	01/16/1998	1998	97.76	4/15/1998	1998	0	1998	-0.012628	105.45
48	Texas	5328	10/16/1999	1999	103.02	10/16/1999	1999	0	1999	-0.020021	105.24
48	Texas	5328	09/20/2001	2001	101.44	1/22/2001	2001	0	2001	-0.004189	105.69
48	Texas	5328	10/07/2003	2003	103.09	12/3/2003	2003	0	2003	0.003769	105.92
48	Texas	5328	03/01/2005	2005	100.74	3/10/2005	2005	0	2005	0.002093	105.87
48	Texas	5328	04/30/2010	2010	103.47	04/30/2010	2010	0	2010	0.029666	106.65
48	Texas	5328	10/22/2013	2013	103.02	10/22/2013	2013	0	2013	0.021639	106.42
48	Texas	5328	08/27/2014	2014	104.80	6/3/2014	2014	0	2014	0.088373	108.32
48	Texas	5328	09/16/2015	2015	103.78	09/16/2015	2015	0	2015	0.041184	106.98

11.8. Calculations and Results

The stochastic solution developed for the NCHRP 01-59 project mechanistically estimates the average monthly volume change due to environmental effect for a period of 8 years, starting from the date of construction. The outcome included six statistical measurements: mean volume change (Mean VC), change in mean (Δ Mean VC), standard deviation (STD), change in standard deviation (Δ STD), shrink/swell variance (V_{ss}), and change in V_{ss} (ΔV_{ss}). The changes, Δ Mean VC, Δ STD, and ΔV_{ss}, were calculated using the difference from one month to the other. All the six statistical measurements were estimated for 5 different pavement locations, pavement edge (PE), outer wheel path (OWP), mid lane (ML), inner wheel path (IWP), and inner lane edge (ILE). The statistical analysis conducted for the purpose of this study focused mainly on the average of OWP and IWP, named WP, since IRI is measured under the wheel path. In addition, for comparison purposes the statistical analysis was also conducted on the PE, since the developed shrink swell model was calibrated using the elevation changes at the PE. The six statistical measurements were used, and the results were compared to identify the best environmental factor representative. This was done for all 3 pavement categories used in this study, AC, PCC overlays with AC, and CRCP.

The method of least square error was used in the statistical analysis to identify the best model, as summarized in the following steps:

1. For comparison purposes between the new method to the available method, measured vs predicted IRI plots were developed using the original equation with the site factor, SF, and calculate the R^2.
2. Replace the SF column with a statistical measurement.
3. After predicting IRI using the replaced variable for each data point, the residual IRI ($IRI_{measured} - IRI_{predicted}$) was calculated and squared. The sum of the squared residuals (SSR) was then calculated.
4. The standard error of estimate (SEE), which is similar to the standard deviation that statistically represents a measure of the accuracy of predictions, was calculated using the following equation,

$$SEE = \sqrt{\frac{SSR}{n-2}} \qquad (11-10)$$

5. Solve for the coefficients used in the IRI equation that result with the least SSR.
6. Compare the R^2, SSR, and SEE developed for measured and predicted IRI using the 6 statistical measurements.
7. Choose the one with the best correlation and enhance the correlation by eliminating outliers.

The results were divided based on the pavement category, as shown in the following section. As mentioned earlier, the analysis was conducted for the pavement edge (PE) and wheel path (WP) locations. Seven plots were created for each location, one using the original SF equation and six using the statistical measurements. On each plot, the best fit equation, along with the R^2, SSR, SEE, and the four fitting parameters' corresponded coefficients are shown. Those results are shown on the figures so the statistical measurement with the best correlation can be observed and used for the further analysis.

1- Pavement Category 1, AC

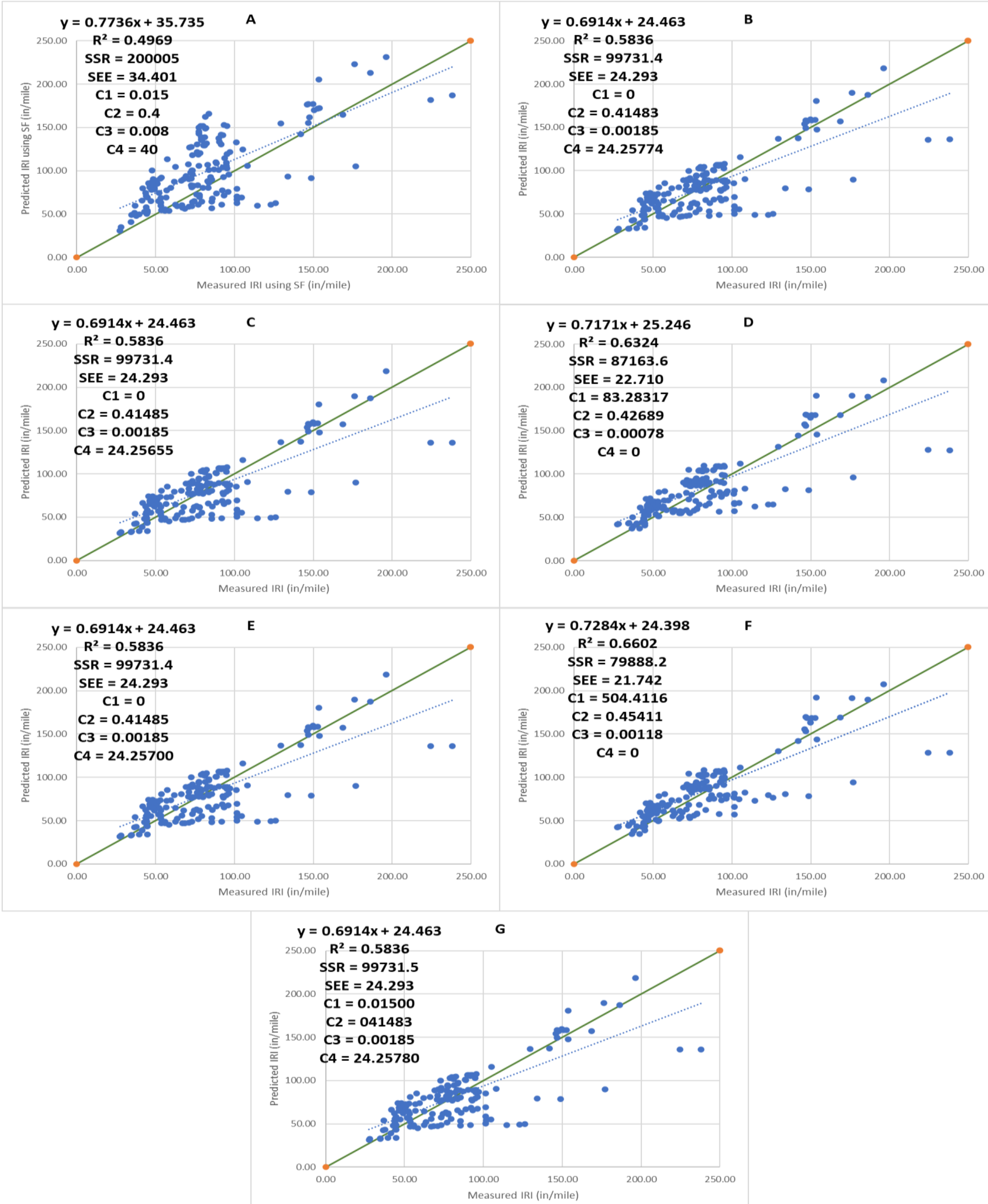


Figure 11.3 Comparison of Measured and Predicted IRI Using Different Environmental Factors A) SF, B) Mean VC, C) ∆ Mean VC, D) STD, E) ∆ STD, F) V_{ss}, and G) ΔV_{ss} for Pavement Category 1 at *PE*

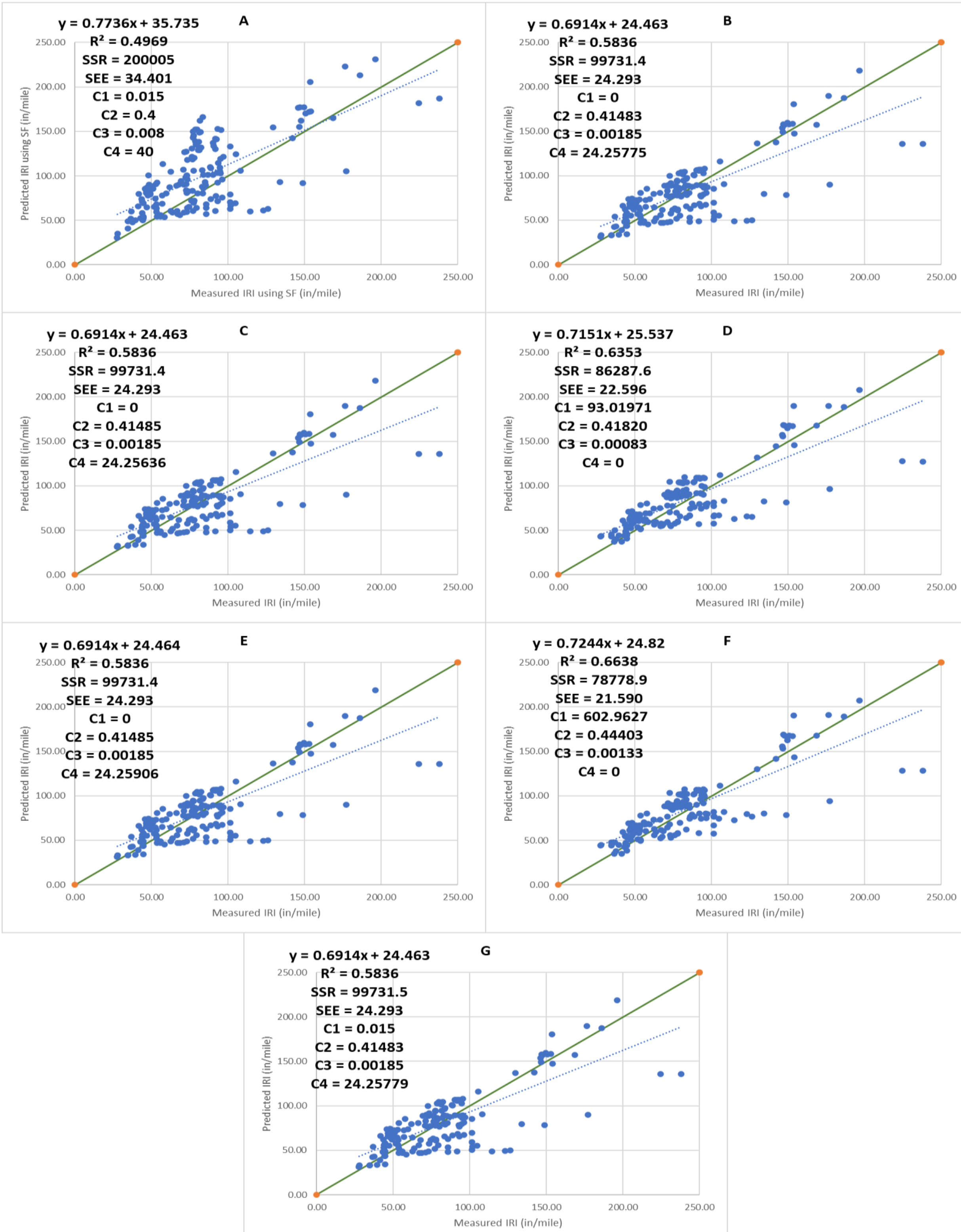


Figure 11.4 Comparison of Measured and Predicted IRI Using Different Environmental Factors A) SF, B) Mean VC, C) ∆ Mean VC, D) STD, E) ∆ STD, F) V_{ss}, and G) ΔV_{ss} for <u>Pavement Category 1</u> at <u>*WP*</u>

2- Pavement Category 2, PCC Overlays with AC

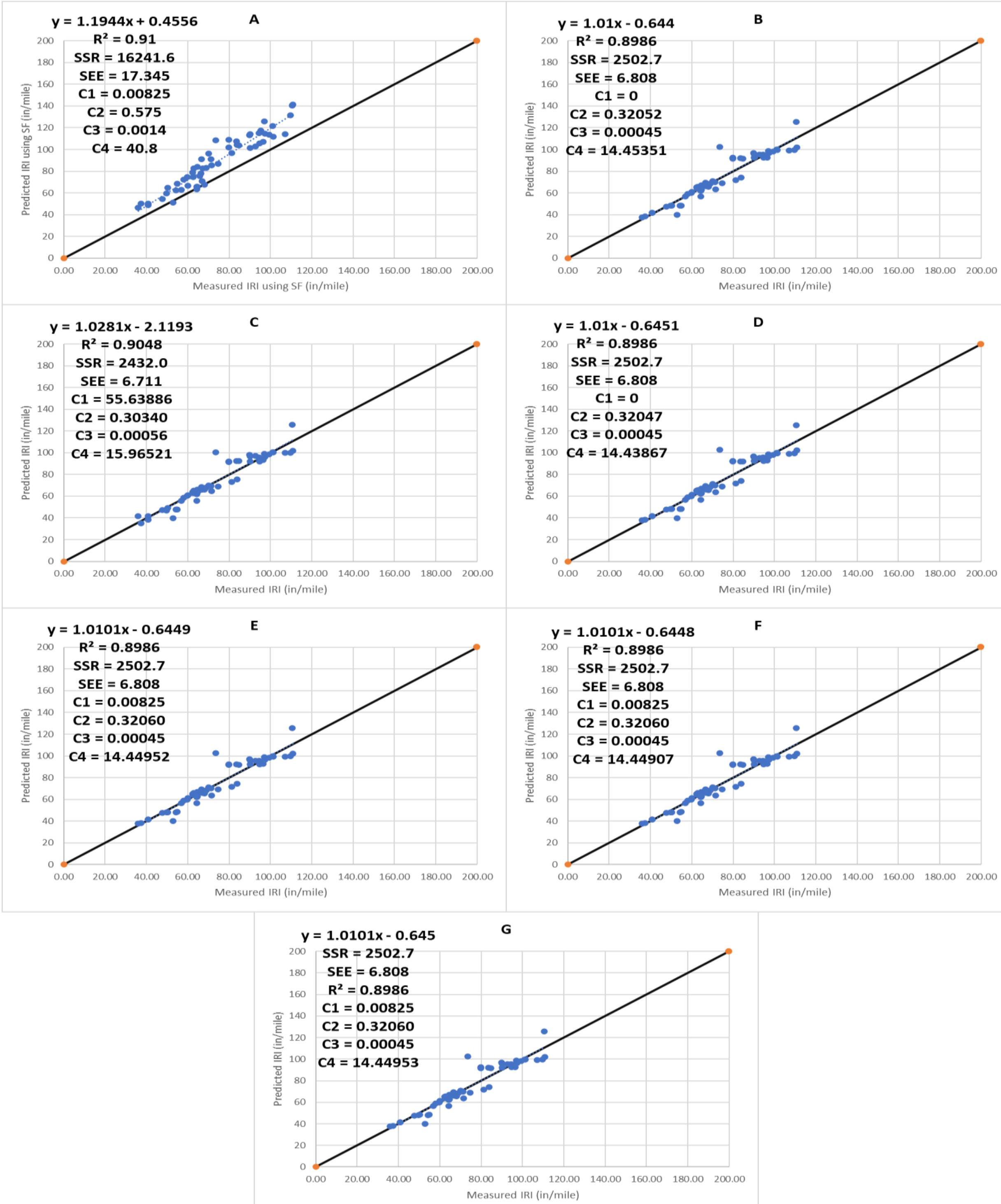


Figure 11.5 Comparison of measured and predicted IRI Using Different Environmental Factors A) SF, B) Mean VC, C) Δ Mean VC, D) STD, E) Δ STD, F) V_{ss}, and G) ΔV_{ss} for Pavement Category 2 at *PE*

