Supplementary Information for Comparative Pavement Life Cycle Assessment and Life Cycle Cost Analysis

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Revision History

July 24, 2014 – Version 2

A new section is added to Chapter 2:

2.3 LCA Model Description – Equations and Assumptions, which presents the calculations and assumptions adopted in our pavement LCA model, including the submodels in all life-cycle phases.

1 Overview

The MIT Concrete Sustainability Hub (CSHub) is conducting life cycle environmental and cost analyses of pavements under a wide range of contexts. The analyses involve the comparison of new asphalt concrete (AC) and portland cement concrete (PCC) pavement designs for a series of defined scenarios. The CSHub commissioned Applied Research Associates (ARA) to create these pavement designs. This section defines the scope of the scenarios and the guidelines set forth in creating the designs. The purpose of this document is to assemble all supporting information for the LCA and LCCAs, including designs, maintenance and repair, and cost data. Results for the scenario analysis will be published on the CSHub website as they become available.

1.1 Scenario definition

A *scenario* is combination of the *operational context* and *performance criteria* (including maintenance and rehabilitation schedule and material mix) within an *analysis period*. The following section describes the types of scenarios which this study analyzes:

- Analysis period:
  - Design life: Pavements are designed such that they do not need a major rehabilitation in most cases for up to 30 years, but with alternatives of 20 or 50 years.
  - Analysis period: Pavement performance and costs will be analyzed over 50 years in most cases, but with alternatives of 30, 75, and 100 years.
  - Each analysis considers at least one major rehabilitation
- Operational context:
  - Specific sites from LTPP or other sections will be selected for analysis. These sites will represent samples of the four major climate zones.
  - Traffic: Average Annual Daily Truck Traffic (AADTT) appropriate for three different situations will be selected.
    - Local street/road (rural): 2 lanes total: AADTT = 300 two directions.
    - State highway (rural): 4 lanes total: AADTT = 1,000 two directions.
    - Interstate highway (urban), 6 lanes total: AADTT = 8,000 two directions.

    3% compound annual increase.
  - Four climates zones will be represented, including:
    - Freeze-dry: low precipitation and deep frost line.
    - Freeze-wet: high precipitation and no frost penetration.
    - Non-freeze-dry: low precipitation and no frost line.
    - Non-freeze-wet: high precipitation and little frost penetration.

    Foundation for each site is based upon specific soils for the project.
- Performance criteria
  - Pavements are designed to reliability levels designated for the location and traffic volume
  - AC failure criteria: International Roughness Index (IRI), total rutting, AC bottom-up fatigue cracking, and thermal cracking. Use levels recommended in MOP for each site and traffic level.
  - PCC failure criteria: IRI, bottom-up and top-down transverse fatigue cracking, faulting. Use levels recommended in MOP for each site and traffic level.

- Maintenance and rehabilitation (M&R) schedule
  - One schedule derived using pavement management data from the local agency.
  - Another schedule derived using data from DARWin-ME analysis. However, modify if necessary based on other distresses that are NOT predicted by DARWin-ME.
  - The schedules will be for the analysis period, which is 50 years in most cases, but will extend up to 100 years.
- Material mix
  - Material mixes for asphalt and concrete pavements that are consistent with local agency practices and pavement design life.

A key element of the scenario is the definition of the performance criteria such that the asphalt and concrete pavement designs are *functionally equivalent*. This is achieved as follows:

- The failure criteria or the maintenance and rehabilitation schedules for the asphalt and concrete designs are based on the same criteria: conditions of the pavement that require major rehabilitation. Those recommended in the AASHTO MOP are mostly used as this is the way in which they were selected.
- Use locally calibrated distress and IRI models if possible.

1.2 Design Scenarios for CSHub

The CSHub seeks to analyze pavements across a range of climate and traffic conditions. The scope of the analyses will include one AC and one PCC project for the range of scenarios. There are four parameters that can vary for each scenario (The table on the following page presents a general summary of this):

- Climate Zone: four alternatives (Arizona, Colorado, Florida, and Missouri).
- Traffic Level: Three alternatives (rural local highway, state highway, and urban Interstate highway).
- Design life: Three alternatives (baseline of 30 years and two alternatives that will depend on the traffic level: 20 years or 40 years).
- Analysis period: four alternatives (baseline of 50 years and three alternatives that will depend on the traffic level and design life: 30 years, 75 years, or 100 years).
- Maintenance Schedule: Each scenario includes two M&R schedules, one derived from local agency recommendations, and another derived from DARWin-ME output plus consideration of other distress types not predicted by DARWin-ME.

Bold numbers in the table indicate scenario numbers. DL = design life, AP = analysis period. Deviations from baseline values of 30 years for design life and 50 years for analysis period are listed in italics. An equitable HMA and JPCP will be designed for each of the design scenario site conditions defined below.

Traffic Level 2-Direction AADTT	**LTPP Climate Zone**			
	Wet Freeze (Missouri)	**Dry No Freeze (Arizona)**	**Dry Freeze (Colorado)**	**Wet No Freeze (Florida)**
Local Street/ Highway (Rural) AADTT = 300	**1.** *DL=20*, AP=50 **2.** DL=30, AP=50	(N/A)	(N/A)	(N/A)
State Highway (Rural) AADTT = 1,000	**3.** *DL=20*, AP=50 **4.** DL=30, AP=50 **5.** *DL=40*, AP=50	**6.** DL=30, AP=50	**7.** DL=30, AP=50	**8.** DL=30, AP=50
Interstate (Urban) AADTT = 8,000	**9a.** *DL=20*, *AP=30* **9b.** *DL=20*, AP=50 **10a.** DL=30, AP=50 **10b.** DL=30, *AP=75* **11a.** *DL=50*, *AP=75* **11b.** *DL=50*, *AP=100*	**12.** DL=30, AP=50	**13.** DL=30, AP=50	**14.** DL=30, AP=50

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2 Life Cycle Assessment (LCA) Inputs – Data Sources and Equations

2.1 LCA Data Sources and Assumptions

Lifecycle Phase		Quantity Data Source	COV[1]	Impact Data Source	Key Assumptions
Materials					
	Steel reinforcement	MEPDG	0.073	Worldsteel	70% recycled content; 70% recycled at EOL
Concrete		MEPDG	0.058	n/a	Mix design from MEPDG
	Cement	MEPDG	0.060	*See Table 2*	See Cement LCA inputs
	Cement Materials	PCA Environmental Surveys	-	*See Table 2*	See Cement LCA inputs
	Water	MEPDG	0.107	Ecoinvent	
	Fly ash		0.460	PE International	
	Aggregate	MEPDG	0.063	Ecoinvent	
	Concrete Mixing	NCSA/Zapata	0.302	Ecoinvent	Diesel
Asphalt Concrete		MEPDG	0.058	n/a	
	Bitumen	MEPDG	0.060	Ecoinvent	Bitumen, at refinery/RER
	Aggregate	MEPDG	0.063	Ecoinvent	
Cement Stabilized SG		MEPDG	0.058	n/a	
	Cement	Ohio DOT	0.072	*See Table 2*	See Cement LCA inputs
	Soil	Ohio DOT	0.070	n/a	
Cement Treated Agg Base		MEPDG	0.058	n/a	
	Cement	Ohio DOT	0.072	*See Table 2*	See Cement LCA inputs
	Aggregate	Ohio DOT	0.075	Ecoinvent	

[1] COV = standard deviation/mean; calculated from pedigree matrix (underlying normal distribution)