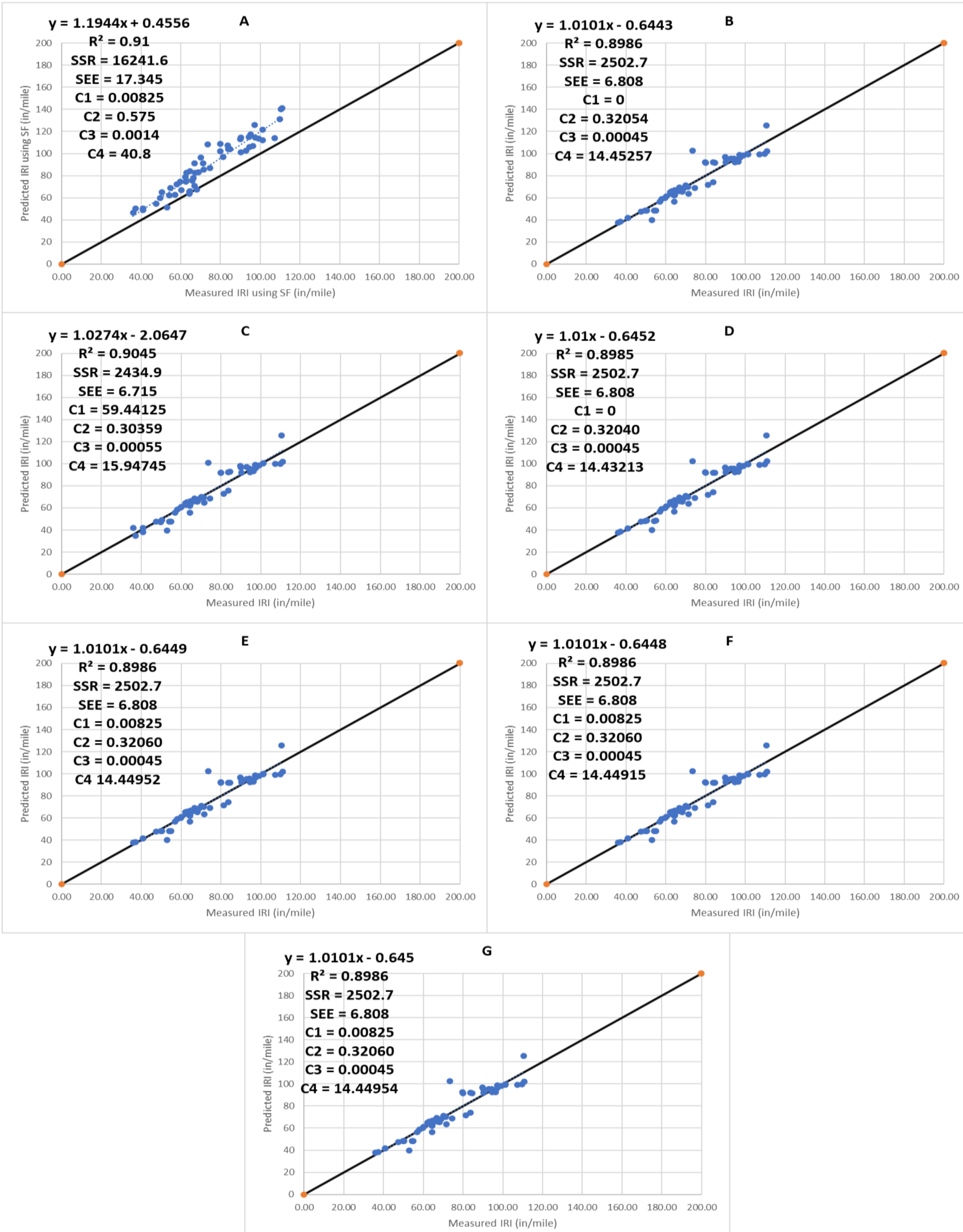


Figure 11.6 Comparison of measured and predicted IRI Using Different Environmental Factors A) SF, B) Mean VC, C) Δ Mean VC, D) STD, E) Δ STD, F) V_{ss}, and G) ΔV_{ss} for <u>Pavement Category 2</u> at <u>*WP*</u>

3- Pavement Category 4, CRCP

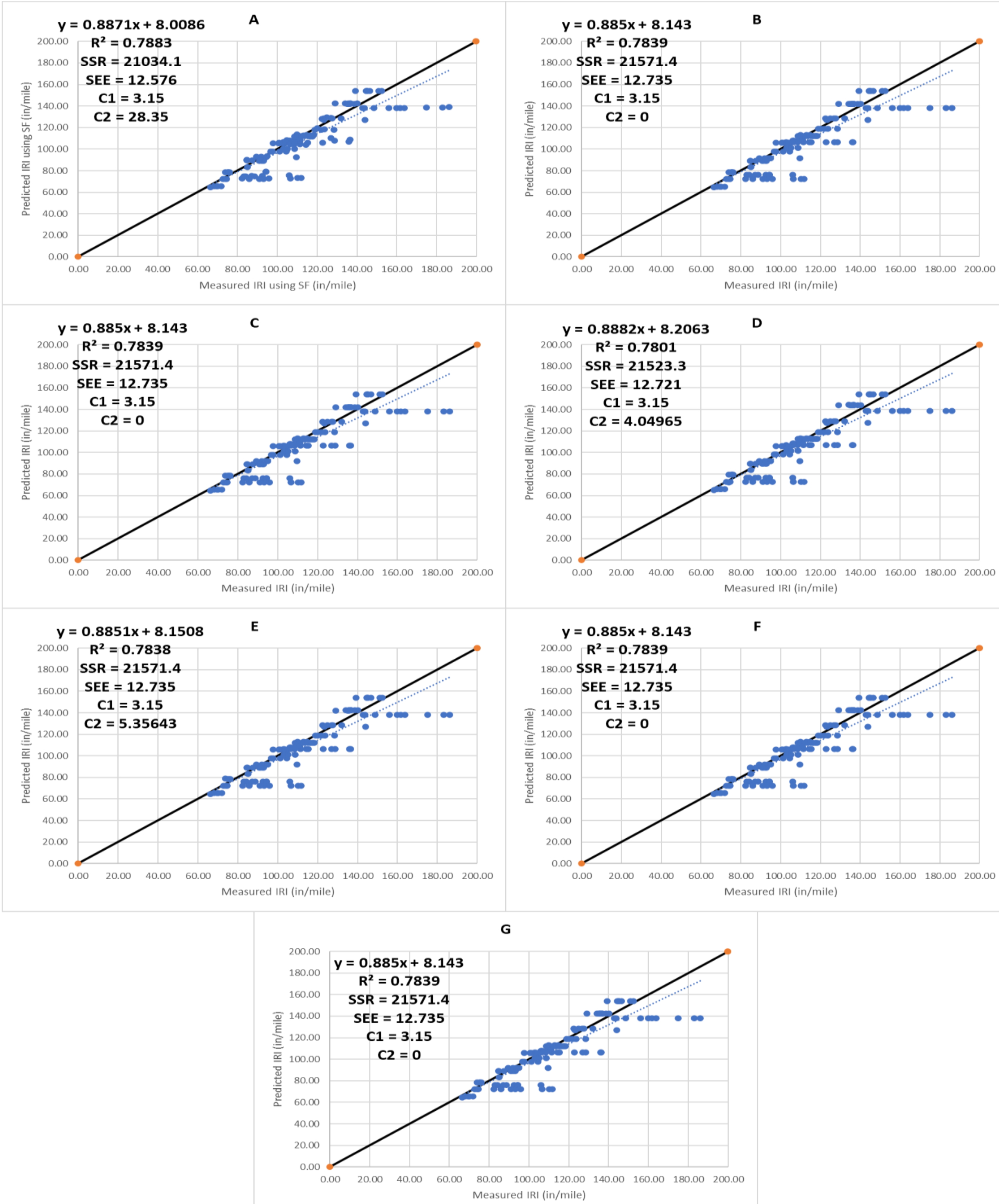


Figure 11.7 Comparison of Measured and predicted IRI Using Different Environmental Factors A) SF, B) Mean VC, C) Δ Mean VC, D) STD, E) Δ STD, F) V_{ss}, and G) ΔV_{ss} for Pavement Category 3 at *PE*

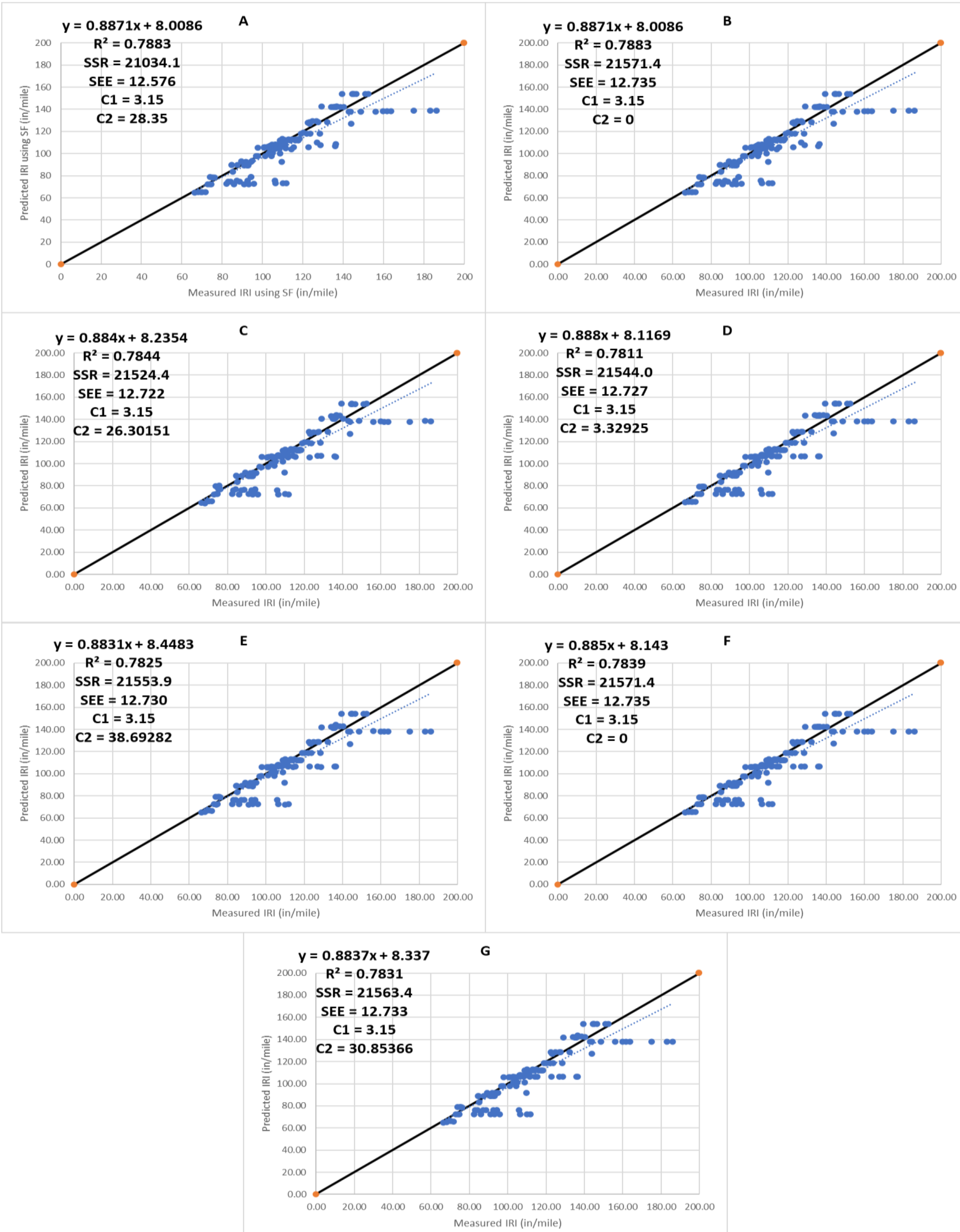


Figure 11.8 Comparison of measured and predicted IRI Using Different Environmental Factors A) SF, B) Mean VC, C) Δ Mean VC, D) STD, E) Δ STD, F) V_{ss}, and G) ΔV_{ss} for Pavement Category 3 at *WP*

11.9. Discussion

11.9.1. Analysis

In general, after comparing the results for each pavement category at PE and WP, the difference can be considered negligible. For example, plot B in Figure 11.3 and Figure 11.4 is identical. Plot D in the same figures has small differences in R^2, SSR, and SEE, but those differences are negligible. This means that the model that allows for the estimation of the transverse variability is adequate. Thus, only the results at WP were used henceforward.

1- Pavement Category 1, AC

The best plot in Figure 11.4 is plot F, using the shrink/swell variance (V_{ss}). When compared with plot A, the original SF equation, the SSR dropped more than 60%, the SEE dropped more than 35%, and the R^2 increased from about 50% to 66%. Thus, for this category, V_{ss} was used henceforth.

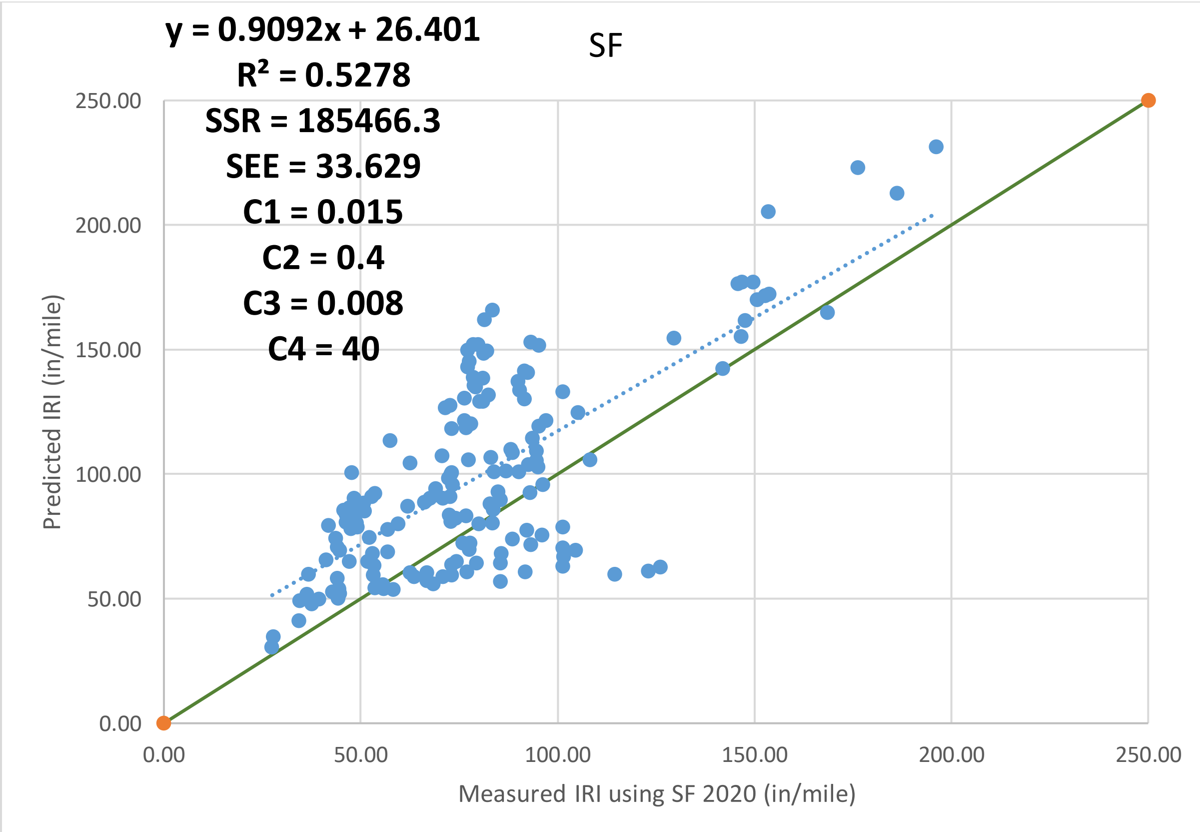
It was found that 5 points were ***statistically*** outliers, 2 points in section AR 05-3048, 2 points in section TX 48-2133, and 1 point in section TX 48-9005. All five points were underestimated by the model since a relatively dramatical increase in the measured IRI value was reported. Those sections were constructed in 1981, 1985, and 1986 respectively. It is true that some of the distresses, especially in section AR 05-3048, was showing a massive increase, which may be reflected in the IRI value. However, other sections, such as TX 48-A503 and TX 48-A509, had similar increase in distresses, yet no such increase in IRI occurred. Measurements/calculations errors could be behind the unrealistic increase in measured IRI. As a result, those 5 outliers were eliminated to possibly enhance the model. For a comparison purposes between the original SF model and the enhance V_{ss} model, those points were also eliminated from the original SF model results. The final model and comparison can be found in Figure 11.9. An enhancement can be observed where the sum squared residual (SSR) had more than 75% reduction, the standard error of estimate had more than 50% reduction, and the R^2 increased from about 53% to 78%.

2- Pavement Category 2, PCC Overlays with AC

The best plot in Figure 11.6 is plot C, using the difference in the mean volume change. When compared with plot A, the original SF equation, the SSR dropped more than 85%, the SEE dropped more than 60%, but the R^2 slightly decreased from about 91% to 90.5%.

3- Pavement Category 4, CRCP

The best plot in Figure 11.8 is plot C, using the difference in the mean volume change. When compared with plot A, the original SF equation, the SSR increased a bit about 2%, the SEE also had a little increase about 1.2%, and the R^2 slightly decreased from 78.8% to 78.4%.



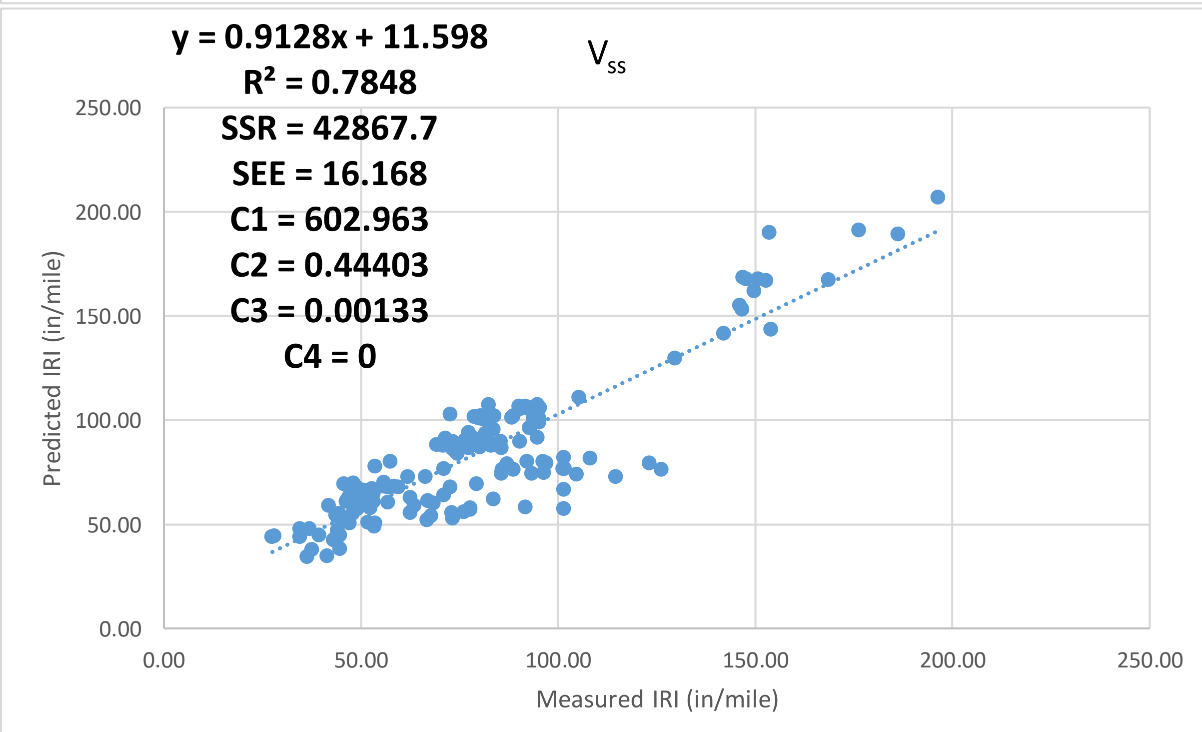


Figure 11.9 Comparison of Measured vs Predicted IRI for the Original SF Model and the Enhanced V_{ss} Model

11.9.2. Sensitivity Analysis

The model developed for AC pavements shows a good correlation between the environmental effect, shrink/swell variance (V_{ss}), fatigue cracking, FC, and transverse cracking, TC. However, no correlation is shown for rutting. This was found questionable since rutting depth is the result of the sum of permanent deformation that occurs in AC, unbound, and soil foundation layers (MEPDG, 2020). Further statistical analysis was developed to better understand the correlations. To simplify the analysis, the initial IRI was moved to the other side of the equation and the change in IRI, d_IRI = ($IRI_{measured}$ - $IRI_{initial}$), was calculated and used. Of course, this would not reflect the real relationship and may minorly affect the weight of each variable since $IRI_{initial}$ is an independent value. However, IRI_{inital} was found to be responsible of increasing the R^2 by about 50%. In other words, a 50% value should be added to the R^2 values found in Figure 11.10 through Figure 11.13 to reflect the true relationship. Figure 11.10 summarizes the simple linear regression that clearly reflects the effect of each variable.