Lifecycle Phase		Quantity Data Source	COV[1]		Impact Data Source	Key Assumptions
PATB		MEPDG	0.058		n/a	
	Bitumen	FL DOT	0.072		Ecoinvent	
	Aggregate	FL DOT	0.075		Ecoinvent	
Construction						
	Concrete Paving	Chappat and Bilal (2003)/IVL	0.215		Ecoinvent	Diesel
	Asphalt Paving	Chappat and Bilal (2003)/IVL	0.215		Ecoinvent	Diesel
	Placement of other layers	Chappat and Bilal (2003)/IVL	0.229		Ecoinvent	Diesel
Transportation			**Avg (km)**	**SD (km)[2]**		
Concrete (km)	Truck	U.S. Commodity Flow Survey (2007)	40.2	8.4	Ecoinvent	Concrete truck (tank)
Steel (km)	Truck	BTS (2007) – Articles of Base Metal	684	143	Ecoinvent	
	Rail	BTS (2007) – Articles of Base Metal	1624	155.1	Ecoinvent	
Cement (km)	Truck	PCA Environmental Surveys	201	48.2	Ecoinvent	
	Rail	PCA Environmental Surveys	430	68.5	Ecoinvent	
	Water	PCA Environmental Surveys	644	644	Ecoinvent	
Fly Ash	Truck	BTS (2007) – Waste and scrap	201	42.1	Ecoinvent	
	Rail	BTS (2007) – Waste and scrap	589	56.3	Ecoinvent	
	Water	BTS (2007) – Waste and scrap	1880	75.3	Ecoinvent	

[2] Standard deviation for transportation calculated from empirical data (arithmetic std dev) and pedigree matrix (underlying normal)

Lifecycle Phase			Quantity Data Source	COV[1]	Impact Data Source		Key Assumptions
Aggregates	Truck		BTS (2007) – Gravel and crushed stone	88.5	18.5	Ecoinvent	
	Rail		BTS (2007) – Gravel and crushed stone	684	65.3	Ecoinvent	
	Water		BTS (2007) – Gravel and crushed stone	620	24.8	Ecoinvent	
Bitumen	Truck		BTS (2007) – Coal and petroleum products	158	33.0	Ecoinvent	
	Rail		BTS (2007) – Coal and petroleum products	1893	181	Ecoinvent	
	Water		BTS (2007) – Coal and petroleum products	1207	48.3	Ecoinvent	
Waste	Truck		assumption	50	10.5	Ecoinvent	
Use							
	Carbonation		Lagerblad (2005)	0.104	Lagerblad (2005)		
	Lighting	Electricity	Santero (2009)	0.045	Ecoinvent (electricity)		US average grid mix
		Tech Efficacy	Mn/DOT Roadway Lighting	0.073	n/a		
	Albedo	Radiative Forcing	Akbari et al (2009)	0.110	Akbari et al (2009)		38 kg CO_2e/m^2/0.15 decrease in albedo
		Urban Heat Island Effect	Rosenfeld et al (1998)	0.228	Rosenfeld et al (1998)		4.85×10^{-3} kg CO_2e/m^2/0.01 decrease in albedo
	PVI	Roughness	MEPDG	0.058	n/a		
		Average Fuel Use	FHWA Statistics	0.039	n/a		Car: 23.7 mpg Truck: 6.5 mpg
		AADT	FHWA Statistics	0.038	n/a		

Lifecycle Phase			Quantity Data Source	COV[1]	Impact Data Source	Key Assumptions
		AADTT	FHWA Statistics	0.038	n/a	
		AADT % increase	FHWA Statistics	0.100	n/a	
		AADTT % increase	MEPDG	0.058	n/a	
		Fuel increase due to roughness	Zaabar and Chatti (2010)	0.361	n/a	Same source for cars and trucks
		Gas	(based on purely mathematical formula using above inputs)	0.017	Ecoinvent: (divided by amount of fuel used) (Operation, passenger car, petrol, fleet average 2010/RER U)	Gas: 6.073 lb/gal
		Diesel	(based on purely mathematical formula using above inputs)	0.017	Ecoinvent: (divided by amount of fuel used) (Operation, lorry >16t, fleet average/RER U)	Diesel: 6.943 lb/gal
	PVI	Deflection				
		Gas	(from Mehdi)	0.365	Ecoinvent: (divided by amount of fuel used) (Operation, passenger car, petrol, fleet average 2010/RER U)	Gas: 6.073 lb/gal
		Diesel	(from Mehdi)	0.365	Ecoinvent: (divided by amount of fuel used) (Operation, lorry >16t, fleet average/RER U)	Diesel: 6.943 lb/gal

Lifecycle Phase			Quantity Data Source	COV[1]	Impact Data Source	Key Assumptions
Maintenance						
	Onsite activities: diamond grinding, joint sawing, milling, overlay placement		International Grooving & Grinding Association (IGGA) (2009)	0.501	Ecoinvent	Diesel
	Traffic Delay					
		Fuel loss	Santero (2009)	0.459	n/a	
		User cost	RealCost	0.039	n/a	
		Work Zone Speed		0.459	n/a	
		Gas	(based on purely mathematical formula using above inputs)	0.017	Ecoinvent: (divided by amount of fuel used) (Operation, passenger car, petrol, fleet average 2010/RER U)	Gas: 6.073 lb/gal
		Diesel	(based on purely mathematical formula using above inputs)	0.017	Ecoinvent: (divided by amount of fuel used) (Operation, lorry >16t, fleet average/RER U)	Diesel: 6.943 lb/gal
	Landfilling			0.127	Ecoinvent	Half of all recovered waste is landfilled
	Crushing/recycling concrete		Stripple 2001	0.327	Ecoinvent	Energy required to crush aggregate
	Excavation		IVL (2001)	0.340	Ecoinvent	

2.2 Cement LCA Inputs and Assumptions

Cement LCA Inputs	Impact Data (Base Case) Source	Key Assumptions
	Energy	
Gasoline	USLCI – Gasoline combusted in equipment/US	Impact Uncertainty: Ecoinvent – Heat production, light fuel oil, at industrial furnace 1MW/RER
Middle Distillates	USLCI – Diesel, combusted in industrial boiler/US	Impact Uncertainty: Ecoinvent – Heat production, light fuel oil, at industrial furnace 1MW/RER
Coal	USLCI – Bituminous coal, combusted in industrial boiler/US	Impact Uncertainty: Ecoinvent – Heat, at hard coal industrial furnace 1-10MW/RER U
Residual Oil	USLCI – Residual fuel oil, combusted in industrial boiler/US	Impact Uncertainty: Ecoinvent – heat production, heavy fuel oil, at industrial furnace 1MW/RER
Natural Gas	USCLI – Natural gas, combusted in industrial boiler/US	Impact Uncertainty: Ecoinvent – heat production, natural gas, at boiler >100kW
Petroleum Coke	Converted from coal http://www.epa.gov/climateleadership/documents/emission-factors.pdf	Density: 55 lb/ft3 Impact Uncertainty: Ecoinvent – Heat, at hard coal industrial furnace 1-10MW/RER U
LPG	USLCI – Liquefied petroleum gas, combusted in industrial boiler/US	Impact Uncertainty: Ecoinvent – heat production, natural gas, at boiler >100kW
Electricity	Ecoinvent – Electricity, high voltage {US}| production mix	Impact Uncertainty: Ecoinvent – Electricity, high voltage {US}| production mix
Waste Oil	Treated as zero-impact contributor	
Tire Derived	Treated as zero-impact contributor	
Wood	Treated as zero-impact contributor	
Transportation		
Conveyer	unavailable	Neglected from total (minimal amount used)
Pipeline	Ecoinvent – natural gas, pipeline, long distance/RER	
Cement LCA Inputs	**Impact Data (Base Case) Source**	**Key Assumptions**
Truck	Ecoinvent – lorry 3.5-16t, fleet average	
Cement LCA Inputs	**Impact Data (Base Case) Source**	**Key Assumptions**