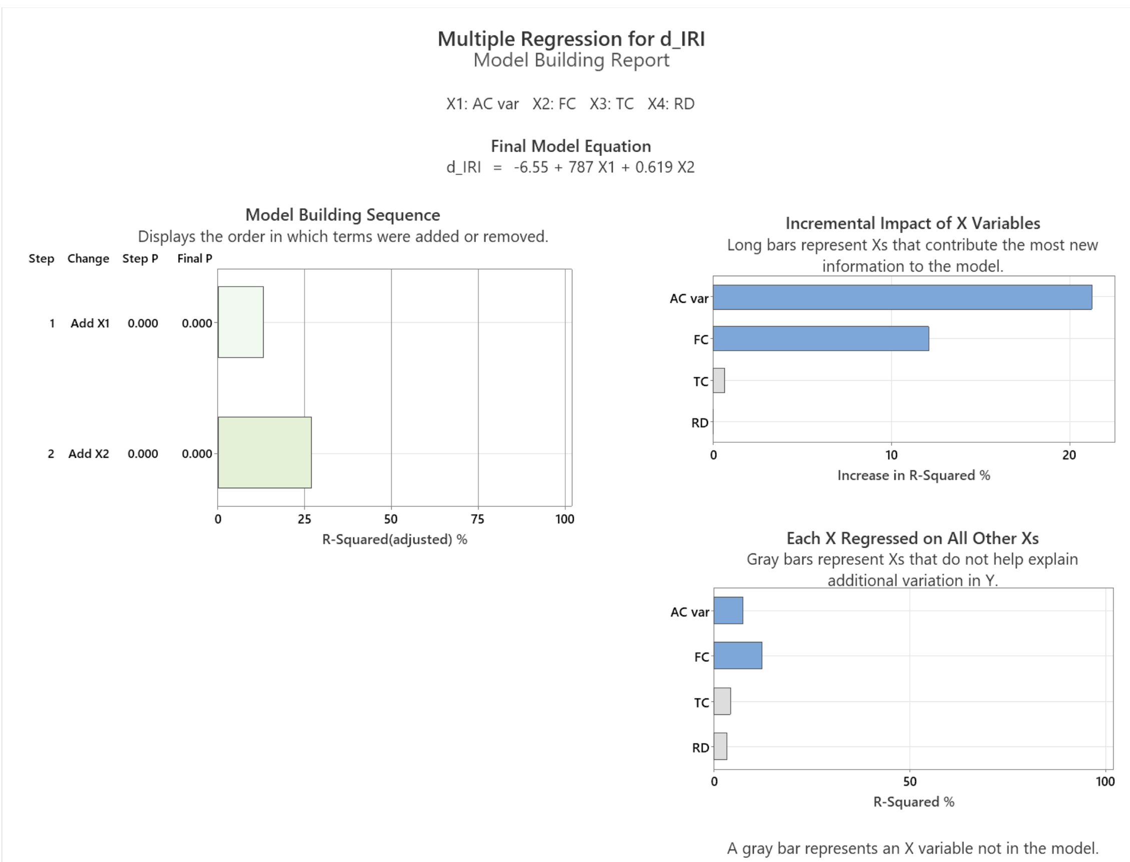


Figure 11.10 The Weight of Each Variable on the IRI Equation Using Linear Regression

- A multi regression analysis was used and the results are shown in Figure 11.11.
- A new parameter, duration, which is the time in days from the date of the initial IRI, the reference point, to the date of the measured value, was added as a variable to possibly enhance the model. Figure 11.12 and Figure 11.13 show the results of linear and multi regressions, respectively.

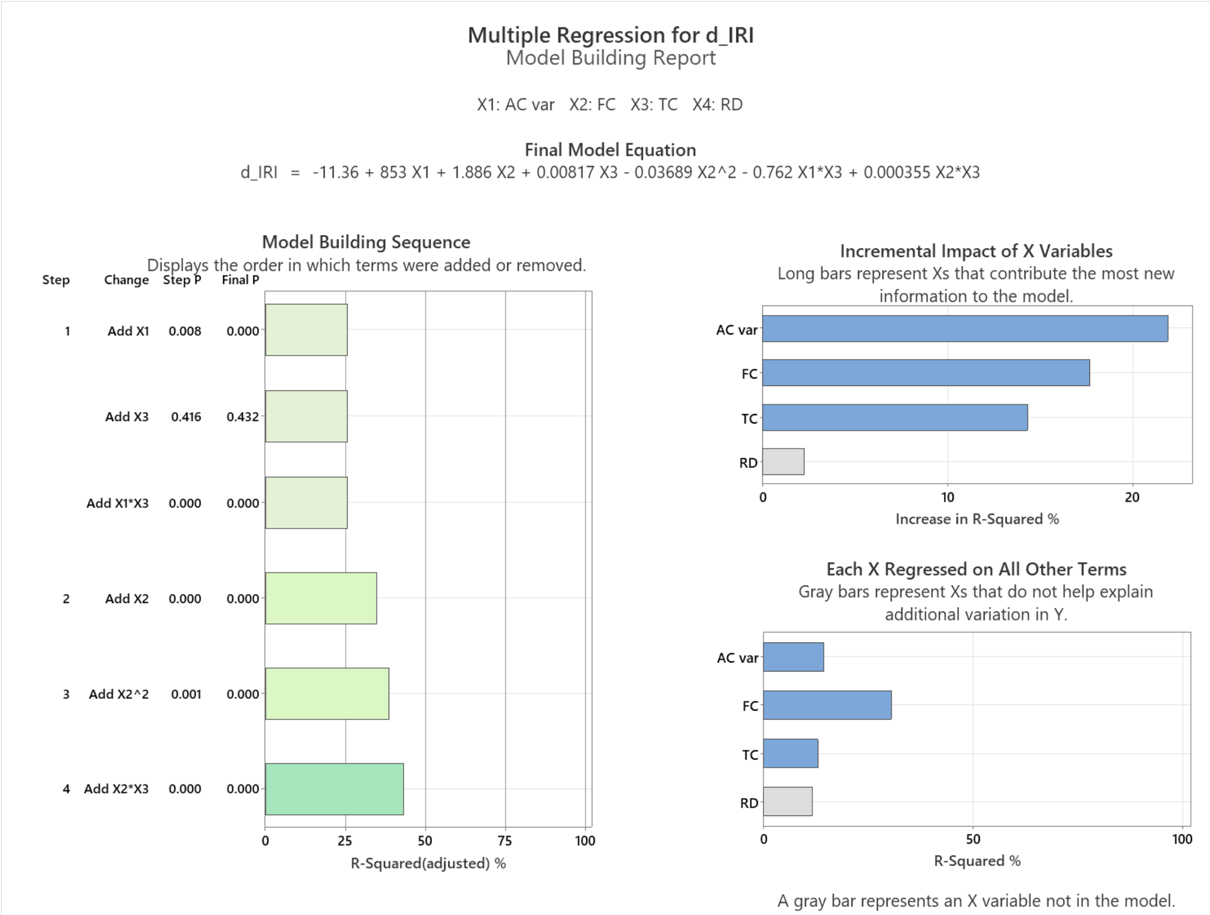


Figure 11.11 The Weight of Each Variable on the IRI Equation Using Multi Regression

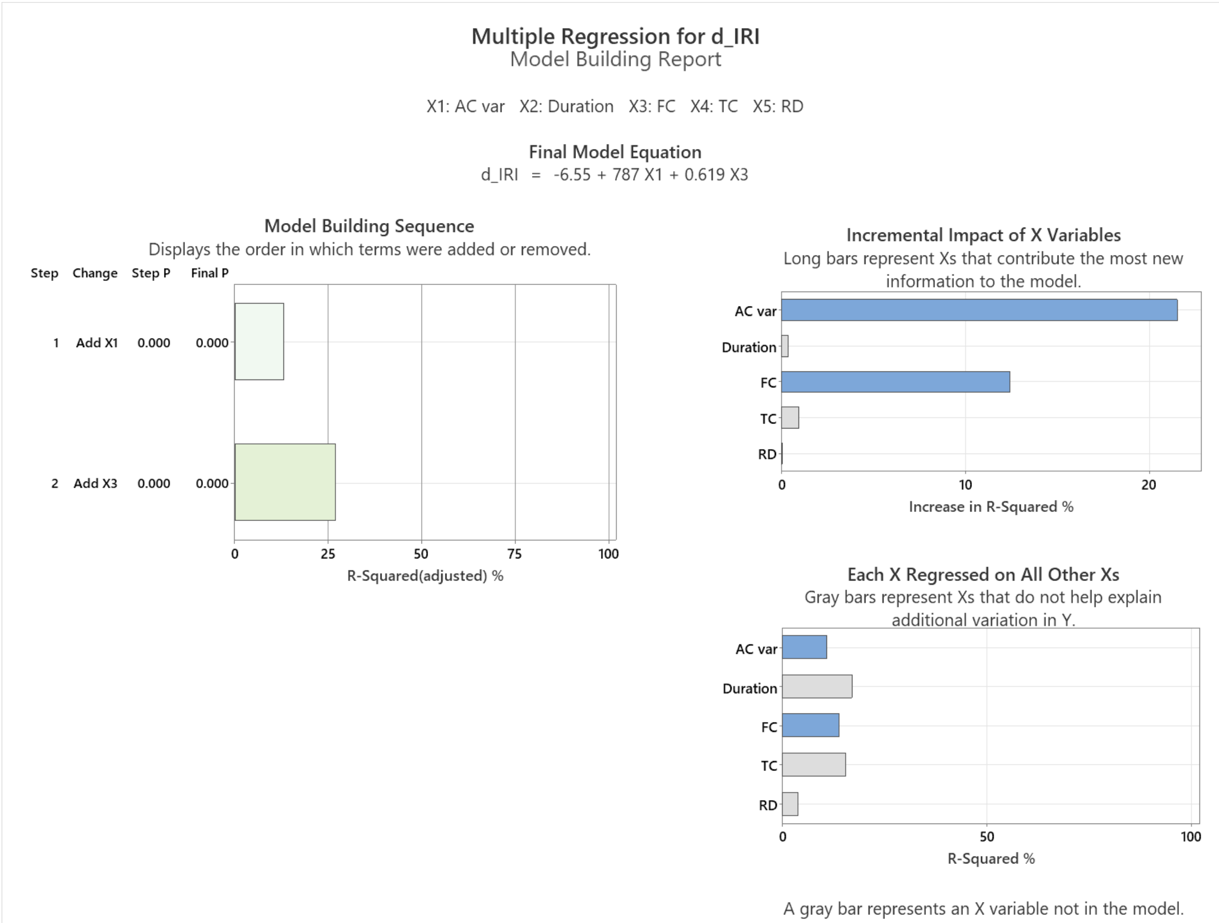


Figure 11.12 The Weight of Each Variable on the IRI Equation, After Adding Duration, Using Linear Regression

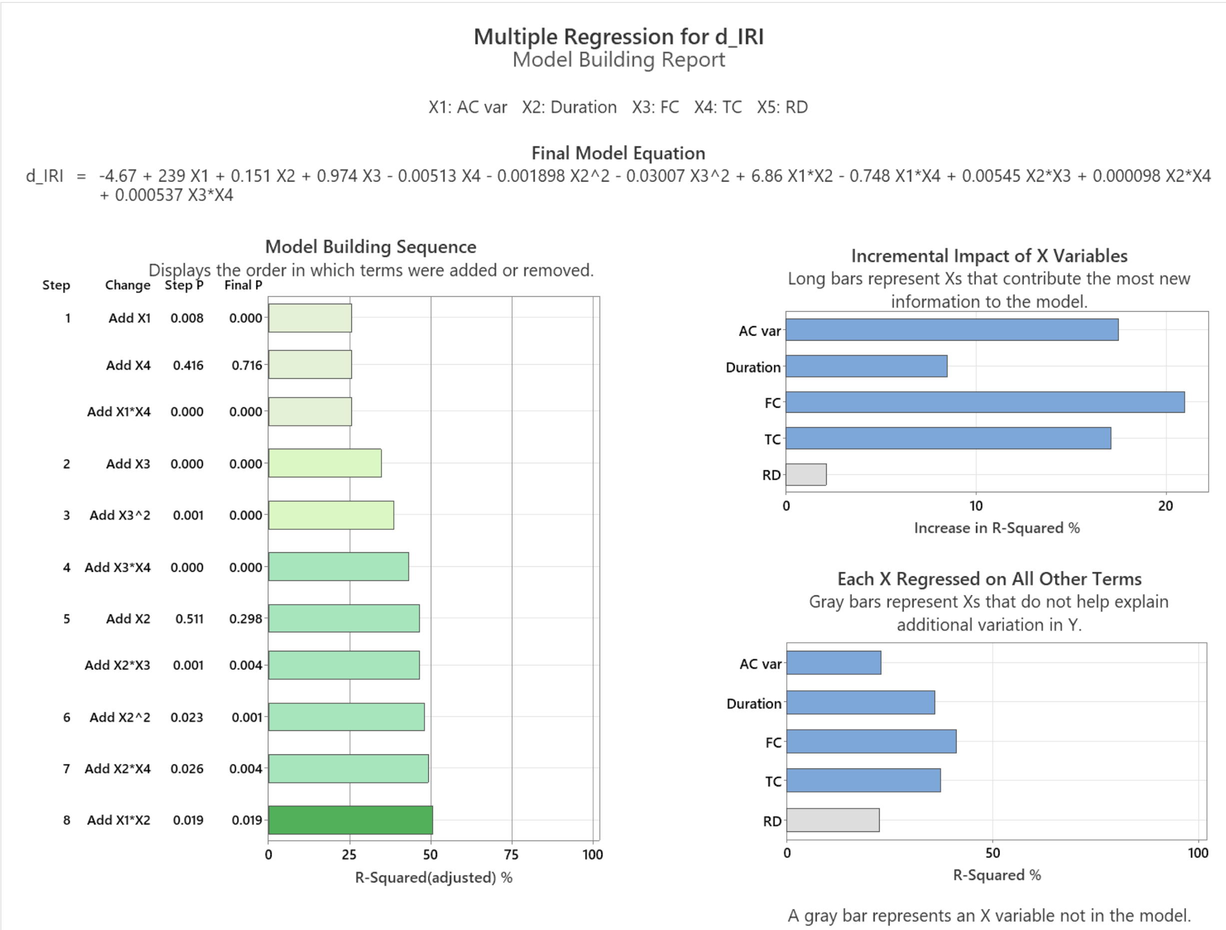


Figure 11.13 The Weight of Each Variable on the IRI Equation, After Adding Duration, Using Multi Regression

In all cases, rutting showed no correlation with the IRI. Further research was conducted to find whether rutting is directly affected by shrink/swell behavior or not. Table 11.20 was found in an FHWA report, TX-11/0-6589-1, which shows the pavement distresses and their possible causes in low volume roads. In this table, shrink/swell behavior is not a direct cause of rutting. As a result, <u>it can be concluded that the IRI change due to environmental effect ***does not*** have a direct correlation with rutting</u>. Thus, the results of the linear regression, without duration, was used as the <u>***final***</u> model, Figure 11.9.

Table 11.20 Pavement Distresses and Their Causes in Low Volume Roads (Dessouky et al., 2012)

	Excessive loading /Heavy traffic	Base failure or consolidated subgrade	Poor drainage	Lack of lateral support/ shoulder or narrow pavement	Shrinkage/swelling of drying out sulfate soil/ expansive soil	vegetation along edge/ Erosion	Settlement of underlying material	Poorly constructed joint / segregation	Shrinkage of asphalt layer	Cycles of temperature change	Differential movement between asphalt and concrete layers	Insufficient design thickness	moisture infiltration/damage	Lack of good bond between surface layer	Poor quality mixture/ improper aggregates	Tack coat not been used	Poor construction /lack of compaction	Asphalt binder hardened excessively	Frost heave and freeze/thaw	Vehicular turning or stopping movements
Fatigue (Alligator) Cracking	•	•	•																	
Block Cracking					•												•			
Edge Cracks/drop-off		•	•	•	•	•	•												•	
Long./ Transverse Cracking					•			•	•	•										
Reflection Cracking					•						•									
Rutting		•										•	•		•		•			
Upheaval/Swell					•					•			•						•	
Shoulder drop-off	•			•		•													•	
Popouts/ potholes															•			•		
Raveling													•		•			•		
Stripping													•					•		
Polished Aggregate	•														•					
Corrugation and Shoving															•					•
Bleeding															•		•			

Although the correlation developed for pavement category 2 seems to be acceptable, a higher corresponded coefficient, more than 500, was expected for the environment factor to have a weight on the IRI. It was found that all 56 points, but 3, used in this analysis had a weight of 3.5% or less. The other 3 points had a weight between 9 and 11%. This minimal impact indicates that the environmental effect on pavement category 2 may be considered low or even negligible. Physically, this conclusion may be true considering the effect of volume change on a concrete slab. At this point, the results of pavement category 4, CRCP, may support this finding.

The IRI equation of pavement category 4 includes IRI_0, environmental factor, and punchout, PO, distress. With PO values being zero in all of 135 points used in the analysis, environmental factor is expected to have a high impact, mathematically, on the IRI equation. However, the weight of the environmental factor, Δ Mean VC, was found to be no more than 2.1%. As a result, it was concluded that the environmental factor has ***low, negligible***, impact on the IRI equation.

11.10. Conclusion

The environmental factor originally used in the IRI equation known as the Site Factor, SF, is empirical in nature and does not incorporate a mechanistic procedure. As part of NCHRP 01-59 project, a new environmental factor based on the shrink/swell variance (V_{ss}) obtained from a Monte Carlo simulation was developed mechanistically and calibrated using field data gathered from the LTPP program to replace the SF. The analysis was conducted for AC, PCC covered with AC, and CRCP pavements.

For the AC pavement, a better correlation was found and a new equation to estimate IRI was developed. It is suggested to use the following equation for the AC pavement when designing over expansive soils,

$$IRI = IRI_0 + 602.96\,SV + 0.444\,FC_{Total} + 0.00133\,TC \qquad (11-11)$$

For the other pavement categories, it was found that the environmental impact is very minimal or negligible. It is believed that the reason is the existence of the concrete slabs, which are rigid by design and do not allow differential movement to be reflected at the surface of the pavement. That means the volume change effect into IRI equation is negligible. Therefore, the IRI for those pavements are recommended to be estimated based on the currently available equations in the MEPDG (2020) design manual.

Table 11A.21 Distresses Records for AC Pavements at the WP

State	SHRP_ID	IRI Measured (in/mile)	IRI Initial (in/mile)	SF (2020)	shrink/swell variance (V_{ss})	FC	TC	RD	IRI Predicted (in/mile)	Residual (R)	R^2	Env Weight
Alabama	0101	42.96	41.63	57	0.000385	2	0	0.24	42.75	0.21	0.0	1%
Alabama	0101	44.54	41.63	110	0.000400	6	0	0.20	44.53	0.01	0.0	1%
Alabama	0101	44.04	41.63	150	0.000562	12	0	0.24	47.29	-3.26	10.6	1%
Alabama	0101	47.08	41.63	400	0.000894	19	28	0.24	50.64	-3.56	12.7	1%
Alabama	0101	44.73	41.63	486	0.000894	25	121	0.24	53.43	-8.70	75.6	1%
Alabama	0101	46.38	41.63	621	0.000813	41	506	0.24	60.99	-14.61	213.6	1%
Alabama	0101	49.17	41.63	681	0.000901	33	544	0.24	57.54	-8.38	70.2	1%
Alabama	0101	49.80	41.63	808	0.000495	45	506	0.24	62.58	-12.78	163.3	0%
Alabama	0102	56.83	60.00	38	0.000514	1	0	0.20	60.76	-3.92	15.4	1%
Alabama	0102	56.90	60.00	94	0.000542	17	0	0.24	67.88	-10.98	120.6	0%
Alabama	0102	59.56	60.00	148	0.000566	17	0	0.28	67.89	-8.33	69.4	1%
Alabama	0102	61.97	60.00	189	0.000572	29	17	0.31	73.25	-11.28	127.2	0%
Alabama	0102	71.03	60.00	189	0.000842	37	0	0.31	76.94	-5.91	35.0	1%
Alabama	0102	86.99	60.00	439	0.001152	41	121	0.43	79.06	7.93	62.9	1%
Alabama	0102	108.22	60.00	525	0.001152	47	239	0.43	81.88	26.34	693.6	1%
Alabama	0102	196.35	188.05	128	0.000564	41	551	0.51	207.33	-10.98	120.5	0%
Alabama	0103	52.34	50.31	347	0.001292	16	0	0.31	58.19	-5.86	34.3	1%
Alabama	0103	49.10	50.31	435	0.001292	26	52	0.31	62.70	-13.60	184.9	1%
Alabama	0103	50.94	50.31	571	0.001092	29	274	0.31	64.21	-13.26	176.0	1%
Alabama	0103	50.75	50.31	632	0.001433	34	301	0.31	66.67	-15.92	253.3	1%
Alabama	0103	52.84	50.31	761	0.000775	36	277	0.31	67.13	-14.28	204.1	1%
Alabama	0106	36.88	47.33	96	0.001026	0	0	0.28	47.95	-11.07	122.6	1%
Alabama	0106	43.66	47.33	445	0.001305	15	0	0.35	54.78	-11.12	123.7	1%
Alabama	0106	41.82	47.33	533	0.001305	25	0	0.35	59.22	-17.40	302.8	1%
Alabama	0106	46.44	47.33	670	0.001064	31	0	0.35	61.74	-15.29	233.9	1%

State	SHRP_ID	IRI Measured (in/mile)	IRI Initial (in/mile)	SF (2020)	shrink/swell variance (V_{ss})	FC	TC	RD	IRI Predicted (in/mile)	Residual (R)	R^2	Env Weight
Alabama	0106	47.08	47.33	732	0.001387	35	0	0.35	63.71	-16.63	276.6	1%
Alabama	0106	48.41	47.33	861	0.000722	36	0	0.39	63.75	-15.34	235.4	1%
Alabama	0109	47.52	46.38	319	0.001670	40	0	0.28	65.15	-17.63	310.7	2%
Alabama	0109	47.77	46.38	402	0.001670	46	312	0.28	68.23	-20.45	418.3	1%
Alabama	0109	45.68	46.38	527	0.001336	50	42	0.28	69.44	-23.76	564.5	1%
Alabama	0109	48.09	46.38	589	0.001820	50	139	0.28	69.86	-21.77	474.0	2%
Alabama	0109	49.10	46.38	711	0.000785	46	163	0.28	67.49	-18.39	338.2	1%
Arkansas	0804	72.74	87.88	99	0.000560	0	0	0.04	88.22	-15.48	239.7	0%
Arkansas	0804	84.97	87.88	229	0.000633	0	0	0.04	88.26	-3.30	10.9	0%
Arkansas	0804	69.19	87.88	306	0.000662	0	0	0.04	88.28	-19.09	364.4	0%
Arkansas	0804	73.31	87.88	420	0.000630	0	0	0.04	88.26	-14.95	223.6	0%
Arkansas	0804	72.29	87.88	585	0.000782	0	0	0.04	88.35	-16.06	257.9	1%
Arkansas	0804	72.93	87.88	684	0.000715	1	0	0.04	88.76	-15.83	250.5	0%
Arkansas	0804	83.13	87.88	1070	0.000790	1	90	0.04	88.92	-5.79	33.5	1%
Arkansas	0804	73.24	87.88	1470	0.000715	2	540	0.08	89.92	-16.67	277.9	0%
Arkansas	3048	105.30	103.91	89	0.000260	14	738	0.20	111.26	-5.96	35.5	0%
Arkansas	3048	224.48	103.91	1722	0.000393	47	2581	0.31	128.44	96.05	9225.1	
Arkansas	3048	238.11	103.91	1996	0.000261	47	2692	0.31	128.50	109.60	12012.6	
Arkansas	3071	37.64	37.38	70	0.000963	0	0	0.24	37.96	-0.33	0.1	2%
Arkansas	3071	44.73	37.38	331	0.001139	1	0	0.24	38.51	6.22	38.7	2%
Arkansas	3071	51.77	50.50	233	0.001038	0	0	0.28	51.12	0.64	0.4	1%
Arkansas	3071	67.73	50.50	764	0.000769	1	2103	0.28	54.19	13.54	183.3	1%
Arkansas	3071	62.54	50.50	954	0.000740	1	3323	0.31	55.79	6.74	45.5	1%
Georgia	1001	53.60	51.96	212	0.001190	54	946	0.20	77.90	-24.30	590.6	1%
Georgia	1001	57.53	51.96	486	0.001122	54	2910	0.24	80.47	-22.94	526.0	1%
Hawaii	1006	147.76	153.33	141	0.024054	0	0	0.16	167.83	-20.08	403.2	9%
Hawaii	1006	168.66	153.33	355	0.023871	0	0	0.16	167.72	0.94	0.9	9%

State	SHRP_ID	IRI Measured (in/mile)	IRI Initial (in/mile)	SF (2020)	shrink/swell variance (V_{ss})	FC	TC	RD	IRI Predicted (in/mile)	Residual (R)	R^2	Env Weight
Hawaii	1006	150.73	153.33	593	0.024054	0	0	0.20	167.83	-17.10	292.5	9%
Hawaii	1006	152.82	153.33	670	0.022081	1	0	0.20	167.09	-14.26	203.5	8%
Hawaii	1006	149.66	153.33	930	0.014260	1	0	0.24	162.37	-12.72	161.7	5%
Hawaii	1006	146.87	153.33	1089	0.023871	2	62	0.16	168.69	-21.83	476.4	9%
Hawaii	1006	153.65	153.33	1505	0.021645	54	10	0.20	190.37	-36.73	1348.7	7%
Louisiana	0113	96.31	67.03	568	0.000879	16	336	0.28	75.11	21.19	449.1	1%
Louisiana	0113	97.07	67.03	1144	0.000718	21	2054	0.31	79.51	17.55	308.1	1%
Mississippi	0806	66.78	51.77	155	0.001106	0	0	0.16	52.43	14.35	205.9	1%
Mississippi	0806	73.24	51.77	226	0.000654	2	0	0.20	53.05	20.20	407.9	1%
Mississippi	0806	76.03	51.77	298	0.000507	9	0	0.31	56.07	19.96	398.6	1%
Mississippi	0806	77.68	51.77	389	0.001137	11	0	0.20	57.34	20.34	413.9	1%
Mississippi	0806	77.81	51.77	493	0.000961	13	0	0.20	58.12	19.69	387.7	1%
Mississippi	0806	83.51	51.77	744	0.000961	22	94	0.20	62.24	21.27	452.4	1%
Mississippi	0806	101.31	51.77	1946	0.001173	49	2082	0.39	76.99	24.32	591.6	1%
N. Mexico	0101	53.67	37.64	172	0.018574	4	0	0.31	50.61	3.05	9.3	22%
N. Mexico	0101	68.49	37.64	307	0.032457	7	0	0.28	60.31	8.18	66.9	32%
N. Mexico	0101	73.12	37.64	441	0.022756	10	14	0.28	55.82	17.30	299.4	25%
N. Mexico	0101	91.81	37.64	498	0.026371	11	28	0.28	58.46	33.35	1112.3	27%
N. Mexico	0101	101.38	37.64	544	0.022831	14	66	0.28	57.71	43.67	1907.0	24%
N. Mexico	0102	63.61	42.51	171	0.022468	7	0	0.28	59.17	4.44	19.7	23%
N. Mexico	0102	79.39	42.51	307	0.034033	15	17	0.28	69.72	9.67	93.5	29%
N. Mexico	0102	101.50	42.51	441	0.024775	21	17	0.31	66.80	34.70	1204.3	22%
N. Mexico	0103	55.88	40.42	173	0.046630	0	0	0.28	68.54	-12.66	160.2	41%
N. Mexico	0103	85.60	40.42	312	0.075361	2	0	0.28	86.75	-1.15	1.3	52%
N. Mexico	0103	114.62	40.42	448	0.050951	4	0	0.28	72.92	41.70	1738.6	42%
N. Mexico	0103	123.05	40.42	507	0.061374	5	0	0.28	79.65	43.40	1883.2	46%
N. Mexico	0103	126.21	40.42	554	0.054937	7	14	0.28	76.68	49.54	2454.0	43%

State	SHRP_ID	IRI Measured (in/mile)	IRI Initial (in/mile)	SF (2020)	shrink/swell variance (V_{ss})	FC	TC	RD	IRI Predicted (in/mile)	Residual (R)	R^2	Env Weight
N. Mexico	0105	44.42	35.99	158	0.030723	2	0	0.28	55.40	-10.99	120.7	33%
N. Mexico	0105	58.35	35.99	285	0.049505	6	0	0.28	68.50	-10.15	103.0	44%
N. Mexico	0105	66.97	35.99	414	0.035170	10	0	0.28	61.63	5.34	28.5	34%
N. Mexico	0105	71.03	35.99	466	0.038150	12	0	0.28	64.32	6.71	45.0	36%
N. Mexico	0105	62.60	35.99	506	0.033848	15	0	0.28	63.06	-0.46	0.2	32%
N. Mexico	0107	55.76	42.20	172	0.046797	0	0	0.28	70.41	-14.66	214.8	40%
N. Mexico	0107	77.11	42.20	307	0.069399	7	0	0.28	87.15	-10.04	100.8	48%
N. Mexico	0107	85.54	42.20	441	0.046316	10	59	0.28	74.64	10.89	118.7	37%
N. Mexico	0107	101.69	42.20	498	0.050070	10	62	0.31	76.91	24.78	614.2	39%
N. Mexico	0107	104.67	42.20	544	0.044020	12	208	0.31	74.34	30.33	919.7	36%
N. Mexico	0506	27.50	27.69	-222	0.027564	0	0	0.16	44.31	-16.81	282.6	38%
N. Mexico	0506	27.94	27.69	-80	0.027564	1	0	0.20	44.75	-16.81	282.6	37%
N. Mexico	0506	34.47	27.69	338	0.026872	1	0	0.20	44.34	-9.87	97.4	37%
N. Mexico	0506	34.59	27.69	857	0.032199	2	0	0.20	47.99	-13.40	179.5	40%
N. Mexico	0506	39.47	27.69	847	0.026516	3	59	0.20	45.09	-5.61	31.5	35%
N. Mexico	0506	44.61	27.69	1045	0.026194	3	187	0.20	45.06	-0.46	0.2	35%
N. Mexico	0801	80.15	73.56	96	0.022098	1	0	0.12	87.33	-7.18	51.5	15%
N. Mexico	0801	73.05	73.56	146	0.021073	1	0	0.12	86.71	-13.66	186.5	15%
N. Mexico	0801	74.13	73.56	225	0.017748	2	0	0.12	85.15	-11.02	121.4	13%
N. Mexico	0801	83.70	73.56	326	0.022355	3	0	0.16	88.37	-4.67	21.8	15%
N. Mexico	0801	83.00	73.56	384	0.019711	6	0	0.16	88.11	-5.11	26.1	13%
N. Mexico	0801	85.47	73.56	467	0.019711	10	35	0.12	89.93	-4.46	19.9	13%
N. Mexico	0801	95.10	73.56	858	0.028015	23	305	0.12	101.07	-5.97	35.6	17%
N. Mexico	0801	93.65	73.56	1286	0.024676	26	814	0.12	101.06	-7.42	55.0	15%
N. Mexico	0801	95.23	73.56	1410	0.019711	27	1323	0.08	99.19	-3.96	15.7	12%
N. Mexico	0802	74.38	57.85	55	0.043620	0	0	0.16	84.15	-9.76	95.3	31%
N. Mexico	0802	85.85	57.85	153	0.031225	0	0	0.20	76.68	9.18	84.2	25%

State	SHRP_ID	IRI Measured (in/mile)	IRI Initial (in/mile)	SF (2020)	shrink/swell variance (V_{ss})	FC	TC	RD	IRI Predicted (in/mile)	Residual (R)	R^2	Env Weight
N. Mexico	0802	93.27	57.85	204	0.022307	7	0	0.20	74.41	18.86	355.7	18%
N. Mexico	0802	88.64	57.85	285	0.023611	10	0	0.20	76.52	12.12	146.8	19%
N. Mexico	0802	96.12	57.85	386	0.026889	14	0	0.16	80.28	15.84	250.9	20%
N. Mexico	0802	92.19	57.85	446	0.024901	17	0	0.16	80.41	11.78	138.7	19%
N. Mexico	0802	101.38	57.85	530	0.024901	21	0	0.12	82.19	19.19	368.2	18%
N. Mexico	0802	93.01	57.85	932	0.035780	38	118	0.12	96.45	-3.44	11.8	22%
N. Mexico	0802	92.63	57.85	1364	0.033955	39	634	0.12	96.48	-3.85	14.8	21%
N. Mexico	0802	94.72	57.85	1492	0.024901	40	1060	0.12	92.03	2.69	7.3	16%
Tennessee	1028	44.04	44.61	569	0.001298	1	0	0.43	45.83	-1.80	3.2	2%
Tennessee	1028	47.84	44.61	1866	0.001298	22	236	0.43	55.47	-7.63	58.3	1%
Tennessee	3101	72.61	67.35	134	0.001159	0	0	0.35	68.05	4.56	20.8	1%
Tennessee	3101	53.41	48.66	549	0.000969	0	0	0.16	49.24	4.17	17.4	1%
Tennessee	3108	36.43	33.96	233	0.001279	0	0	0.35	34.73	1.70	2.9	2%
Tennessee	3108	41.37	33.96	1504	0.001463	0	139	0.20	35.03	6.35	40.3	3%
Texas	1046	186.28	151.68	-22	0.013355	56	3707	0.24	189.51	-3.24	10.5	4%
Texas	1046	176.27	151.68	660	0.018002	56	2910	0.39	191.26	-14.99	224.8	6%
Texas	1065	153.90	132.04	369	0.009297	7	2207	0.35	143.68	10.22	104.5	4%
Texas	1068	88.70	84.84	258	0.011854	23	177	0.24	102.43	-13.73	188.5	7%
Texas	1068	88.26	84.84	258	0.011140	22	173	0.28	101.55	-13.29	176.7	7%
Texas	1116	66.34	66.27	137	0.000942	14	87	0.35	73.17	-6.84	46.7	1%
Texas	1174	90.22	75.21	381	0.014485	13	87	0.35	89.83	0.39	0.2	10%
Texas	1174	129.57	112.40	487	0.014987	19	76	0.67	129.97	-0.40	0.2	7%
Texas	2133	53.22	51.45	125	0.013088	4	0	0.12	61.12	-7.89	62.3	13%
Texas	2133	53.16	51.45	250	0.013083	13	0	0.20	65.11	-11.95	142.8	12%
Texas	2133	148.77	70.96	549	0.012716	0	0	0.31	78.63	70.14	4919.4	
Texas	2133	134.01	70.96	567	0.013502	2	55	0.31	80.07	53.94	2909.6	
Texas	9005	177.03	76.67	695	0.012876	21	409	0.16	94.30	82.73	6844.6	