Rail	Ecoinvent – freight rail, diesel, US	
Barge	Ecoinvent – barge tanker/RER	
Ship	Ecoinvent – transoceanic freight ship	
Materials		
Limestone	USLCI – Limestone, at mine/US	Impact Uncertainty: Ecoinvent – Limestone, crushed, washed {CH}| production
Cement Rock	USLCI – Limestone, at mine/US	Similar to limestone
Shale	Ecoinvent – Gravel, crushed {CH}| production	
Clay	Ecoinvent – Clay, at mine/CH	
Sand	Ecoinvent – Silica sand {CH}| production	
Fly Ash	unavailable	Neglected from total (minimal amount used)
Bottom Ash/Slag	unavailable	Neglected from total (minimal amount used)
Blast Furnace Slag	Ecoinvent – Ground granulated blast furnace slag {US}| production	
Iron/Iron Ore	Ecoinvent – Iron mine operation, crude ore, 46% Fe/CH	
Steel Slag	unavailable	Neglected from total (minimal amount used)
Foundry Sand	Ecoinvent – Silica sand {CH}| production	
Blast Sand	Ecoinvent – Silica sand {CH}| production	
Gypsum	Ecoinvent – Gypsum, mineral {CH}| gypsum quarry operation	
Bauxite	Ecoinvent – Bauxite, at mine/GLO	
Calcination	IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, 2006	Based on clinker production data

2.3 LCA Model Description – Equations and Assumptions

The following sections detail how the LCA model and its submodels were formulated. The scope of our pavement LCA model is presented in Figure 1.

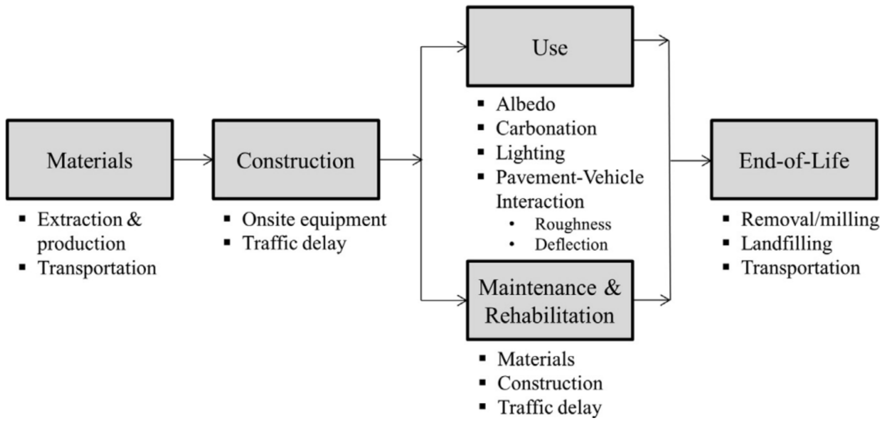

Figure 1: Scope and boundary of pavement LCA

2.3.1 Materials

The models for calculating the impacts associated with materials are simple and straight forward. Based on the input data provided by the pavement design firms and various data sources, The CO_2e emissions can be simply calculated as the sum of the impacts of all materials used:

$$GWP_{materials} = \sum_i Quantity \times Impact\_Factor$$

where i represents various materials for pavement.

2.3.2 Construction

Construction phase of pavements involves a series activities which require energy consumptions by equipment. The major construction activities considered in this analysis include: concrete mixing and layer placement, asphalt mixing and paving. The GWP of the construction phase can be calculated in the following equation:

$$GWP_{construction} = \sum construction\ fuel\ consumption_{diesel/gas} \times Impact\_Factor_{diesel/gas}$$

2.3.3 Use

The use phase submodels are more complicated than materials and construction, which includes quantification of impacts from roughness-induced pavement-vehicle interaction (PVI), deflection-derived PVI, albedo, carbonation and lighting.

Pavement-vehicle interaction (PVI) accounts for the excess fuel consumption in the vehicles as a result of the changes in the structural and surface characteristics of pavements. Two major sources of

PVI considered in this study are fuel losses due to changes in roughness and fuel losses due to deflection of the pavement. Both effects are quantified using submodels outlined in Figure 2.

Pavement roughness (also referred to as smoothness) is characterized by the international roughness index (IRI), in terms of the accumulated vertical displacements per distance traveled of a vehicle, with units of inches/mile or m/km. The progression of IRI over time is extracted from output of the pavement design software, Pavement-ME, which implements the calculations specified by the Mechanistic-Empirical Pavement Design Guide (MEPDG). Pavement maintenance and rehabilitation treatments can reduce pavement roughness, and therefore lower fuel use and GHG emissions. The progressive change in the roughness relative to its value at initial construction is calculated and translated to the extra fuel consumption using the empirical model presented by Zaabar and Chatti. Equation below shows the simplified expression of the emission from roughness induced PVI:

$$GWP_{IRI} = \sum_{t=1}^{T} \Delta IRI_t \times (\Delta AADTT_t \times K_{fc_{truck}} \times EF_{diesel} + \Delta AADT_t \times K_{fc_{car}} \times EF_{gas}) \times t$$

where ΔIRI_t is the change in IRI within time interval t, $\Delta AADTT_t$ and $\Delta AADT_t$ are truck and car traffic during t, $K_{fc_{truck}}$ and $K_{fc_{car}}$ are the coefficients that translates ΔIRI into fuel consumption derived from Zaaba and Chatti's calibration of HDM-4 model, and EF_{diesel}, EF_{gas} are the GWP emission factors for diesel and gas.

Pavement deflection has two major effects. Firstly, it creates a change in the geometry of the pavement, resulting in curvature in the pavement surface that increases fuel consumption. Secondly, energy dissipates in the pavement structure due to the viscoelastic nature of asphaltic materials. Both effects have been studies by Akbarian et al. at MIT, and mechanistic models have been developed to quantify fuel losses associated with them. The first generation of the MIT deflection model (Gen I) is a first-order understanding of the effect of structural and material properties on fuel consumption. The second generation of the model (Gen II) accounts for the energy dissipation due to viscoelasticity, which is affected by temperature, vehicle speed and traffic loadings. Current pavement LCA model adopted in this study implements the Gen I of the deflection model. Gen II of the model is subject to further validation before its implementation in the LCA model. Additional fuel loss due to deflection calculated from the MIT deflection model (Gen I) can then be translated to GWP as shown in the equation below:

$$GWP_{DEF} = \sum_{t=1}^{T} f_{truck}(E,k,h)_t \times \Delta AADTT_t \times EF_{diesel} + f_{car}(E,k,h)_t \times \Delta AADT_t \times EF_{gas}) \times t$$

where $f_{truck}(E,k,h)_t$ and $f_{car}(E,k,h)_t$ are fuel consumptions for trucks and cars in time t as functions of elastic modulus E, subgrade modulus k and pavement thickness h, calculated from MIT deflection model.