State	SHRP_ID	IRI Measured (in/mile)	IRI Initial (in/mile)	SF (2020)	shrink/swell variance (V_{ss})	FC	TC	RD	IRI Predicted (in/mile)	Residual (R)	R^2	Env Weight
Texas	9005	141.99	134.01	196	0.011837	1	52	0.12	141.66	0.33	0.1	5%
Texas	9005	146.68	142.37	95	0.012777	6	326	0.16	153.17	-6.49	42.1	5%
Texas	9005	145.98	142.37	872	0.012284	10	939	0.24	155.46	-9.48	89.9	5%
Texas	A503	73.18	71.41	1341	0.023805	1	111	0.20	86.35	-13.17	173.5	17%
Texas	A503	77.36	71.41	1448	0.023175	2	499	0.20	86.93	-9.57	91.5	16%
Texas	A503	70.77	71.41	1539	0.025273	2	506	0.20	88.20	-17.43	303.8	17%
Texas	A503	78.00	71.41	1705	0.023836	2	1614	0.24	88.81	-10.81	116.9	16%
Texas	A503	76.41	71.41	1963	0.023836	2	2443	0.24	89.90	-13.49	182.1	16%
Texas	A503	78.88	71.41	1906	0.021210	4	3070	0.24	90.04	-11.16	124.5	14%
Texas	A503	78.63	71.41	2704	0.022011	5	3364	0.28	91.36	-12.73	162.0	15%
Texas	A503	82.05	71.41	2500	0.023476	6	3593	0.24	92.99	-10.94	119.6	15%
Texas	A504	94.72	97.83	-15	0.015986	0	0	0.20	107.47	-12.74	162.4	9%
Texas	A504	91.62	97.83	1315	0.014302	0	17	0.31	106.47	-14.86	220.7	8%
Texas	A504	90.48	97.83	1421	0.013092	0	38	0.35	105.77	-15.29	233.9	7%
Texas	A504	82.43	97.83	1510	0.016341	0	52	0.28	107.75	-25.32	641.0	9%
Texas	A504	90.10	97.83	1675	0.014852	0	28	0.35	106.82	-16.72	279.6	8%
Texas	A504	91.62	97.83	1931	0.014852	0	62	0.35	106.87	-15.25	232.5	8%
Texas	A504	92.57	97.83	1872	0.012617	0	107	0.35	105.58	-13.01	169.2	7%
Texas	A504	93.27	97.83	2666	0.013498	0	111	0.35	106.11	-12.85	165.1	8%
Texas	A504	95.36	97.83	2460	0.013359	0	173	0.39	106.11	-10.76	115.7	8%
Texas	A507	83.89	91.81	-15	0.017513	0	0	0.24	102.37	-18.48	341.5	10%
Texas	A507	80.34	91.81	1315	0.016575	1	0	0.43	102.25	-21.91	479.9	10%
Texas	A507	81.10	91.81	1421	0.014419	1	0	0.39	100.95	-19.85	393.9	9%
Texas	A507	72.67	91.81	1510	0.018152	1	0	0.31	103.20	-30.52	931.7	11%
Texas	A507	79.33	91.81	1674	0.015980	1	45	0.43	101.95	-22.62	511.7	9%
Texas	A507	78.76	91.81	1931	0.015980	1	35	0.43	101.93	-23.18	537.2	9%
Texas	A507	81.04	91.81	1872	0.013153	2	59	0.43	100.71	-19.67	386.8	8%

State	SHRP_ID	IRI Measured (in/mile)	IRI Initial (in/mile)	SF (2020)	shrink/swell variance (V_{ss})	FC	TC	RD	IRI Predicted (in/mile)	Residual (R)	R^2	Env Weight
Texas	A507	79.90	91.81	2665	0.014073	2	59	0.47	101.26	-21.36	456.4	8%
Texas	A507	81.35	91.81	2460	0.013784	1	76	0.47	100.66	-19.31	372.9	8%
Texas	A509	76.73	78.76	-15	0.014523	0	0	0.12	87.51	-10.78	116.3	10%
Texas	A509	76.92	78.76	1313	0.015217	3	1174	0.24	90.82	-13.90	193.2	10%
Texas	A509	76.48	78.76	1419	0.014044	4	1299	0.24	90.72	-14.25	203.0	9%
Texas	A509	71.47	78.76	1508	0.015614	3	1635	0.28	91.67	-20.20	408.0	10%
Texas	A509	77.30	78.76	1672	0.013443	7	3180	0.28	94.18	-16.89	285.1	9%
Texas	A509	77.30	78.76	1928	0.013443	6	3582	0.28	94.27	-16.97	288.1	9%
Texas	A509	77.62	78.76	1869	0.011479	6	3142	0.28	92.51	-14.89	221.7	7%
Texas	A509	81.54	78.76	2662	0.012173	6	3749	0.28	93.73	-12.18	148.5	8%
Texas	A509	83.57	78.76	2455	0.013425	6	4604	0.28	95.62	-12.05	145.1	8%

Table 11A.22 Distresses Records for PCC Covered with AC Pavements

State	SHRP_ID	IRI Measured (in/mile)	IRI Initial (in/mile)	SF (2020)	ΔVC	FC	TC	RD	IRI Predicted (in/mile)	Residual (R)	R^2	Env Weight
Alabama	0606	90.29	89.72	473	-0.01578	0	3132	0.08	91.76	-1.48	2.18	-1.0%
Alabama	0606	79.83	89.72	532	-0.01578	0	3288	0.08	91.85	-12.02	144.37	-1.0%
Alabama	0606	94.66	89.72	997	-0.01232	0	3323	0.08	92.07	2.59	6.68	-0.8%
Alabama	0606	96.37	89.72	1077	0.00228	1	3333	0.08	93.25	3.12	9.73	0.1%
Alabama	0608	57.02	55.12	476	-0.01435	1	0	0.08	55.83	1.19	1.43	-1.5%
Alabama	0608	64.37	55.12	538	-0.01435	1	83	0.08	55.88	8.50	72.22	-1.5%
Alabama	0608	58.04	55.12	1005	-0.00991	7	1032	0.08	58.48	-0.45	0.20	-1.0%
Alabama	0608	59.75	55.12	1086	0.00269	10	1157	0.08	60.21	-0.46	0.22	0.3%
Arkansas	A606	64.50	60.95	0	0.00492	0	0	0.12	63.13	1.37	1.88	0.5%
Arkansas	A606	64.31	60.95	186	-0.00829	0	0	0.08	61.72	2.59	6.73	-0.8%
Arkansas	A606	62.54	60.95	716	-0.02473	2	1230	0.12	62.65	-0.12	0.01	-2.3%
Arkansas	A606	62.22	60.95	850	-0.02473	4	2633	0.12	64.03	-1.81	3.29	-2.3%
Arkansas	A606	62.98	60.95	1151	-0.01793	5	3347	0.12	65.13	-2.15	4.64	-1.6%
Arkansas	A606	64.63	60.95	1049	-0.01793	8	3676	0.12	66.23	-1.60	2.56	-1.6%
Arkansas	A606	66.78	60.95	1329	-0.01793	15	4019	0.12	68.54	-1.76	3.10	-1.6%
Arkansas	A606	70.14	60.95	1572	-0.02521	20	4261	0.12	69.76	0.38	0.14	-2.1%
Arkansas	A606	83.83	60.95	1756	0.01710	28	4438	0.16	75.43	8.40	70.49	1.3%
Arkansas	A607	68.18	64.37	0	0.00308	0	0	0.08	65.81	2.36	5.58	0.3%
Arkansas	A607	66.97	64.37	183	-0.00523	0	0	0.12	65.95	1.02	1.05	-0.5%
Arkansas	A607	65.77	64.37	709	-0.01516	1	28	0.12	65.68	0.09	0.01	-1.4%
Arkansas	A607	66.27	64.37	842	-0.01516	2	586	0.12	66.29	-0.01	0.00	-1.4%
Arkansas	A607	67.22	64.37	1142	-0.01083	4	1147	0.12	67.46	-0.24	0.06	-1.0%
Arkansas	A607	68.94	64.37	1038	-0.01083	5	1781	0.12	68.11	0.82	0.67	-0.9%
Arkansas	A607	74.64	64.37	1317	-0.01083	5	2917	0.12	68.74	5.90	34.78	-0.9%
Arkansas	A607	71.22	64.37	1558	-0.01552	7	3662	0.12	69.48	1.74	3.02	-1.3%

State	SHRP_ID	IRI Measured (in/mile)	IRI Initial (in/mile)	SF (2020)	ΔVC	FC	TC	RD	IRI Predicted (in/mile)	Residual (R)	R^2	Env Weight
Arkansas	A607	81.29	64.37	1740	0.01052	9	4636	0.16	72.80	8.49	72.09	0.9%
California	7455	36.05	34.28	329	0.06216	0	0	0.24	41.74	-5.69	32.35	8.9%
California	7455	37.26	34.28	632	-0.06308	2	0	0.24	34.90	2.35	5.54	-10.7%
California	7455	40.87	38.14	131	-0.06308	0	0	0.24	38.16	2.71	7.33	-9.8%
California	7455	40.93	38.14	320	-0.00115	0	0	0.24	41.84	-0.91	0.83	-0.2%
Mississippi	3099	52.97	36.50	608	-0.01085	0	0	0.24	39.62	13.35	178.26	-1.6%
Oklahoma	0603	84.65	84.84	296	0.00820	9	1337	0.24	92.56	-7.91	62.64	0.5%
Oklahoma	0603	83.70	84.84	659	0.00103	10	1285	0.24	92.41	-8.71	75.92	0.1%
Oklahoma	0603	79.96	84.84	930	-0.00669	10	1902	0.20	91.67	-11.71	137.02	-0.4%
Oklahoma	0603	95.23	84.84	1319	-0.00669	12	2408	0.28	93.81	1.42	2.02	-0.4%
Oklahoma	0603	110.50	116.71	276	-0.00669	12	3385	0.24	125.59	-15.09	227.69	-0.3%
Oklahoma	0604	89.84	87.50	310	0.01259	11	2668	0.31	98.08	-8.24	67.86	0.8%
Oklahoma	0604	90.10	87.50	679	0.00238	8	2702	0.31	96.58	-6.49	42.07	0.1%
Oklahoma	0604	94.34	87.50	958	-0.00773	10	3097	0.24	95.55	-1.21	1.46	-0.5%
Oklahoma	0604	97.13	87.50	1354	-0.00773	15	3995	0.31	98.82	-1.69	2.86	-0.5%
Oklahoma	0604	110.88	87.50	2679	-0.00773	30	2262	0.28	101.79	9.09	82.61	-0.5%
Oklahoma	0606	101.31	93.90	297	0.00742	1	2740	0.28	100.55	0.76	0.58	0.4%
Oklahoma	0606	107.21	93.90	659	0.00165	1	2169	0.28	99.89	7.31	53.47	0.1%
Oklahoma	0606	99.22	93.90	931	-0.00475	1	2474	0.20	98.42	0.80	0.64	-0.3%
Oklahoma	0606	101.19	93.90	1320	-0.00475	1	2332	0.31	100.23	0.96	0.91	-0.3%
Oklahoma	0606	109.74	93.90	2602	-0.00475	2	3724	0.24	100.05	9.69	93.97	-0.3%
Tennessee	0603	47.58	44.73	200	-0.00781	0	0	0.20	47.41	0.18	0.03	-1.0%
Tennessee	0603	49.67	44.73	619	-0.02616	0	83	0.24	46.99	2.68	7.21	-3.3%
Tennessee	0603	54.24	44.73	928	-0.01847	0	281	0.24	47.56	6.68	44.62	-2.3%
Tennessee	0603	50.43	44.73	1212	0.00676	0	353	0.24	49.10	1.34	1.79	0.8%
Tennessee	0603	54.93	44.73	1650	-0.01847	0	475	0.24	47.66	7.27	52.85	-2.3%
Texas	5154	60.19	59.50	310	-0.00803	0	0	0.12	60.90	-0.71	0.50	-0.8%

State	SHRP_ID	IRI Measured (in/mile)	IRI Initial (in/mile)	SF (2020)	ΔVC	FC	TC	RD	IRI Predicted (in/mile)	Residual (R)	R^2	Env Weight
Texas	5154	71.53	59.50	1772	0.00982	0	128	0.28	64.54	6.99	48.85	0.9%
Texas	5274	73.50	100.24	198	-0.03485	0	0	0.16	100.68	-27.18	738.64	-2.1%
Texas	5287	92.89	91.43	0	0.01725	0	17	0.28	96.86	-3.97	15.78	1.1%
Texas	5287	97.38	91.43	1075	-0.01587	1	2931	0.24	96.17	1.21	1.47	-1.0%

Table 11A.23 Distresses Records for CRCP Pavements

State	SHRP_ID	IRI Measured (in/mile)	IRI Initial (in/mile)	Punchout	SF (2020)	ΔVC	IRI Predicted (in/mile)	Residual (R)	R^2	Env Weight
Arizona	7079	1.075	68.11	0	0.0003	-0.0388	64.30	-3.81	14.51	-2%
Arizona	7079	1.098	69.57	0	0.0004	0.0521	66.69	-2.88	8.27	2%
Arizona	7079	1.134	71.85	0	0.0005	0.0228	65.92	-5.93	35.13	1%
Arizona	7079	1.107	70.14	0	0.0007	0.0356	66.26	-3.88	15.05	1%
California	7455	1.202	76.16	0	0.0001	-0.0628	76.98	0.82	0.67	-2%
California	7455	1.166	73.88	0	0.0014	0.0335	79.51	5.63	31.73	1%
California	7455	1.191	75.46	0	0.0005	0.0622	80.26	4.80	23.07	2%
California	7455	1.185	75.08	0	0.0006	-0.0380	77.63	2.55	6.50	-1%
Louisiana	0705	1.344	85.16	0	0.0002	-0.0032	83.30	-1.86	3.46	0%
Louisiana	0708	1.048	66.40	0	0.0002	-0.0023	64.69	-1.71	2.92	0%
Mississippi	5006	1.475	93.46	0	-0.0018	0.0014	91.78	-1.67	2.81	0%
Mississippi	5006	1.411	89.40	0	0.0437	0.0097	92.00	2.60	6.75	0%
Mississippi	5006	1.73	109.61	0	0.0287	0.0015	91.78	-17.83	317.85	0%
Mississippi	5006	1.49	94.41	0	0.0312	-0.0078	91.54	-2.87	8.22	0%
Mississippi	5006	1.45	91.87	0	0.0364	-0.0061	91.59	-0.29	0.08	0%
Mississippi	5006	1.499	94.98	0	0.0584	-0.0127	91.41	-3.57	12.72	0%
Texas	3569	1.328	84.14	0	-0.0622	0.0161	76.71	-7.43	55.24	1%
Texas	3569	1.311	83.06	0	-0.0575	-0.0152	75.89	-7.18	51.54	-1%
Texas	3569	1.398	88.58	0	-0.0502	0.0014	76.32	-12.25	150.16	0%
Texas	3569	1.377	87.25	0	-0.0319	-0.0063	76.12	-11.13	123.81	0%
Texas	3569	1.488	94.28	0	0.0895	-0.0010	76.26	-18.02	324.76	0%
Texas	3569	1.673	106.00	0	-0.0296	-0.0063	76.12	-29.88	892.90	0%
Texas	3569	1.461	92.57	0	-0.0317	-0.0152	75.89	-16.68	278.32	-1%
Texas	3569	1.488	94.28	0	0.0892	0.0164	76.72	-17.56	308.41	1%
Texas	3719	2.405	152.38	0	0.0001	0.0094	154.21	1.83	3.35	0%