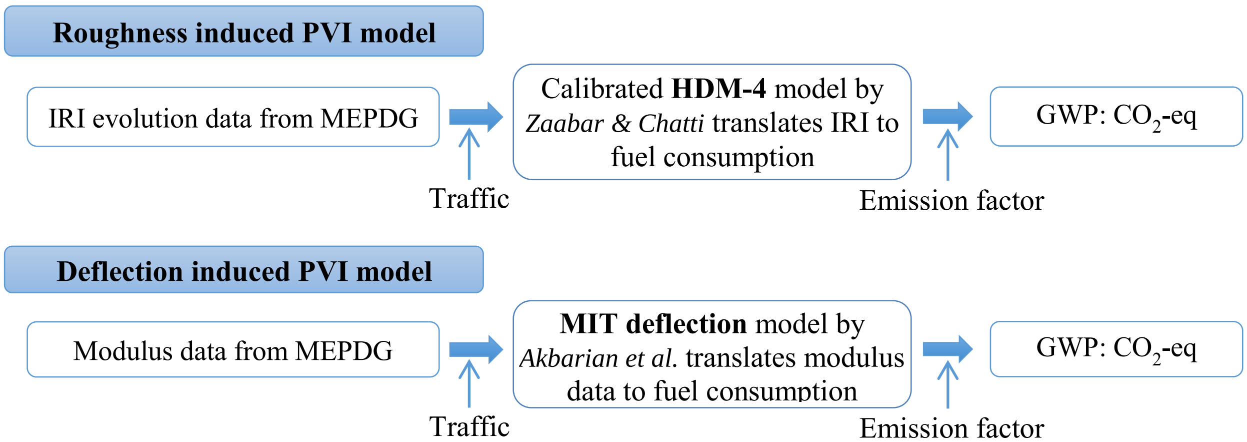

Figure 2 Submodels for Calculating Additional Fuel Consumption Due to Pavement Deterioration

Albedo accounts for the effect of solar reflectance of a pavement on the global warming potential. Two major effects associated with albedo are radiative forcing and urban heat island. Radiative forcing accounts for the direct reflectance of the incoming solar radiation, while urban heat island indirectly contributes to global warming by increasing the ambient temperature and the energy demand for cooling devices.

The carbon dioxide-equivalent offset attributed to the reflectivity of the pavements can be estimated based on the work of Akbari et al. The model uses an offset rate of 2.55 kg CO_2-eq/m^2 due to increased radiative forcing, and an offset of 4.85 g CO_2-eq/m^2 per year due to decreased electricity consumption for every 0.01 increase of albedo. The albedo of a pavement is characterized by a dimensionless number, which varies from 0 (fully absorbent) to 1 (fully reflective). The estimation of offset also requires a baseline value of reflectivity with respect to which an equivalent carbon dioxide quantity is calculated. In this work we set the baseline value to 0.33, which roughly represents the average reflectivity of the earth. Quantitative information on the evolution of pavement albedo over time is not available and thus, ranges of 0.25-0.4 are used for concrete pavements and 0.05-0.2 are used for asphalt pavements in the probabilistic analysis, where in each run of the 10,000 simulations a constant value is selected randomly from the range to represent the average pavement albedo over the entire analysis period. The CO_2 offsets due to radiative forcing and urban heat island are calculated using the following equations:

$$m_{CO_2,RF} = \frac{\Delta\alpha}{0.01} \times A \times Ef_{RF}$$

$$m_{CO_2,UHI} = \frac{\Delta\alpha}{0.01} \times A \times Ef_{UHI} \times t$$

where $\Delta\alpha$ is the change in albedo calculated with reference to a baseline albedo 0.33, A is the surface area of the pavement, Ef_{RF} is a one-time offset of CO_2 emissions per 0.01 change in albedo over the life of pavement, Ef_{UHI} is an annual CO_2 emission per 0.01change in albedo, and t is the analysis period.

Carbonation is the process by which a portion of carbon dioxide, which was originally liberated from the limestone during calcination, rebinds itself to the cement in the pavement. The process of carbonation is complex and depends on various factors. In particular, the rate of carbonation is difficult to determine, varied by the chemical composition of the concrete, its structural dimensions, and the ambient environment. Lagerblad presented a simple model for quantifying the carbonation of concrete, based on Fick's second law of diffusion. In our model, Lagerblad's model is used to account for carbon dioxide offset due to concrete carbonation during the service life of pavements. The mass of CO_2 sequestered through carbonation is given by equations below:

$$m_{CO_2,carb} = d_c \times A \times \rho_{concrete} \times m_{cement/concrete} \times m_{CaO/cement} \times \frac{M_{CO_2}}{M_{CaO}} \times \varepsilon$$

$$d_c = k\sqrt{t}$$

where d_c is depth of carbonation, k is the rate factor and t is time duration, A is surface area of pavement, $\rho_{concrete}$ is density of concrete, $m_{cement/concrete}$ is the mass ratio of cement in concrete, and $m_{CaO/cement}$ is the mass ratio of CaO in cement, $M_{CO_2}$and M_{CaO} is the molar mass of CO_2 (44 g/mol) and CaO (56 g/mol), and ε is binding efficiency of CO_2 to CaO.

Lighting accounts for the associated energy demand required to adequately illuminate the roadways. The electricity required for lighting varies based on the properties of the surface material, land use of surrounding areas and roadway classification. The requirements are often specified by state DOTs for different pavement types. The CO_2-eq emissions from lighting is calculated by the following equation:

$$m_{CO_2-eq} = \frac{r \times A \times t \times Ef_E}{\varepsilon}$$

where r is the lighting requirement recommended by AASHTO standards, *A* is the surface area of pavement, t is the total usage time, Ef_E is the CO_2 emission factor for electricity and ε is the lighting technology efficacy. More supporting information about the calculation of lighting can be found in Santero & Horvath.

2.3.4 Maintenance and Rehabilitation (M&R)

Emissions from M&R phase come from both materials production and construction energy. Onsite activities include diamond grinding, joint sawing, milling, overlay placement, etc. The calculations follow the same equations as presented in 2.3.1 and 2.3.2.

2.3.5 End-of-Life

End-of-Life phase includes the removal and landfilling of the demolished pavements. Current model doesn't account for recycling and re-use of the pavement materials. The equations for calculating the emissions from excavation and milling also apply here.

$$GWP_{EOL} = \sum EOL\ fuel\ consumption_{diesel/gas} \times Impact\_Factor_{diesel/gas}$$

2.3.6 Transportation

Transportation energy is required in the material production phase to transport the materials from the production plants to the pavement site, and transport the end-of-life materials to the landfill. Transportation mode and average transportation distance are estimated from PCA surveys.

$$GWP_{Transport} = \sum Transport\ fuel\ consumption_{diesel/gas} \times Impact\_Factor_{diesel/gas}$$

2.4 LCA Data Validation Sources

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3 Life Cycle Cost Analysis Cost Inputs – Data Sources and Equations

Unit-cost characterization is based upon historical bid data collected from each state using the Oman Bid Systems Database. Characterization has been carried out through a regression analysis between cost and quantity, and if there is no significant relationship, a best-fit distribution is used instead. Time-series model forecasts have been developed implementing various econometric models for data available from the Bureau of Labor Statistics (BLS) and the United States Geological Service (USGS).