Texas	3719	2.384	151.05	0	0.0003	-0.0106	153.69	2.64	6.95	0%
Texas	3719	2.281	144.52	0	0.0004	-0.0028	153.89	9.37	87.76	0%
Texas	3719	2.313	146.55	0	0.0007	-0.0085	153.74	7.19	51.70	0%
Texas	3719	2.292	145.22	0	0.0009	-0.0057	153.81	8.59	73.84	0%
Texas	3719	2.199	139.33	0	0.0010	0.0110	154.25	14.92	222.74	0%
Texas	3719	2.286	144.84	0	0.0012	0.0061	154.13	9.29	86.22	0%
Texas	3779	2.143	135.78	0	-0.0018	-0.0534	140.78	4.99	24.95	-1%
Texas	3779	2.118	134.20	0	0.0044	0.0336	143.06	8.87	78.64	1%
Texas	3779	2.189	138.70	0	-0.0038	0.0512	143.53	4.83	23.35	1%
Texas	3779	2.039	129.19	0	0.0111	-0.0667	140.42	11.23	126.19	-1%
Texas	3779	2.154	136.48	0	-0.0039	-0.0341	141.28	4.80	23.09	-1%
Texas	3779	2.13	134.96	0	-0.0038	-0.0534	140.78	5.82	33.85	-1%
Texas	3779	2.141	135.65	0	0.0029	0.0023	142.24	6.59	43.39	0%
Texas	3779	2.213	140.22	0	0.0027	-0.0574	140.67	0.45	0.21	-1%
Texas	3779	2.155	136.54	0	0.0144	0.0511	143.52	6.98	48.78	1%
Texas	3779	2.159	136.79	0	0.0082	0.0620	143.81	7.02	49.22	1%
Texas	3779	2.142	135.72	0	-0.0029	-0.0574	140.67	4.95	24.53	-1%
Texas	3845	1.804	114.30	0	-0.0804	0.0269	107.09	-7.21	52.02	1%
Texas	3845	1.71	108.35	0	-0.0669	-0.0208	105.83	-2.51	6.31	-1%
Texas	3845	1.68	106.44	0	-0.0632	0.0030	106.46	0.01	0.00	0%
Texas	3845	1.759	111.45	0	-0.0607	-0.0227	105.78	-5.67	32.10	-1%
Texas	3845	1.624	102.90	0	-0.0043	0.0170	106.83	3.93	15.46	0%
Texas	3845	1.82	115.32	0	-0.0239	-0.0106	106.10	-9.21	84.87	0%
Texas	3845	1.938	122.79	0	-0.0239	-0.0227	105.78	-17.01	289.25	-1%
Texas	3845	2.003	126.91	0	0.1296	0.0280	107.12	-19.79	391.74	1%
Texas	3845	2.03	128.62	0	0.0455	0.0269	107.09	-21.53	463.62	1%
Texas	3845	2.153	136.41	0	0.0829	-0.0021	106.33	-30.09	905.22	0%
Texas	3845	2.145	135.91	0	0.0203	0.0141	106.75	-29.15	849.97	0%
Texas	5026	1.679	106.38	0	0.0001	-0.0188	107.41	1.03	1.05	0%
Texas	5026	1.674	106.06	0	0.0003	-0.0122	107.58	1.52	2.30	0%
Texas	5026	1.684	106.70	0	0.0005	-0.0047	107.78	1.08	1.17	0%

Texas	5026	1.719	108.92	0	0.0008	-0.0123	107.58	-1.34	1.79	0%
Texas	5026	1.741	110.31	0	0.0010	-0.0050	107.77	-2.54	6.44	0%
Texas	5026	1.756	111.26	0	0.0011	0.0151	108.30	-2.96	8.76	0%
Texas	5026	1.724	109.23	0	0.0012	-0.0122	107.58	-1.65	2.73	0%
Texas	5026	1.751	110.94	0	0.0014	0.0034	107.99	-2.95	8.71	0%
Texas	5026	1.738	110.12	0	0.0046	0.0101	108.17	-1.95	3.81	0%
Texas	5026	1.725	109.30	0	0.0022	0.0110	108.19	-1.10	1.22	0%
Texas	5035	1.837	116.39	0	-0.0173	-0.0094	111.96	-4.43	19.62	0%
Texas	5035	1.716	108.73	0	-0.0151	-0.0143	111.83	3.11	9.66	0%
Texas	5035	1.859	117.79	0	-0.0123	0.0126	112.54	-5.25	27.51	0%
Texas	5035	1.752	111.01	0	-0.0007	-0.0143	111.83	0.83	0.69	0%
Texas	5035	1.779	112.72	0	0.0009	-0.0094	111.96	-0.75	0.57	0%
Texas	5035	1.797	113.86	0	-0.0023	-0.0159	111.79	-2.06	4.26	0%
Texas	5035	1.855	117.53	0	0.0183	-0.0159	111.79	-5.74	32.95	0%
Texas	5035	1.836	116.33	0	0.0240	0.0171	112.66	-3.67	13.45	0%
Texas	5035	1.868	118.36	0	0.0363	0.0005	112.22	-6.13	37.61	0%
Texas	5154	1.54	97.57	0	0.0001	-0.0360	96.75	-0.82	0.67	-1%
Texas	5154	1.649	104.48	0	0.0002	0.0098	97.96	-6.52	42.53	0%
Texas	5154	1.527	96.75	0	0.0011	-0.0253	97.04	0.29	0.08	-1%
Texas	5154	1.598	101.25	0	0.0004	-0.0213	97.14	-4.11	16.88	-1%
Texas	5274	1.716	108.73	0	-0.0316	0.0327	101.92	-6.81	46.33	1%
Texas	5274	1.625	102.96	0	-0.0280	-0.0385	100.05	-2.91	8.49	-1%
Texas	5274	1.658	105.05	0	-0.0242	0.0266	101.76	-3.29	10.83	1%
Texas	5283	1.168	74.00	0	-0.0048	0.0150	72.75	-1.25	1.57	1%
Texas	5283	1.15	72.86	0	-0.0037	-0.0132	72.01	-0.85	0.73	0%
Texas	5283	1.178	74.64	0	-0.0022	0.0105	72.63	-2.00	4.02	0%
Texas	5283	1.355	85.85	0	-0.0001	-0.0126	72.03	-13.83	191.18	0%
Texas	5283	1.299	82.30	0	0.0174	0.0109	72.64	-9.66	93.34	0%
Texas	5283	1.471	93.20	0	0.0035	-0.0080	72.15	-21.05	443.31	0%
Texas	5283	1.437	91.05	0	0.0035	0.0059	72.51	-18.54	343.57	0%
Texas	5283	1.511	95.74	0	0.0064	-0.0142	71.98	-23.75	564.26	-1%

Texas	5283	1.681	106.51	0	0.0230	-0.0142	71.98	-34.53	1192.00	-1%
Texas	5283	1.738	110.12	0	0.0284	0.0104	72.63	-37.49	1405.36	0%
Texas	5283	1.765	111.83	0	0.0384	-0.0011	72.33	-39.50	1560.44	0%
Texas	5287	1.926	122.03	0	-0.0254	0.0173	119.13	-2.90	8.44	0%
Texas	5287	1.878	118.99	0	-0.0195	-0.0159	118.26	-0.73	0.54	0%
Texas	5287	2.027	128.43	0	-0.0188	0.0143	119.05	-9.38	87.99	0%
Texas	5287	1.953	123.74	0	-0.0150	-0.0146	118.29	-5.45	29.74	0%
Texas	5287	1.896	120.13	0	0.0186	0.0183	119.16	-0.98	0.95	0%
Texas	5317	2.256	142.94	0	-0.0091	0.0173	138.64	-4.30	18.47	0%
Texas	5317	2.269	143.76	0	-0.0083	-0.0114	137.89	-5.88	34.52	0%
Texas	5317	2.346	148.64	0	-0.0062	0.0149	138.58	-10.06	101.25	0%
Texas	5317	2.463	156.06	0	-0.0035	-0.0154	137.78	-18.27	333.89	0%
Texas	5317	2.552	161.69	0	-0.0028	-0.0114	137.89	-23.81	566.73	0%
Texas	5317	2.523	159.86	0	0.0030	-0.0065	138.02	-21.84	477.00	0%
Texas	5317	2.585	163.79	0	0.0001	-0.0135	137.83	-25.95	673.58	0%
Texas	5317	2.762	175.00	0	0.0139	-0.0135	137.83	-37.17	1381.48	0%
Texas	5317	2.889	183.05	0	0.0202	0.0173	138.64	-44.40	1971.76	0%
Texas	5317	2.938	186.15	0	0.0288	0.0020	138.24	-47.91	2295.46	0%
Texas	5323	1.784	113.03	0	-0.0025	0.0049	113.10	0.06	0.00	0%
Texas	5323	1.735	109.93	0	0.0174	-0.0064	112.80	2.87	8.26	0%
Texas	5323	1.81	114.68	0	0.0005	0.0049	113.10	-1.58	2.50	0%
Texas	5328	1.633	103.47	0	-0.0263	-0.0069	105.63	2.16	4.68	0%
Texas	5328	1.589	100.68	0	-0.0151	-0.0102	105.54	4.86	23.65	0%
Texas	5328	1.63	103.28	0	-0.0164	0.0098	106.07	2.79	7.79	0%
Texas	5328	1.543	97.76	0	-0.0126	0.0042	105.92	8.16	66.52	0%
Texas	5328	1.626	103.02	0	-0.0200	0.0213	106.37	3.35	11.20	1%
Texas	5328	1.601	101.44	0	-0.0042	0.0128	106.15	4.71	22.17	0%
Texas	5328	1.627	103.09	0	0.0038	0.0213	106.37	3.28	10.78	1%
Texas	5328	1.59	100.74	0	0.0021	-0.0069	105.63	4.89	23.90	0%
Texas	5328	1.633	103.47	0	0.0297	-0.0102	105.54	2.08	4.31	0%
Texas	5328	1.626	103.02	0	0.0216	0.0213	106.37	3.35	11.20	1%

Texas	5328	1.654	104.80	0	0.0884	0.0028	105.89	1.09	1.18	0%
Texas	5328	1.638	103.78	0	0.0412	0.0128	106.15	2.36	5.59	0%
Texas	5335	2.086	132.17	0	-0.0027	0.0076	128.82	-3.35	11.20	0%
Texas	5335	2.002	126.85	0	0.0184	-0.0086	128.40	1.55	2.40	0%
Texas	5335	2.013	127.54	0	0.0006	0.0076	128.82	1.28	1.63	0%
Texas	5335	1.97	124.82	0	0.0233	-0.0102	128.35	3.53	12.48	0%
Texas	5335	1.933	122.47	0	-0.0163	0.0076	128.82	6.35	40.28	0%
Texas	5335	2.272	143.95	0	0.0014	-0.0007	127.08	-16.87	284.70	0%
Texas	5335	1.945	123.24	0	0.0537	-0.0053	126.96	3.72	13.87	0%
Texas	5335	1.947	123.36	0	-0.0023	0.0063	127.27	3.90	15.25	0%
Texas	5336	1.468	93.01	0	0.0021	-0.0074	88.83	-4.19	17.52	0%
Texas	5336	1.456	92.25	0	0.0108	-0.0145	88.64	-3.61	13.06	0%
Texas	5336	1.435	90.92	0	0.0045	0.0267	89.72	-1.20	1.44	1%
Texas	5336	1.338	84.78	0	0.0235	-0.0180	88.55	3.77	14.22	-1%
Texas	5336	1.336	84.65	0	0.0336	-0.0023	88.96	4.31	18.58	0%
Texas	5336	1.38	87.44	0	0.0228	-0.0023	88.96	1.52	2.32	0%
Texas	5336	1.439	91.18	0	0.0299	-0.0104	88.75	-2.43	5.89	0%

11.11. Distress Records

Project No. 01-59

PROPOSED ENHANCEMENTS TO PAVEMENT ME DESIGN: IMPROVED CONSIDERATION OF THE INFLUENCE OF SUBGRADE SOILS SUSCEPTIBLE TO SHRINK/SWELL AND/OR FROST HEAVE ON PAVEMENT PERFORMANCE

APPENDIX 11A

PAVEMENT DISTRESSES RECORDS

MAY 2023

LIST OF TABLES

Table 11A-1 Distresses Records for AC Pavements at the WP

State	SHRP_ID	IRI Measured (in/mile)	IRI Initial (in/mile)	SF (2020)	shrink/swell variance (V_{ss})	FC	TC	RD	IRI Predicted (in/mile)	Residual (R)	R^2	Env Weight
Alabama	0101	42.96	41.63	57	0.000385	2	0	0.24	42.75	0.21	0.0	1%
Alabama	0101	44.54	41.63	110	0.000400	6	0	0.20	44.53	0.01	0.0	1%
Alabama	0101	44.04	41.63	150	0.000562	12	0	0.24	47.29	-3.26	10.6	1%
Alabama	0101	47.08	41.63	400	0.000894	19	28	0.24	50.64	-3.56	12.7	1%
Alabama	0101	44.73	41.63	486	0.000894	25	121	0.24	53.43	-8.70	75.6	1%
Alabama	0101	46.38	41.63	621	0.000813	41	506	0.24	60.99	-14.61	213.6	1%
Alabama	0101	49.17	41.63	681	0.000901	33	544	0.24	57.54	-8.38	70.2	1%
Alabama	0101	49.80	41.63	808	0.000495	45	506	0.24	62.58	-12.78	163.3	0%
Alabama	0102	56.83	60.00	38	0.000514	1	0	0.20	60.76	-3.92	15.4	1%
Alabama	0102	56.90	60.00	94	0.000542	17	0	0.24	67.88	-10.98	120.6	0%
Alabama	0102	59.56	60.00	148	0.000566	17	0	0.28	67.89	-8.33	69.4	1%
Alabama	0102	61.97	60.00	189	0.000572	29	17	0.31	73.25	-11.28	127.2	0%
Alabama	0102	71.03	60.00	189	0.000842	37	0	0.31	76.94	-5.91	35.0	1%
Alabama	0102	86.99	60.00	439	0.001152	41	121	0.43	79.06	7.93	62.9	1%
Alabama	0102	108.22	60.00	525	0.001152	47	239	0.43	81.88	26.34	693.6	1%
Alabama	0102	196.35	188.05	128	0.000564	41	551	0.51	207.33	-10.98	120.5	0%
Alabama	0103	52.34	50.31	347	0.001292	16	0	0.31	58.19	-5.86	34.3	1%
Alabama	0103	49.10	50.31	435	0.001292	26	52	0.31	62.70	-13.60	184.9	1%
Alabama	0103	50.94	50.31	571	0.001092	29	274	0.31	64.21	-13.26	176.0	1%
Alabama	0103	50.75	50.31	632	0.001433	34	301	0.31	66.67	-15.92	253.3	1%
Alabama	0103	52.84	50.31	761	0.000775	36	277	0.31	67.13	-14.28	204.1	1%
Alabama	0106	36.88	47.33	96	0.001026	0	0	0.28	47.95	-11.07	122.6	1%
Alabama	0106	43.66	47.33	445	0.001305	15	0	0.35	54.78	-11.12	123.7	1%
Alabama	0106	41.82	47.33	533	0.001305	25	0	0.35	59.22	-17.40	302.8	1%
Alabama	0106	46.44	47.33	670	0.001064	31	0	0.35	61.74	-15.29	233.9	1%

Alabama	0106	47.08	47.33	732	0.001387	35	0	0.35	63.71	-16.63	276.6	1%
Alabama	0106	48.41	47.33	861	0.000722	36	0	0.39	63.75	-15.34	235.4	1%
Alabama	0109	47.52	46.38	319	0.001670	40	0	0.28	65.15	-17.63	310.7	2%
Alabama	0109	47.77	46.38	402	0.001670	46	312	0.28	68.23	-20.45	418.3	1%
Alabama	0109	45.68	46.38	527	0.001336	50	42	0.28	69.44	-23.76	564.5	1%
Alabama	0109	48.09	46.38	589	0.001820	50	139	0.28	69.86	-21.77	474.0	2%
Alabama	0109	49.10	46.38	711	0.000785	46	163	0.28	67.49	-18.39	338.2	1%
Arkansas	0804	72.74	87.88	99	0.000560	0	0	0.04	88.22	-15.48	239.7	0%
Arkansas	0804	84.97	87.88	229	0.000633	0	0	0.04	88.26	-3.30	10.9	0%
Arkansas	0804	69.19	87.88	306	0.000662	0	0	0.04	88.28	-19.09	364.4	0%
Arkansas	0804	73.31	87.88	420	0.000630	0	0	0.04	88.26	-14.95	223.6	0%
Arkansas	0804	72.29	87.88	585	0.000782	0	0	0.04	88.35	-16.06	257.9	1%
Arkansas	0804	72.93	87.88	684	0.000715	1	0	0.04	88.76	-15.83	250.5	0%
Arkansas	0804	83.13	87.88	1070	0.000790	1	90	0.04	88.92	-5.79	33.5	1%
Arkansas	0804	73.24	87.88	1470	0.000715	2	540	0.08	89.92	-16.67	277.9	0%
Arkansas	3048	105.30	103.91	89	0.000260	14	738	0.20	111.26	-5.96	35.5	0%
Arkansas	3048	224.48	103.91	1722	0.000393	47	2581	0.31	128.44	96.05	9225.1	
Arkansas	3048	238.11	103.91	1996	0.000261	47	2692	0.31	128.50	109.60	12012.6	
Arkansas	3071	37.64	37.38	70	0.000963	0	0	0.24	37.96	-0.33	0.1	2%
Arkansas	3071	44.73	37.38	331	0.001139	1	0	0.24	38.51	6.22	38.7	2%
Arkansas	3071	51.77	50.50	233	0.001038	0	0	0.28	51.12	0.64	0.4	1%
Arkansas	3071	67.73	50.50	764	0.000769	1	2103	0.28	54.19	13.54	183.3	1%
Arkansas	3071	62.54	50.50	954	0.000740	1	3323	0.31	55.79	6.74	45.5	1%
Georgia	1001	53.60	51.96	212	0.001190	54	946	0.20	77.90	-24.30	590.6	1%
Georgia	1001	57.53	51.96	486	0.001122	54	2910	0.24	80.47	-22.94	526.0	1%
Hawaii	1006	147.76	153.33	141	0.024054	0	0	0.16	167.83	-20.08	403.2	9%
Hawaii	1006	168.66	153.33	355	0.023871	0	0	0.16	167.72	0.94	0.9	9%
Hawaii	1006	150.73	153.33	593	0.024054	0	0	0.20	167.83	-17.10	292.5	9%
Hawaii	1006	152.82	153.33	670	0.022081	1	0	0.20	167.09	-14.26	203.5	8%
Hawaii	1006	149.66	153.33	930	0.014260	1	0	0.24	162.37	-12.72	161.7	5%
Hawaii	1006	146.87	153.33	1089	0.023871	2	62	0.16	168.69	-21.83	476.4	9%