3.1 Missouri Relevant Cost Data

Input	Units	R^2	Regression Equation *Ln(P)=a*Ln(Q)+b*	Best-fit Log-Normal Distribution
Initial Concrete Design				
JPCP	Cubic Yards	0.70	a = -0.15 (0.0076) b = 6.19 (0.052)	N/A
Type 5 Aggregate Base	Cubic Yards	0.49	a = -0.17 (0.014) b = 5.02 (0.091)	N/A
Initial Asphalt Design				
Surface Mixture SP125 (PG 76-22 Binder)	Tons	0.49	a = -0.11(0.017) b = 5.49 (0.15)	N/A
Surface Mixture (PG 70-22 Binder)	Tons	0.65	a = -0.16(0.0086) b = 5.55 (0.07)	N/A
Surface Mixture BP1(PG 64-22 Binder)	Tons	0.62	a = -0.18 (0.0083) b = 5.50 (0.062)	N/A
Base Mixture (PG 64-22 Binder)	Tons	0.55	a = -0.16 (0.0044) b = 5.29 (0.035)	N/A
Type 5 Aggregate Base	Cubic Yards	0.49	a = -0.17 (0.014) b = 5.02 (0.091)	N/A
Placing Rock Base	Cubic Yards	0.38	a = -0.26 (0.086) b = 4.44 (0.70)	N/A
Maintenance Specific Input Parameters				
Diamond Grinding	Square Yards	0.78	a = -0.33 (0.034) b = 3.50 (0.33)	N/A
Cold Milling	Square Yards	0.70	a = -0.39 (0.013) b = 4.27 (0.12)	N/A
Patching - Additional Material	Cubic Yards	0.53	a = -0.38 (0.070) b = 7.30 (0.20)	N/A
Patching – Removal of Material	Cubic Yards	N/A	N/A	Mean = 4.65 St. Dev. = 0.93

3.2 Colorado Relevant Input Data

Input	Units	R^2	Regression Equation *Ln(P)=a*Ln(Q)+b*	Best-fit Log-Normal Distribution
Initial Concrete Design				
JPCP	Cubic Yards	0.44	a = -0.13 (0.015) b = 6.15 (0.098)	N/A
Type 6 Aggregate Base	Cubic Yards	0.42	a = -0.17 (0.023) b = 4.65 (0.15)	N/A
Initial Asphalt Design				
Surface Mixture SX (PG 64-28)	Tons	0.22	a = -0.22(0.059) b = 6.35 (0.47)	N/A
Surface Mixture (PG 76-28)	Tons	0.57	a = -0.35(0.045) b = 7.36 (0.352)	N/A
Binder Mixture SX – 100 (PG 76-28)	Tons	0.56	a = -0.17 (0.026) b = 5.70 (0.21)	N/A
Base Mixture S-100 (PG 64-22)	Tons	0.29	a = -0.09 (0.030) b = 4.83 (0.23)	N/A
Type 6 Aggregate Base	Cubic Yards	0.42	a = -0.17 (0.023) b = 4.65 (0.15)	N/A
Maintenance Specific Input Parameters				
Diamond Grinding	Square Yards	0.38	a = -0.33 (0.034) b = 5.07 (0.33)	Mean = 2.08 St. Dev. = 0.89
Cold Milling	Square Yards	0.56	a = -0.33 (0.026) b = 4.00 (0.21)	Mean = 1.97 St. Dev. = 0.70
Patching	Cubic Yards	0.38	a = -0.83 (0.43) b = 8.60 (0.43)	N/A

3.3 Arizona Relevant Input Data

Input	Units	R^2	Regression Equation *Ln(P)=a*Ln(Q)+b*	Best-fit Log-Normal Distribution
Initial Concrete Design				
JPCP	Cubic Yards	0.70	a = -0.16 (0.020) b = 6.16 (0.13)	N/A
Base Course	Cubic Yards	0.44	a = -0.18 (0.017) b = 5.00 (0.12)	N/A
Initial Asphalt Design				
Asphalt Concrete ¾" mixture	Tons	0.38	a = -0.14(0.021) b = 4.89 (0.22)	N/A
Asphalt Concrete – Asphalt Rubber	Tons	0.30	a = -0.14(0.028) b = 4.72 (0.24)	N/A
Base Course	Cubic Yards	0.44	a = -0.18 (0.017) b = 5.00 (0.12)	N/A
Maintenance Specific Input Parameters				
Diamond Grinding	Square Yards	0.56	a = -0.33 (0.026) b = 4.00 (0.21)	Mean = 2.58 St. Dev. = 0.75
Cold Milling	Square Yards	0.56	a = -0.33 (0.026) b = 4.00 (0.21)	N/A
Patching	Cubic Yards	N/A	N/A	Mean = 4.28 St. Dev. = 0.73

3.4 Florida Relevant Input Data

Input	Units	R^2	Regression Equation *Ln(P)=a*Ln(Q)+b*	Best-fit Log-Normal Distribution
Initial Concrete Design				
JPCP	Cubic Yards	0.79	a = -0.11 (0.039) b = 6.14 (0.30)	N/A
Aggregate Base	Cubic Yards	0.56	a = -0.39 (0.038) b = 5.61 (0.29)	N/A
Initial Asphalt Design				
Asphalt Superpave Class E (PG 76-22)	Tons	0.71	a = -0.18 (0.039) b = 6.22 (0.36)	N/A
Asphalt Superpave Class D	Tons	0.46	a = -0.14 (0.030) b = 5.76 (0.25)	N/A
Aggregate Base	Cubic Yards	0.56	a = -0.39 (0.038) b = 5.61 (0.29)	N/A
Maintenance Specific Input Parameters				
Diamond Grinding	Square Yards	0.97	a = -0.26 (0.020) b = 4.03 (0.22)	N/A
Cold Milling	Square Yards	0.40	a = -0.28 (0.017) b = 5.42 (0.11)	N/A

3.5 Time-Series Data and Equations

Data sources for the time-series forecasting are as follows:

1. BLS. Consumer Price Index. U.S. Bureau of Labor Statistics; 2012; Available from: http://www.bls.gov/cpi/home.html.

2. BLS. Ready-Mix Concrete. U.S. Bureau of Labor Statistics; 2012; Available from: http://www.bls.gov/cpi/home.html.

3. BLS. Asphalt Paving Mixture and Block Manufacturing. U.S. Bureau of Labor Statistics; 2012; Available from: http://www.bls.gov/cpi/home.html.

4. BLS. Construction Sand and Gravel Mining. U.S. Bureau of Labor Statistics; 2012; Available from: http://www.bls.gov/cpi/home.html.

5. BLS. Cement Manufacturing. U.S. Bureau of Labor Statistics; 2012; Available from: http://www.bls.gov/cpi/home.html.

6. BLS. Stone Mining and Quarrying. U.S. Bureau of Labor Statistics; 2012; Available from: http://www.bls.gov/cpi/home.html.

7. BP. Statistical Review of Energy Prices. British Petroleum; 2012.

8. Kelly TD, Matos GR. Historical Statistics for Mineral and Material Commodities in the United States - Cement. United States Geological Services; 2012.

9. Kelly TD, Matos GR. Historical Statistics for Mineral and Material Commodities in the United States – Sand & Gravel. United States Geological Services; 2012.

10. Kelly TD, Matos GR. Historical Statistics for Mineral and Material Commodities in the United States – Crushed Stone. United States Geological Services; 2012.

Time-series have been forecasted by:

a) Estimating a long-run price equilibrium between concrete and asphalt and constituent materials
b) Forecasting each constituent material separately
c) Integrating those forecasts within the long-run price equilibrium equation

The following presents the developed equations from the analysis:

Crushed Stone: $P_t = P_{t-1}e^{(-0.0043+N(0,0.0492))}$

Cement: $P_t = 0.883P_{t-1} + 15.62 + N\ (0,9.66)$

Sand & Gravel: $P_t = 0.868P_{t-1} + 13.17 + N(0,4.82)$

Oil: $Log(P_t) = 0.278 - 0.00189t + 1.75 * 10^{-5}t^2 + 0.823Log(P_{t-1})$

$$P_{Concrete,t} = 0.484P_{Cement,t} + 0.596P_{Crushed\ Stone,t} - 3.82 + N(0,1.16)$$

$$P_{Asphalt,t} = 1.005P_{Sand\ \&\ Gravel,t} + 0.563P_{Crushed\ Stone,t} + 0.264P_{Oil,t} - 77.49 + N(0,4.68)$$

4 SUMMARY OF RESULTS FROM CELL 1 (DETAILED INFORMATION CAN BE FOUND IN SECTION 21): 20 YEAR DESIGN PERIOD, 50 YEAR ANALYSIS PERIOD

MoDOT Maintenance and Rehabilitation (M&R) Strategy:

MoDOT generally designs AC pavements for 20 years and PCC pavements for 30 years with an analysis period of 45 years. For comparison, both were designed for 20 years. The analysis was extended to a 50 year period and the most probable survival lives for rehabilitated pavements were used from the MoDOT Pavement Design Manual and were applied for the M&R strategy. Typical MoDOT M&R strategies for the pavements are presented in the following table:

Year	AC Pavement	PCC Pavement
0	New Construction	New Construction
20	1st Overlay	1st Restoration
1. 35	2nd Overlay	2nd Restoration
50	End of analysis period	End of analysis period

4.1 Site conditions:

- Rural local roadway.
- Traffic loadings: The AADTT two directions for this two lane section is low at 300 (class 4 through 13 vehicles).
- Soil support: AASHTO class is A-2-6, coarse grained soil. The mean subgrade resilient modulus is 12,000 psi (optimum moisture) as determined from backcalculation and adjustment to optimum moisture content.
- Climate: The project site is located near Rolla/Vichy, MO. The climate is wet-freeze overall. The mean precipitation is 34.9 inches, freezing index is 391.6 degree days below freezing, and there are 61 air freeze-thaw cycles per year.

4.2 SUMMARY OF RESULTS

4.2.1 Scenario 1: Wet Freeze Rural Local Roadway (MoDOT based M&R)

Design & Analysis Period

Parameter	Value	Units
Design Period	20	years
Analysis Period	50	years

Operational Context

Parameter	Value	Units
AADTT two Directions	300	vehicles/day
Number of Total Lanes-two Directions	2	
AADTT Linear Annual Increase	3%	
Climate	Wet Freeze - MO	
Soil Type	A-2-6	
Total Trucks in Design Lane (50-yr Analysis Period)	4,752,820	No. of Trucks

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting (mean both wheel paths)	0.65	in
AC bottom-up (alligator) fatigue cracking	20	Percent lane area
Total cracking (alligator + reflection) at 50% reliability (for AC overlays)	15	Percent lane area
Thermal cracking	700	ft/mi

Performance Criteria – Portland cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	20	Percent slabs
Faulting	0.25	In

Asphalt Concrete MoDOT M&R Schedule

Year	Activity
New construction	Place 5.75 in. AC over 4 in. crushed stone base material
20	Mill 1.75 in. of existing pavement and replace with 1.75 in. AC Overlay (patching of 4.16% lane area is required in the travel lane)
35	Mill 1.75 in. of existing pavement and replace with 1.75 in. AC Overlay (patching of 8.37% lane area is required in the travel lane)
50	End of analysis period

Portland cement Concrete MoDOT M&R Schedule

Year	Activity
New construction	Place 7.5 in. PCC (with 1 in diameter dowel) over 4 in. crushed stone material
20	¼ inch diamond grinding and full depth repair (1.5% slab replacement is required in the travel lane)
35	¼ inch diamond grinding and full depth repair (1.5% slab replacement is required in the travel lane)
50	End of analysis period

4.2.2 Scenario 2: Wet Freeze Rural Local Roadway (DARWin-ME based M&R)

Analysis Period

Parameter	Value	Units
Design Period	20	years
Analysis Period	50	years

Operational Context

Parameter	Value	Units
AADTT two Directions	300	vehicles/day
Number of Total Lanes	2	
AADTT Linear Annual Increase	3%	
Climate	Wet Freeze - MO	
Soil Type	A-2-6	

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting	0.65	in
AC bottom-up (alligator) fatigue cracking	20	Percent lane area
Total cracking (alligator + reflection) at 50% reliability (for AC overlays)	15	Percent lane area
Thermal cracking	700	ft/mi

Performance Criteria – Portland Cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	20	percent
Faulting	0.25	in

Asphalt Concrete DARWin -ME M&R Schedule

Year	Activity
New construction	Place 5.75 in. AC over 4 in. crushed stone base material
20	Mill 1.75 in. of existing pavement and replace with 1.75 in. AC Overlay (patching of 4.16% lane area is required in the travel lane)
37	Mill 1.75 in. of existing pavement and replace with 1.75 in. AC Overlay (patching of 9.15% lane area is required in the travel lane)
Salvage at 50	2 years

Portland Cement Concrete DARWin-ME M&R Schedule

Year	Activity
New construction	Place 7.5 in. PCC (with 1 in diameter dowel) over 4 in. crushed stone material
20	¼ inch diamond grinding and full depth repair (slab replacement of 1.59% is required in the travel lane)
40	Full depth repair (slab replacement of 10.45% is required in the travel lane)
Salvage at 50	3 years

5 SUMMARY OF RESULTS FROM CELL 2 (DETAILED INFORMATION CAN BE FOUND IN SECTION 22): 30 YEAR DESIGN PERIOD, 50 YEAR ANALYSIS PERIOD

MoDOT Maintenance and Rehabilitation (M&R) Strategy:

MoDOT generally designs AC pavements for 20 years and PCC pavements for 30 years with analysis period of 45 years. For comparison, both were designed for 30 years. The analysis was extended to 50 year period and the most probable survival lives for rehabilitated pavements were used from MoDOT Pavement Design Manual and were applied for the M&R strategy. A typical MoDOT M&R strategy for pavements are presented in the following table:

Year	AC Pavement	PCC Pavement
0	New Construction	New Construction
20	1st Overlay	-
25	-	1st Restoration
35	2nd Overlay	-
50	End of analysis period	End of analysis period

5.1 Site conditions:

- Rural local roadway.
- Traffic loadings: The AADTT two directions for this section is low at 300 (class 4 through 13 vehicles).
- Soil support: AASHTO class is A-2-6, coarse grained soil. The mean subgrade resilient modulus is 12,000 psi (optimum moisture) as determined from backcalculation and adjustment to optimum moisture content.
- Climate: The project site is located near Rolla/Vichy, MO. The climate is wet-freeze overall. The mean precipitation is 34.9 inches, freezing index is 391.6 degree days below freezing, and there are 61 air freeze-thaw cycles per year.

5.2 SUMMARY OF RESULTS

5.2.1 Scenario 1: Wet Freeze Rural Local Roadway (MoDOT based M&R)

Design & Analysis Period

Parameter	Value	Units
Design Period	30	years
Analysis Period	50	years

Operational Context

Parameter	Value	Units
AADTT two Directions	300	vehicles/day
Number of Total Lanes-two Directions	2	
AADTT Linear Annual Increase	3%	
Climate	Wet Freeze - MO	
Soil Type	A-2-6	
Total Trucks in Design Lane (50-yr Analysis Period)	4,752,820	No. of Trucks

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting (mean both wheel paths)	0.65	in
AC bottom-up (alligator) fatigue cracking	20	Percent lane area
Total cracking (alligator + reflection) at 50% reliability (for AC overlays)	15	Percent lane area
Thermal cracking	700	ft/mi

Performance Criteria – Portland Cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	20	Percent slabs
Faulting	0.25	In

Asphalt Concrete MoDOT M&R Schedule

Year	Activity
New construction	Place 5.75 in. AC over 4 in. crushed stone base material
20	Mill 1.75 in. of existing pavement and replace with 1.75 in. AC Overlay (patching of 4.16% lane area is required in the travel lane)
35	Mill 1.75 in. of existing pavement and replace with 1.75 in. AC Overlay (patching of 8.37% lane area is required in the travel lane)
50	End of analysis period

Portland Cement Concrete MoDOT M&R Schedule

Year	Activity
New construction	Place 7.5 in. PCC (with 1 in diameter dowel) over 4 in. crushed stone material
25	¼ inch diamond grinding and full depth repair (1.5% slab replacement is required in the travel lane)
50	End of analysis period