Hawaii	1006	153.65	153.33	1505	0.021645	54	10	0.20	190.37	-36.73	1348.7	7%
Louisiana	0113	96.31	67.03	568	0.000879	16	336	0.28	75.11	21.19	449.1	1%
Louisiana	0113	97.07	67.03	1144	0.000718	21	2054	0.31	79.51	17.55	308.1	1%
Mississippi	0806	66.78	51.77	155	0.001106	0	0	0.16	52.43	14.35	205.9	1%
Mississippi	0806	73.24	51.77	226	0.000654	2	0	0.20	53.05	20.20	407.9	1%
Mississippi	0806	76.03	51.77	298	0.000507	9	0	0.31	56.07	19.96	398.6	1%
Mississippi	0806	77.68	51.77	389	0.001137	11	0	0.20	57.34	20.34	413.9	1%
Mississippi	0806	77.81	51.77	493	0.000961	13	0	0.20	58.12	19.69	387.7	1%
Mississippi	0806	83.51	51.77	744	0.000961	22	94	0.20	62.24	21.27	452.4	1%
Mississippi	0806	101.31	51.77	1946	0.001173	49	2082	0.39	76.99	24.32	591.6	1%
N. Mexico	0101	53.67	37.64	172	0.018574	4	0	0.31	50.61	3.05	9.3	22%
N. Mexico	0101	68.49	37.64	307	0.032457	7	0	0.28	60.31	8.18	66.9	32%
N. Mexico	0101	73.12	37.64	441	0.022756	10	14	0.28	55.82	17.30	299.4	25%
N. Mexico	0101	91.81	37.64	498	0.026371	11	28	0.28	58.46	33.35	1112.3	27%
N. Mexico	0101	101.38	37.64	544	0.022831	14	66	0.28	57.71	43.67	1907.0	24%
N. Mexico	0102	63.61	42.51	171	0.022468	7	0	0.28	59.17	4.44	19.7	23%
N. Mexico	0102	79.39	42.51	307	0.034033	15	17	0.28	69.72	9.67	93.5	29%
N. Mexico	0102	101.50	42.51	441	0.024775	21	17	0.31	66.80	34.70	1204.3	22%
N. Mexico	0103	55.88	40.42	173	0.046630	0	0	0.28	68.54	-12.66	160.2	41%
N. Mexico	0103	85.60	40.42	312	0.075361	2	0	0.28	86.75	-1.15	1.3	52%
N. Mexico	0103	114.62	40.42	448	0.050951	4	0	0.28	72.92	41.70	1738.6	42%
N. Mexico	0103	123.05	40.42	507	0.061374	5	0	0.28	79.65	43.40	1883.2	46%
N. Mexico	0103	126.21	40.42	554	0.054937	7	14	0.28	76.68	49.54	2454.0	43%
N. Mexico	0105	44.42	35.99	158	0.030723	2	0	0.28	55.40	-10.99	120.7	33%
N. Mexico	0105	58.35	35.99	285	0.049505	6	0	0.28	68.50	-10.15	103.0	44%
N. Mexico	0105	66.97	35.99	414	0.035170	10	0	0.28	61.63	5.34	28.5	34%
N. Mexico	0105	71.03	35.99	466	0.038150	12	0	0.28	64.32	6.71	45.0	36%
N. Mexico	0105	62.60	35.99	506	0.033848	15	0	0.28	63.06	-0.46	0.2	32%
N. Mexico	0107	55.76	42.20	172	0.046797	0	0	0.28	70.41	-14.66	214.8	40%
N. Mexico	0107	77.11	42.20	307	0.069399	7	0	0.28	87.15	-10.04	100.8	48%
N. Mexico	0107	85.54	42.20	441	0.046316	10	59	0.28	74.64	10.89	118.7	37%

N. Mexico	0107	101.69	42.20	498	0.050070	10	62	0.31	76.91	24.78	614.2	39%
N. Mexico	0107	104.67	42.20	544	0.044020	12	208	0.31	74.34	30.33	919.7	36%
N. Mexico	0506	27.50	27.69	-222	0.027564	0	0	0.16	44.31	-16.81	282.6	38%
N. Mexico	0506	27.94	27.69	-80	0.027564	1	0	0.20	44.75	-16.81	282.6	37%
N. Mexico	0506	34.47	27.69	338	0.026872	1	0	0.20	44.34	-9.87	97.4	37%
N. Mexico	0506	34.59	27.69	857	0.032199	2	0	0.20	47.99	-13.40	179.5	40%
N. Mexico	0506	39.47	27.69	847	0.026516	3	59	0.20	45.09	-5.61	31.5	35%
N. Mexico	0506	44.61	27.69	1045	0.026194	3	187	0.20	45.06	-0.46	0.2	35%
N. Mexico	0801	80.15	73.56	96	0.022098	1	0	0.12	87.33	-7.18	51.5	15%
N. Mexico	0801	73.05	73.56	146	0.021073	1	0	0.12	86.71	-13.66	186.5	15%
N. Mexico	0801	74.13	73.56	225	0.017748	2	0	0.12	85.15	-11.02	121.4	13%
N. Mexico	0801	83.70	73.56	326	0.022355	3	0	0.16	88.37	-4.67	21.8	15%
N. Mexico	0801	83.00	73.56	384	0.019711	6	0	0.16	88.11	-5.11	26.1	13%
N. Mexico	0801	85.47	73.56	467	0.019711	10	35	0.12	89.93	-4.46	19.9	13%
N. Mexico	0801	95.10	73.56	858	0.028015	23	305	0.12	101.07	-5.97	35.6	17%
N. Mexico	0801	93.65	73.56	1286	0.024676	26	814	0.12	101.06	-7.42	55.0	15%
N. Mexico	0801	95.23	73.56	1410	0.019711	27	1323	0.08	99.19	-3.96	15.7	12%
N. Mexico	0802	74.38	57.85	55	0.043620	0	0	0.16	84.15	-9.76	95.3	31%
N. Mexico	0802	85.85	57.85	153	0.031225	0	0	0.20	76.68	9.18	84.2	25%
N. Mexico	0802	93.27	57.85	204	0.022307	7	0	0.20	74.41	18.86	355.7	18%
N. Mexico	0802	88.64	57.85	285	0.023611	10	0	0.20	76.52	12.12	146.8	19%
N. Mexico	0802	96.12	57.85	386	0.026889	14	0	0.16	80.28	15.84	250.9	20%
N. Mexico	0802	92.19	57.85	446	0.024901	17	0	0.16	80.41	11.78	138.7	19%
N. Mexico	0802	101.38	57.85	530	0.024901	21	0	0.12	82.19	19.19	368.2	18%
N. Mexico	0802	93.01	57.85	932	0.035780	38	118	0.12	96.45	-3.44	11.8	22%
N. Mexico	0802	92.63	57.85	1364	0.033955	39	634	0.12	96.48	-3.85	14.8	21%
N. Mexico	0802	94.72	57.85	1492	0.024901	40	1060	0.12	92.03	2.69	7.3	16%
Tennessee	1028	44.04	44.61	569	0.001298	1	0	0.43	45.83	-1.80	3.2	2%
Tennessee	1028	47.84	44.61	1866	0.001298	22	236	0.43	55.47	-7.63	58.3	1%
Tennessee	3101	72.61	67.35	134	0.001159	0	0	0.35	68.05	4.56	20.8	1%
Tennessee	3101	53.41	48.66	549	0.000969	0	0	0.16	49.24	4.17	17.4	1%

Tennessee	3108	36.43	33.96	233	0.001279	0	0	0.35	34.73	1.70	2.9	2%
Tennessee	3108	41.37	33.96	1504	0.001463	0	139	0.20	35.03	6.35	40.3	3%
Texas	1046	186.28	151.68	-22	0.013355	56	3707	0.24	189.51	-3.24	10.5	4%
Texas	1046	176.27	151.68	660	0.018002	56	2910	0.39	191.26	-14.99	224.8	6%
Texas	1065	153.90	132.04	369	0.009297	7	2207	0.35	143.68	10.22	104.5	4%
Texas	1068	88.70	84.84	258	0.011854	23	177	0.24	102.43	-13.73	188.5	7%
Texas	1068	88.26	84.84	258	0.011140	22	173	0.28	101.55	-13.29	176.7	7%
Texas	1116	66.34	66.27	137	0.000942	14	87	0.35	73.17	-6.84	46.7	1%
Texas	1174	90.22	75.21	381	0.014485	13	87	0.35	89.83	0.39	0.2	10%
Texas	1174	129.57	112.40	487	0.014987	19	76	0.67	129.97	-0.40	0.2	7%
Texas	2133	53.22	51.45	125	0.013088	4	0	0.12	61.12	-7.89	62.3	13%
Texas	2133	53.16	51.45	250	0.013083	13	0	0.20	65.11	-11.95	142.8	12%
Texas	2133	148.77	70.96	549	0.012716	0	0	0.31	78.63	70.14	4919.4	
Texas	2133	134.01	70.96	567	0.013502	2	55	0.31	80.07	53.94	2909.6	
Texas	9005	177.03	76.67	695	0.012876	21	409	0.16	94.30	82.73	6844.6	
Texas	9005	141.99	134.01	196	0.011837	1	52	0.12	141.66	0.33	0.1	5%
Texas	9005	146.68	142.37	95	0.012777	6	326	0.16	153.17	-6.49	42.1	5%
Texas	9005	145.98	142.37	872	0.012284	10	939	0.24	155.46	-9.48	89.9	5%
Texas	A503	73.18	71.41	1341	0.023805	1	111	0.20	86.35	-13.17	173.5	17%
Texas	A503	77.36	71.41	1448	0.023175	2	499	0.20	86.93	-9.57	91.5	16%
Texas	A503	70.77	71.41	1539	0.025273	2	506	0.20	88.20	-17.43	303.8	17%
Texas	A503	78.00	71.41	1705	0.023836	2	1614	0.24	88.81	-10.81	116.9	16%
Texas	A503	76.41	71.41	1963	0.023836	2	2443	0.24	89.90	-13.49	182.1	16%
Texas	A503	78.88	71.41	1906	0.021210	4	3070	0.24	90.04	-11.16	124.5	14%
Texas	A503	78.63	71.41	2704	0.022011	5	3364	0.28	91.36	-12.73	162.0	15%
Texas	A503	82.05	71.41	2500	0.023476	6	3593	0.24	92.99	-10.94	119.6	15%
Texas	A504	94.72	97.83	-15	0.015986	0	0	0.20	107.47	-12.74	162.4	9%
Texas	A504	91.62	97.83	1315	0.014302	0	17	0.31	106.47	-14.86	220.7	8%
Texas	A504	90.48	97.83	1421	0.013092	0	38	0.35	105.77	-15.29	233.9	7%
Texas	A504	82.43	97.83	1510	0.016341	0	52	0.28	107.75	-25.32	641.0	9%
Texas	A504	90.10	97.83	1675	0.014852	0	28	0.35	106.82	-16.72	279.6	8%

Texas	A504	91.62	97.83	1931	0.014852	0	62	0.35	106.87	-15.25	232.5	8%
Texas	A504	92.57	97.83	1872	0.012617	0	107	0.35	105.58	-13.01	169.2	7%
Texas	A504	93.27	97.83	2666	0.013498	0	111	0.35	106.11	-12.85	165.1	8%
Texas	A504	95.36	97.83	2460	0.013359	0	173	0.39	106.11	-10.76	115.7	8%
Texas	A507	83.89	91.81	-15	0.017513	0	0	0.24	102.37	-18.48	341.5	10%
Texas	A507	80.34	91.81	1315	0.016575	1	0	0.43	102.25	-21.91	479.9	10%
Texas	A507	81.10	91.81	1421	0.014419	1	0	0.39	100.95	-19.85	393.9	9%
Texas	A507	72.67	91.81	1510	0.018152	1	0	0.31	103.20	-30.52	931.7	11%
Texas	A507	79.33	91.81	1674	0.015980	1	45	0.43	101.95	-22.62	511.7	9%
Texas	A507	78.76	91.81	1931	0.015980	1	35	0.43	101.93	-23.18	537.2	9%
Texas	A507	81.04	91.81	1872	0.013153	2	59	0.43	100.71	-19.67	386.8	8%
Texas	A507	79.90	91.81	2665	0.014073	2	59	0.47	101.26	-21.36	456.4	8%
Texas	A507	81.35	91.81	2460	0.013784	1	76	0.47	100.66	-19.31	372.9	8%
Texas	A509	76.73	78.76	-15	0.014523	0	0	0.12	87.51	-10.78	116.3	10%
Texas	A509	76.92	78.76	1313	0.015217	3	1174	0.24	90.82	-13.90	193.2	10%
Texas	A509	76.48	78.76	1419	0.014044	4	1299	0.24	90.72	-14.25	203.0	9%
Texas	A509	71.47	78.76	1508	0.015614	3	1635	0.28	91.67	-20.20	408.0	10%
Texas	A509	77.30	78.76	1672	0.013443	7	3180	0.28	94.18	-16.89	285.1	9%
Texas	A509	77.30	78.76	1928	0.013443	6	3582	0.28	94.27	-16.97	288.1	9%
Texas	A509	77.62	78.76	1869	0.011479	6	3142	0.28	92.51	-14.89	221.7	7%
Texas	A509	81.54	78.76	2662	0.012173	6	3749	0.28	93.73	-12.18	148.5	8%
Texas	A509	83.57	78.76	2455	0.013425	6	4604	0.28	95.62	-12.05	145.1	8%

Table 11A-2 Distresses Records for PCC Covered with AC Pavements

State	SHRP_ID	IRI Measured (in/mile)	IRI Initial (in/mile)	SF (2020)	ΔVC	FC	TC	RD	IRI Predicted (in/mile)	Residual (R)	R^2	Env Weight
Alabama	0606	90.29	89.72	473	-0.01578	0	3132	0.08	91.76	-1.48	2.18	-1.0%
Alabama	0606	79.83	89.72	532	-0.01578	0	3288	0.08	91.85	-12.02	144.37	-1.0%
Alabama	0606	94.66	89.72	997	-0.01232	0	3323	0.08	92.07	2.59	6.68	-0.8%
Alabama	0606	96.37	89.72	1077	0.00228	1	3333	0.08	93.25	3.12	9.73	0.1%
Alabama	0608	57.02	55.12	476	-0.01435	1	0	0.08	55.83	1.19	1.43	-1.5%
Alabama	0608	64.37	55.12	538	-0.01435	1	83	0.08	55.88	8.50	72.22	-1.5%
Alabama	0608	58.04	55.12	1005	-0.00991	7	1032	0.08	58.48	-0.45	0.20	-1.0%
Alabama	0608	59.75	55.12	1086	0.00269	10	1157	0.08	60.21	-0.46	0.22	0.3%
Arkansas	A606	64.50	60.95	0	0.00492	0	0	0.12	63.13	1.37	1.88	0.5%
Arkansas	A606	64.31	60.95	186	-0.00829	0	0	0.08	61.72	2.59	6.73	-0.8%
Arkansas	A606	62.54	60.95	716	-0.02473	2	1230	0.12	62.65	-0.12	0.01	-2.3%
Arkansas	A606	62.22	60.95	850	-0.02473	4	2633	0.12	64.03	-1.81	3.29	-2.3%
Arkansas	A606	62.98	60.95	1151	-0.01793	5	3347	0.12	65.13	-2.15	4.64	-1.6%
Arkansas	A606	64.63	60.95	1049	-0.01793	8	3676	0.12	66.23	-1.60	2.56	-1.6%
Arkansas	A606	66.78	60.95	1329	-0.01793	15	4019	0.12	68.54	-1.76	3.10	-1.6%
Arkansas	A606	70.14	60.95	1572	-0.02521	20	4261	0.12	69.76	0.38	0.14	-2.1%
Arkansas	A606	83.83	60.95	1756	0.01710	28	4438	0.16	75.43	8.40	70.49	1.3%
Arkansas	A607	68.18	64.37	0	0.00308	0	0	0.08	65.81	2.36	5.58	0.3%
Arkansas	A607	66.97	64.37	183	-0.00523	0	0	0.12	65.95	1.02	1.05	-0.5%
Arkansas	A607	65.77	64.37	709	-0.01516	1	28	0.12	65.68	0.09	0.01	-1.4%
Arkansas	A607	66.27	64.37	842	-0.01516	2	586	0.12	66.29	-0.01	0.00	-1.4%
Arkansas	A607	67.22	64.37	1142	-0.01083	4	1147	0.12	67.46	-0.24	0.06	-1.0%
Arkansas	A607	68.94	64.37	1038	-0.01083	5	1781	0.12	68.11	0.82	0.67	-0.9%
Arkansas	A607	74.64	64.37	1317	-0.01083	5	2917	0.12	68.74	5.90	34.78	-0.9%
Arkansas	A607	71.22	64.37	1558	-0.01552	7	3662	0.12	69.48	1.74	3.02	-1.3%