5.2.2 Scenario 2: Wet Freeze Rural Local Roadway (DARWin-ME based M&R)

Analysis Period

Parameter	Value	Units
Design Period	30	years
Analysis Period	50	years

Operational Context

Parameter	Value	Units
AADTT two Directions	300	vehicles/day
Number of Total Lanes	2	
AADTT Linear Annual Increase	3%	
Climate	Wet Freeze - MO	
Soil Type	A-2-6	

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting	0.65	in
AC bottom-up (alligator) fatigue cracking	20	Percent lane area
Total cracking (alligator + reflection) at 50% reliability (for AC overlays)	15	Percent lane area
Thermal cracking	700	ft/mi

Performance Criteria – Portland Cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	20	percent
Faulting	0.25	in

Asphalt Concrete DARWin -ME M&R Schedule

Year	Activity
New construction	Place 5.75 in. AC over 4 in. crushed stone base material
20	Mill 1.75 in. of existing pavement and replace with 1.75 in. AC Overlay (patching of 4.16% lane area is required in the travel lane)
37	Mill 1.75 in. of existing pavement and replace with 1.75 in. AC Overlay (patching of 9.15% lane area is required in the travel lane)
Salvage at 50	2 years

Portland Cement Concrete DARWin-ME M&R Schedule

Year	Activity
New construction	Place 7.5 in. PCC (with 1 in diameter dowel) over 4 in. crushed stone material
30	Full depth repair (slab replacement of 3.76% is required in the travel lane)
Salvage at 50	2 years

6 SUMMARY OF RESULTS FROM CELL 3 (DETAILED INFORMATION CAN BE FOUND IN SECTION 23): 20 YEAR DESIGN PERIOD, 50 YEAR ANALYSIS PERIOD

MoDOT Maintenance and Rehabilitation (M&R) Strategy:

MoDOT generally designs AC pavements for 20 years and PCC pavements for 30 years with analysis period of 45 years. For comparison, both were designed for 20 years. The analysis was extended to 50-year period and the most probable survival lives for rehabilitated pavements were used from MoDOT Pavement Design Manual and were applied for the M&R strategy. A typical MoDOT M&R strategy for pavements are presented in the following table:

Year	AC Pavement	PCC Pavement
0	New Construction	New Construction
20	1st Overlay	1st Restoration
35	2nd Overlay	2nd Restoration
50	End of analysis period	End of analysis period

6.1 Site conditions:

- Rural state highway
- Traffic loadings: The AADTT two directions for this section is low at 1000 (class 4 through 13 vehicles).
- Soil support: AASHTO class is A-7-6, coarse grained soil. The mean subgrade resilient modulus is 13,000 psi (optimum moisture) as determined from backcalculation and adjustment to optimum moisture content.
- Climate: The project site is located near St. Louis, MO. The climate is wet-freeze overall. The mean precipitation is 37.56 inches, freezing index is 330.25 degree days below freezing, and there are 47.77 air freeze-thaw cycles per year.

6.2 SUMMARY OF RESULTS

6.2.1 Scenario 1: Wet Freeze Rural State Highway (MoDOT based M&R)

Design & Analysis Period

Parameter	Value	Units
Design Period	20	years
Analysis Period	50	years

Operational Context

Parameter	Value	Units
AADTT two Directions	1000	vehicles/day
Number of Total Lanes-two Directions	4	
AADTT Linear Annual Increase	3%	
Climate	Wet Freeze - MO	
Soil Type	A-7-6	
Total Trucks in Design Lane (50-yr Analysis Period)	14,258,400	No. of Trucks

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting (mean both wheel paths)	0.5	In
AC bottom-up (alligator) fatigue cracking	15	Percent lane area
Total cracking (alligator + reflection) at 50% reliability (for AC overlays)	10	Percent lane area
Thermal cracking	700	ft/mi

Performance Criteria – Portland Cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	15	Percent slabs
Faulting	0.20	In

Asphalt Concrete MoDOT M&R Schedule

Year	Activity
New Construction	Place 7 in. AC over 6 in. crushed stone base material
20	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 2.29% lane area is required in the travel lane)
35	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 4.56% lane area is required in the travel lane)
50	End of analysis period

Portland Cement Concrete MoDOT M&R Schedule

Year	Activity
New construction	Place 8 in. PCC (with 1.25 in diameter dowel) over 4 in. crushed stone material
20	¼ inch diamond grinding and full depth repair (1.5% slab replacement is required in the travel lane)
35	¼ inch diamond grinding and full depth repair (1.5% slab replacement is required in the travel lane)
50	End of analysis period

6.2.2 Scenario 2: Wet Freeze Rural State Highway (DARWin-ME based M&R)

Analysis Period

Parameter	Value	Units
Design Period	20	years
Analysis Period	50	years

Operational Context

Parameter	Value	Units
AADTT two Directions	1000	vehicles/day
Number of Total Lanes	4	
AADTT Linear Annual Increase	3%	
Climate	Wet Freeze - MO	
Soil Type	A-7-6	

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting	0.5	in
AC bottom-up (alligator) fatigue cracking	15	Percent lane area
Total cracking (alligator + reflection) at 50% reliability (for AC overlays)	10	Percent lane area
Thermal cracking	700	ft/mi

Performance Criteria – Portland Cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	15	percent
Faulting	0.20	in

Asphalt Concrete DARWin -ME M&R Schedule

Year	Activity
New Construction	Place 7 in. AC over 6 in. crushed stone base material
20	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 2.29% lane area is required in the travel lane)
37	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 4.99% lane area is required in the travel lane)
Salvage at 50	4 years

Portland Cement Concrete DARWin-ME M&R Schedule

Year	Activity
New construction	Place 8 in. PCC (with 1.25 in diameter dowel) over 4 in. crushed stone material
20	¼ inch diamond grinding and full depth repair (slab replacement of 0.41% is required in the travel lane)
40	¼ inch diamond grinding and full depth repair (slab replacement of 2.23% is required in the travel lane)
Salvage at 50	4 years

7 SUMMARY OF RESULTS FROM CELL 4 (DETAILED INFORMATION CAN BE FOUND IN SECTION 24): 30 YEAR DESIGN PERIOD, 50 YEAR ANALYSIS PERIOD

MoDOT Maintenance and Rehabilitation (M&R) Strategy:

MoDOT generally designs AC pavements for 20 years and PCC pavements for 30 years with analysis period of 45 years. For comparison, both were designed for 30 years. The analysis was extended to 50-year period and the most probable survival lives for rehabilitated pavements were used from MoDOT Pavement Design Manual and were applied for the M&R strategy. A typical MoDOT M&R strategy for pavements are presented in the following table:

Year	AC Pavement	PCC Pavement
0	New Construction	New Construction
20	1st Overlay	-
25	-	1st Restoration
35	2nd Overlay	-
50	End of analysis period	End of analysis period

7.1 Site conditions:

- Rural state highway
- Traffic loadings: The AADTT two directions for this section is low at 1000 (class 4 through 13 vehicles).
- Soil support: AASHTO class is A-7-6, coarse grained soil. The mean subgrade resilient modulus is 13,000 psi (optimum moisture) as determined from backcalculation and adjustment to optimum moisture content.
- Climate: The project site is located near St. Louis, MO. The climate is wet-freeze overall. The mean precipitation is 37.56 inches, freezing index is 330.25 degree days below freezing, and there are 47.77 air freeze-thaw cycles per year.