Arkansas	A607	81.29	64.37	1740	0.01052	9	4636	0.16	72.80	8.49	72.09	0.9%
California	7455	36.05	34.28	329	0.06216	0	0	0.24	41.74	-5.69	32.35	8.9%
California	7455	37.26	34.28	632	-0.06308	2	0	0.24	34.90	2.35	5.54	-10.7%
California	7455	40.87	38.14	131	-0.06308	0	0	0.24	38.16	2.71	7.33	-9.8%
California	7455	40.93	38.14	320	-0.00115	0	0	0.24	41.84	-0.91	0.83	-0.2%
Mississippi	3099	52.97	36.50	608	-0.01085	0	0	0.24	39.62	13.35	178.26	-1.6%
Oklahoma	0603	84.65	84.84	296	0.00820	9	1337	0.24	92.56	-7.91	62.64	0.5%
Oklahoma	0603	83.70	84.84	659	0.00103	10	1285	0.24	92.41	-8.71	75.92	0.1%
Oklahoma	0603	79.96	84.84	930	-0.00669	10	1902	0.20	91.67	-11.71	137.02	-0.4%
Oklahoma	0603	95.23	84.84	1319	-0.00669	12	2408	0.28	93.81	1.42	2.02	-0.4%
Oklahoma	0603	110.50	116.71	276	-0.00669	12	3385	0.24	125.59	-15.09	227.69	-0.3%
Oklahoma	0604	89.84	87.50	310	0.01259	11	2668	0.31	98.08	-8.24	67.86	0.8%
Oklahoma	0604	90.10	87.50	679	0.00238	8	2702	0.31	96.58	-6.49	42.07	0.1%
Oklahoma	0604	94.34	87.50	958	-0.00773	10	3097	0.24	95.55	-1.21	1.46	-0.5%
Oklahoma	0604	97.13	87.50	1354	-0.00773	15	3995	0.31	98.82	-1.69	2.86	-0.5%
Oklahoma	0604	110.88	87.50	2679	-0.00773	30	2262	0.28	101.79	9.09	82.61	-0.5%
Oklahoma	0606	101.31	93.90	297	0.00742	1	2740	0.28	100.55	0.76	0.58	0.4%
Oklahoma	0606	107.21	93.90	659	0.00165	1	2169	0.28	99.89	7.31	53.47	0.1%
Oklahoma	0606	99.22	93.90	931	-0.00475	1	2474	0.20	98.42	0.80	0.64	-0.3%
Oklahoma	0606	101.19	93.90	1320	-0.00475	1	2332	0.31	100.23	0.96	0.91	-0.3%
Oklahoma	0606	109.74	93.90	2602	-0.00475	2	3724	0.24	100.05	9.69	93.97	-0.3%
Tennessee	0603	47.58	44.73	200	-0.00781	0	0	0.20	47.41	0.18	0.03	-1.0%
Tennessee	0603	49.67	44.73	619	-0.02616	0	83	0.24	46.99	2.68	7.21	-3.3%
Tennessee	0603	54.24	44.73	928	-0.01847	0	281	0.24	47.56	6.68	44.62	-2.3%
Tennessee	0603	50.43	44.73	1212	0.00676	0	353	0.24	49.10	1.34	1.79	0.8%
Tennessee	0603	54.93	44.73	1650	-0.01847	0	475	0.24	47.66	7.27	52.85	-2.3%
Texas	5154	60.19	59.50	310	-0.00803	0	0	0.12	60.90	-0.71	0.50	-0.8%
Texas	5154	71.53	59.50	1772	0.00982	0	128	0.28	64.54	6.99	48.85	0.9%
Texas	5274	73.50	100.24	198	-0.03485	0	0	0.16	100.68	-27.18	738.64	-2.1%
Texas	5287	92.89	91.43	0	0.01725	0	17	0.28	96.86	-3.97	15.78	1.1%
Texas	5287	97.38	91.43	1075	-0.01587	1	2931	0.24	96.17	1.21	1.47	-1.0%

Table 11A-3 Distresses Records for CRCP Pavements

State	SHRP_ID	IRI Measured (in/mile)	IRI Initial (in/mile)	Punchout	SF (2020)	ΔVC	IRI Predicted (in/mile)	Residual (R)	R^2	Env Weight
Arizona	7079	1.075	68.11	0	0.0003	-0.0388	64.30	-3.81	14.51	-2%
Arizona	7079	1.098	69.57	0	0.0004	0.0521	66.69	-2.88	8.27	2%
Arizona	7079	1.134	71.85	0	0.0005	0.0228	65.92	-5.93	35.13	1%
Arizona	7079	1.107	70.14	0	0.0007	0.0356	66.26	-3.88	15.05	1%
California	7455	1.202	76.16	0	0.0001	-0.0628	76.98	0.82	0.67	-2%
California	7455	1.166	73.88	0	0.0014	0.0335	79.51	5.63	31.73	1%
California	7455	1.191	75.46	0	0.0005	0.0622	80.26	4.80	23.07	2%
California	7455	1.185	75.08	0	0.0006	-0.0380	77.63	2.55	6.50	-1%
Louisiana	0705	1.344	85.16	0	0.0002	-0.0032	83.30	-1.86	3.46	0%
Louisiana	0708	1.048	66.40	0	0.0002	-0.0023	64.69	-1.71	2.92	0%
Mississippi	5006	1.475	93.46	0	-0.0018	0.0014	91.78	-1.67	2.81	0%
Mississippi	5006	1.411	89.40	0	0.0437	0.0097	92.00	2.60	6.75	0%
Mississippi	5006	1.73	109.61	0	0.0287	0.0015	91.78	-17.83	317.85	0%
Mississippi	5006	1.49	94.41	0	0.0312	-0.0078	91.54	-2.87	8.22	0%
Mississippi	5006	1.45	91.87	0	0.0364	-0.0061	91.59	-0.29	0.08	0%
Mississippi	5006	1.499	94.98	0	0.0584	-0.0127	91.41	-3.57	12.72	0%
Texas	3569	1.328	84.14	0	-0.0622	0.0161	76.71	-7.43	55.24	1%
Texas	3569	1.311	83.06	0	-0.0575	-0.0152	75.89	-7.18	51.54	-1%
Texas	3569	1.398	88.58	0	-0.0502	0.0014	76.32	-12.25	150.16	0%
Texas	3569	1.377	87.25	0	-0.0319	-0.0063	76.12	-11.13	123.81	0%
Texas	3569	1.488	94.28	0	0.0895	-0.0010	76.26	-18.02	324.76	0%
Texas	3569	1.673	106.00	0	-0.0296	-0.0063	76.12	-29.88	892.90	0%
Texas	3569	1.461	92.57	0	-0.0317	-0.0152	75.89	-16.68	278.32	-1%
Texas	3569	1.488	94.28	0	0.0892	0.0164	76.72	-17.56	308.41	1%
Texas	3719	2.405	152.38	0	0.0001	0.0094	154.21	1.83	3.35	0%

Texas	3719	2.384	151.05	0	0.0003	-0.0106	153.69	2.64	6.95	0%
Texas	3719	2.281	144.52	0	0.0004	-0.0028	153.89	9.37	87.76	0%
Texas	3719	2.313	146.55	0	0.0007	-0.0085	153.74	7.19	51.70	0%
Texas	3719	2.292	145.22	0	0.0009	-0.0057	153.81	8.59	73.84	0%
Texas	3719	2.199	139.33	0	0.0010	0.0110	154.25	14.92	222.74	0%
Texas	3719	2.286	144.84	0	0.0012	0.0061	154.13	9.29	86.22	0%
Texas	3779	2.143	135.78	0	-0.0018	-0.0534	140.78	4.99	24.95	-1%
Texas	3779	2.118	134.20	0	0.0044	0.0336	143.06	8.87	78.64	1%
Texas	3779	2.189	138.70	0	-0.0038	0.0512	143.53	4.83	23.35	1%
Texas	3779	2.039	129.19	0	0.0111	-0.0667	140.42	11.23	126.19	-1%
Texas	3779	2.154	136.48	0	-0.0039	-0.0341	141.28	4.80	23.09	-1%
Texas	3779	2.13	134.96	0	-0.0038	-0.0534	140.78	5.82	33.85	-1%
Texas	3779	2.141	135.65	0	0.0029	0.0023	142.24	6.59	43.39	0%
Texas	3779	2.213	140.22	0	0.0027	-0.0574	140.67	0.45	0.21	-1%
Texas	3779	2.155	136.54	0	0.0144	0.0511	143.52	6.98	48.78	1%
Texas	3779	2.159	136.79	0	0.0082	0.0620	143.81	7.02	49.22	1%
Texas	3779	2.142	135.72	0	-0.0029	-0.0574	140.67	4.95	24.53	-1%
Texas	3845	1.804	114.30	0	-0.0804	0.0269	107.09	-7.21	52.02	1%
Texas	3845	1.71	108.35	0	-0.0669	-0.0208	105.83	-2.51	6.31	-1%
Texas	3845	1.68	106.44	0	-0.0632	0.0030	106.46	0.01	0.00	0%
Texas	3845	1.759	111.45	0	-0.0607	-0.0227	105.78	-5.67	32.10	-1%
Texas	3845	1.624	102.90	0	-0.0043	0.0170	106.83	3.93	15.46	0%
Texas	3845	1.82	115.32	0	-0.0239	-0.0106	106.10	-9.21	84.87	0%
Texas	3845	1.938	122.79	0	-0.0239	-0.0227	105.78	-17.01	289.25	-1%
Texas	3845	2.003	126.91	0	0.1296	0.0280	107.12	-19.79	391.74	1%
Texas	3845	2.03	128.62	0	0.0455	0.0269	107.09	-21.53	463.62	1%
Texas	3845	2.153	136.41	0	0.0829	-0.0021	106.33	-30.09	905.22	0%
Texas	3845	2.145	135.91	0	0.0203	0.0141	106.75	-29.15	849.97	0%
Texas	5026	1.679	106.38	0	0.0001	-0.0188	107.41	1.03	1.05	0%
Texas	5026	1.674	106.06	0	0.0003	-0.0122	107.58	1.52	2.30	0%
Texas	5026	1.684	106.70	0	0.0005	-0.0047	107.78	1.08	1.17	0%

Texas	5026	1.719	108.92	0	0.0008	-0.0123	107.58	-1.34	1.79	0%
Texas	5026	1.741	110.31	0	0.0010	-0.0050	107.77	-2.54	6.44	0%
Texas	5026	1.756	111.26	0	0.0011	0.0151	108.30	-2.96	8.76	0%
Texas	5026	1.724	109.23	0	0.0012	-0.0122	107.58	-1.65	2.73	0%
Texas	5026	1.751	110.94	0	0.0014	0.0034	107.99	-2.95	8.71	0%
Texas	5026	1.738	110.12	0	0.0046	0.0101	108.17	-1.95	3.81	0%
Texas	5026	1.725	109.30	0	0.0022	0.0110	108.19	-1.10	1.22	0%
Texas	5035	1.837	116.39	0	-0.0173	-0.0094	111.96	-4.43	19.62	0%
Texas	5035	1.716	108.73	0	-0.0151	-0.0143	111.83	3.11	9.66	0%
Texas	5035	1.859	117.79	0	-0.0123	0.0126	112.54	-5.25	27.51	0%
Texas	5035	1.752	111.01	0	-0.0007	-0.0143	111.83	0.83	0.69	0%
Texas	5035	1.779	112.72	0	0.0009	-0.0094	111.96	-0.75	0.57	0%
Texas	5035	1.797	113.86	0	-0.0023	-0.0159	111.79	-2.06	4.26	0%
Texas	5035	1.855	117.53	0	0.0183	-0.0159	111.79	-5.74	32.95	0%
Texas	5035	1.836	116.33	0	0.0240	0.0171	112.66	-3.67	13.45	0%
Texas	5035	1.868	118.36	0	0.0363	0.0005	112.22	-6.13	37.61	0%
Texas	5154	1.54	97.57	0	0.0001	-0.0360	96.75	-0.82	0.67	-1%
Texas	5154	1.649	104.48	0	0.0002	0.0098	97.96	-6.52	42.53	0%
Texas	5154	1.527	96.75	0	0.0011	-0.0253	97.04	0.29	0.08	-1%
Texas	5154	1.598	101.25	0	0.0004	-0.0213	97.14	-4.11	16.88	-1%
Texas	5274	1.716	108.73	0	-0.0316	0.0327	101.92	-6.81	46.33	1%
Texas	5274	1.625	102.96	0	-0.0280	-0.0385	100.05	-2.91	8.49	-1%
Texas	5274	1.658	105.05	0	-0.0242	0.0266	101.76	-3.29	10.83	1%
Texas	5283	1.168	74.00	0	-0.0048	0.0150	72.75	-1.25	1.57	1%
Texas	5283	1.15	72.86	0	-0.0037	-0.0132	72.01	-0.85	0.73	0%
Texas	5283	1.178	74.64	0	-0.0022	0.0105	72.63	-2.00	4.02	0%
Texas	5283	1.355	85.85	0	-0.0001	-0.0126	72.03	-13.83	191.18	0%
Texas	5283	1.299	82.30	0	0.0174	0.0109	72.64	-9.66	93.34	0%
Texas	5283	1.471	93.20	0	0.0035	-0.0080	72.15	-21.05	443.31	0%
Texas	5283	1.437	91.05	0	0.0035	0.0059	72.51	-18.54	343.57	0%
Texas	5283	1.511	95.74	0	0.0064	-0.0142	71.98	-23.75	564.26	-1%

Texas	5283	1.681	106.51	0	0.0230	-0.0142	71.98	-34.53	1192.00	-1%
Texas	5283	1.738	110.12	0	0.0284	0.0104	72.63	-37.49	1405.36	0%
Texas	5283	1.765	111.83	0	0.0384	-0.0011	72.33	-39.50	1560.44	0%
Texas	5287	1.926	122.03	0	-0.0254	0.0173	119.13	-2.90	8.44	0%
Texas	5287	1.878	118.99	0	-0.0195	-0.0159	118.26	-0.73	0.54	0%
Texas	5287	2.027	128.43	0	-0.0188	0.0143	119.05	-9.38	87.99	0%
Texas	5287	1.953	123.74	0	-0.0150	-0.0146	118.29	-5.45	29.74	0%
Texas	5287	1.896	120.13	0	0.0186	0.0183	119.16	-0.98	0.95	0%
Texas	5317	2.256	142.94	0	-0.0091	0.0173	138.64	-4.30	18.47	0%
Texas	5317	2.269	143.76	0	-0.0083	-0.0114	137.89	-5.88	34.52	0%
Texas	5317	2.346	148.64	0	-0.0062	0.0149	138.58	-10.06	101.25	0%
Texas	5317	2.463	156.06	0	-0.0035	-0.0154	137.78	-18.27	333.89	0%
Texas	5317	2.552	161.69	0	-0.0028	-0.0114	137.89	-23.81	566.73	0%
Texas	5317	2.523	159.86	0	0.0030	-0.0065	138.02	-21.84	477.00	0%
Texas	5317	2.585	163.79	0	0.0001	-0.0135	137.83	-25.95	673.58	0%
Texas	5317	2.762	175.00	0	0.0139	-0.0135	137.83	-37.17	1381.48	0%
Texas	5317	2.889	183.05	0	0.0202	0.0173	138.64	-44.40	1971.76	0%
Texas	5317	2.938	186.15	0	0.0288	0.0020	138.24	-47.91	2295.46	0%
Texas	5323	1.784	113.03	0	-0.0025	0.0049	113.10	0.06	0.00	0%
Texas	5323	1.735	109.93	0	0.0174	-0.0064	112.80	2.87	8.26	0%
Texas	5323	1.81	114.68	0	0.0005	0.0049	113.10	-1.58	2.50	0%
Texas	5328	1.633	103.47	0	-0.0263	-0.0069	105.63	2.16	4.68	0%
Texas	5328	1.589	100.68	0	-0.0151	-0.0102	105.54	4.86	23.65	0%
Texas	5328	1.63	103.28	0	-0.0164	0.0098	106.07	2.79	7.79	0%
Texas	5328	1.543	97.76	0	-0.0126	0.0042	105.92	8.16	66.52	0%
Texas	5328	1.626	103.02	0	-0.0200	0.0213	106.37	3.35	11.20	1%
Texas	5328	1.601	101.44	0	-0.0042	0.0128	106.15	4.71	22.17	0%
Texas	5328	1.627	103.09	0	0.0038	0.0213	106.37	3.28	10.78	1%
Texas	5328	1.59	100.74	0	0.0021	-0.0069	105.63	4.89	23.90	0%
Texas	5328	1.633	103.47	0	0.0297	-0.0102	105.54	2.08	4.31	0%
Texas	5328	1.626	103.02	0	0.0216	0.0213	106.37	3.35	11.20	1%

Texas	5328	1.654	104.80	0	0.0884	0.0028	105.89	1.09	1.18	0%
Texas	5328	1.638	103.78	0	0.0412	0.0128	106.15	2.36	5.59	0%
Texas	5335	2.086	132.17	0	-0.0027	0.0076	128.82	-3.35	11.20	0%
Texas	5335	2.002	126.85	0	0.0184	-0.0086	128.40	1.55	2.40	0%
Texas	5335	2.013	127.54	0	0.0006	0.0076	128.82	1.28	1.63	0%
Texas	5335	1.97	124.82	0	0.0233	-0.0102	128.35	3.53	12.48	0%
Texas	5335	1.933	122.47	0	-0.0163	0.0076	128.82	6.35	40.28	0%
Texas	5335	2.272	143.95	0	0.0014	-0.0007	127.08	-16.87	284.70	0%
Texas	5335	1.945	123.24	0	0.0537	-0.0053	126.96	3.72	13.87	0%
Texas	5335	1.947	123.36	0	-0.0023	0.0063	127.27	3.90	15.25	0%
Texas	5336	1.468	93.01	0	0.0021	-0.0074	88.83	-4.19	17.52	0%
Texas	5336	1.456	92.25	0	0.0108	-0.0145	88.64	-3.61	13.06	0%
Texas	5336	1.435	90.92	0	0.0045	0.0267	89.72	-1.20	1.44	1%
Texas	5336	1.338	84.78	0	0.0235	-0.0180	88.55	3.77	14.22	-1%
Texas	5336	1.336	84.65	0	0.0336	-0.0023	88.96	4.31	18.58	0%
Texas	5336	1.38	87.44	0	0.0228	-0.0023	88.96	1.52	2.32	0%
Texas	5336	1.439	91.18	0	0.0299	-0.0104	88.75	-2.43	5.89	0%