7.2 SUMMARY OF RESULTS

7.2.1 Scenario 1: Wet Freeze Rural State Highway (MoDOT based M&R)

Design & Analysis Period

Parameter	Value	Units
Design Period	30	years
Analysis Period	50	years

Operational Context

Parameter	Value	Units
AADTT two Directions	1000	vehicles/day
Number of Total Lanes-two Directions	4	
AADTT Linear Annual Increase	3%	
Climate	Wet Freeze - MO	
Soil Type	A-7-6	
Total Trucks in Design Lane (50-yr Analysis Period)	14,258,400	No. of Trucks

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting (mean both wheel paths)	0.5	In
AC bottom-up (alligator) fatigue cracking	15	Percent lane area
Total cracking (alligator + reflection) at 50% reliability (for AC overlays)	10	Percent lane area
Thermal cracking	700	ft/mi

Performance Criteria – Portland Cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	15	Percent slabs
Faulting	0.20	In

Asphalt Concrete MoDOT M&R Schedule

Year	Activity
New Construction	Place 7.5 in. AC over 6 in. crushed stone base material
20	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 1.6% lane area is required in the travel lane)
35	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 3.17% lane area is required in the travel lane)
50	End of analysis period

Portland Cement Concrete MoDOT M&R Schedule

Year	Activity
New construction	Place 8 in. PCC (with 1.25 in diameter dowel) over 4 in. crushed stone material
20	¼ inch diamond grinding and full depth repair (1.5% slab replacement is required in the travel lane)
35	¼ inch diamond grinding and full depth repair (1.5% slab replacement is required in the travel lane)
50	End of analysis period

7.2.2 Scenario 2: Wet Freeze Rural State Highway (DARWin-ME based M&R)

Analysis Period

Parameter	Value	Units
Design Period	30	years
Analysis Period	50	years

Operational Context

Parameter	Value	Units
AADTT two Directions	1000	vehicles/day
Number of Total Lanes	4	
AADTT Linear Annual Increase	3%	
Climate	Wet Freeze - MO	
Soil Type	A-7-6	

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting	0.5	in
AC bottom-up (alligator) fatigue cracking	15	Percent lane area
Total cracking (alligator + reflection) at 50% reliability (for AC overlays)	10	Percent lane area
Thermal cracking	700	ft/mi

Performance Criteria – Portland Cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	15	percent
Faulting	0.20	in

Asphalt Concrete DARWin -ME M&R Schedule

Year	Activity
New Construction	Place 7.5 in. AC over 6 in. crushed stone base material
20	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 1.6% lane area is required in the travel lane)
37	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 3.47% lane area is required in the travel lane)
Salvage at 50	4 years

Portland Cement Concrete DARWin-ME M&R Schedule

Year	Activity
New construction	Place 8 in. PCC (with 1.25 in diameter dowel) over 4 in. crushed stone material
30	¼ inch diamond grinding and full depth repair (slab replacement of 0.77% is required in the travel lane)
Salvage at 50	5 years

8 SUMMARY OF RESULTS FROM CELL 5 (DETAILED INFORMATION CAN BE FOUND IN SECTION 25): 40 YEAR DESIGN PERIOD, 50 YEAR ANALYSIS PERIOD

MoDOT Maintenance and Rehabilitation (M&R) Strategy:

MoDOT generally designs AC pavements for 20 years and PCC pavements for 30 years with analysis period of 45 years. For comparison, both were designed for 40 years. The analysis was extended to 50-year period and the most probable survival lives for rehabilitated pavements were used from MoDOT Pavement Design Manual and were applied for the M&R strategy. A typical MoDOT M&R strategy for pavements are presented in the following table:

Year	AC Pavement	PCC Pavement
0	New Construction	New Construction
20	1st Overlay	-
25	-	1st Restoration
35	2nd Overlay	-
50	End of analysis period	End of analysis period

8.1 Site conditions:

- Rural state highway
- Traffic loadings: The AADTT two directions for this section is low at 1000 (class 4 through 13 vehicles).
- Soil support: AASHTO class is A-7-6, coarse grained soil. The mean subgrade resilient modulus is 13,000 psi (optimum moisture) as determined from backcalculation and adjustment to optimum moisture content.
- Climate: The project site is located near St. Louis, MO. The climate is wet-freeze overall. The mean precipitation is 37.56 inches, freezing index is 330.25 degree days below freezing, and there are 47.77 air freeze-thaw cycles per year.

8.2 SUMMARY OF RESULTS

8.2.1 Scenario 1: Wet Freeze Rural State Highway (MoDOT based M&R)

Design & Analysis Period

Parameter	Value	Units
Design Period	40	years
Analysis Period	50	years

Operational Context

Parameter	Value	Units
AADTT two Directions	1000	vehicles/day
Number of Total Lanes-two Directions	4	
AADTT Linear Annual Increase	3%	
Climate	Wet Freeze - MO	
Soil Type	A-7-6	
Total Trucks in Design Lane (50-yr Analysis Period)	14,258,400	No. of Trucks

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting (mean both wheel paths)	0.5	In
AC bottom-up (alligator) fatigue cracking	15	Percent lane area
Total cracking (alligator + reflection) at 50% reliability (for AC overlays)	10	Percent lane area
Thermal cracking	700	ft/mi

Performance Criteria – Portland Cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	15	Percent slabs
Faulting	0.20	In

Asphalt Concrete MoDOT M&R Schedule

Year	Activity
New Construction	Place 8.25 in. AC over 6 in. crushed stone base material
20	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 0.985% lane area is required in the travel lane)
35	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 1.96% lane area is required in the travel lane)
50	End of analysis period

Portland Cement Concrete MoDOT M&R Schedule

Year	Activity
New construction	Place 8 in. PCC (with 1.25 in diameter dowel) over 4 in. crushed stone material
20	¼ inch diamond grinding and full depth repair (1.5% slab replacement is required in the travel lane)
35	¼ inch diamond grinding and full depth repair (1.5% slab replacement is required in the travel lane)
50	End of analysis period

8.2.2 Scenario 2: Wet Freeze Rural State Highway (DARWin-ME based M&R)

Analysis Period

Parameter	Value	Units
Design Period	40	years
Analysis Period	50	years

Operational Context

Parameter	Value	Units
AADTT two Directions	1000	vehicles/day
Number of Total Lanes	4	
AADTT Linear Annual Increase	3%	
Climate	Wet Freeze - MO	
Soil Type	A-7-6	

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting	0.5	in
AC bottom-up (alligator) fatigue cracking	15	Percent lane area
Total cracking (alligator + reflection) at 50% reliability (for AC overlays)	10	Percent lane area
Thermal cracking	700	ft/mi

Performance Criteria – Portland Cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	15	percent
Faulting	0.20	in

Asphalt Concrete DARWin -ME M&R Schedule

Year	Activity
New Construction	Place 8.25 in. AC over 6 in. crushed stone base material
20	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 0.985% lane area is required in the travel lane)
37	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 2.15% lane area is required in the travel lane)
Salvage at 50	4 years

Portland Cement Concrete DARWin-ME M&R Schedule

Year	Activity
New construction	Place 8 in. PCC (with 1.25 in diameter dowel) over 4 in. crushed stone material
40	¼ inch diamond grinding and full depth repair (slab replacement of 1.32% is required in the travel lane)
Salvage at 50	10 years

9 SUMMARY OF RESULTS FROM CELL 6 (DETAILED INFORMATION CAN BE FOUND IN SECTION 26): 30 YEAR DESIGN PERIOD, 50 YEAR ANALYSIS PERIOD

9.1 Site conditions:

- Rural State Highway
- Traffic loadings: The AADTT two directions for this section is 1,000 (class 4 through 13 vehicles).
- Soil support: AASHTO class is A-4, fine grained soil. The mean subgrade resilient modulus is 11,454 psi (optimum moisture) as determined from backcalculation and adjustment to optimum moisture content.
- Climate: The project site is located near Phoenix, AZ. The climate is dry-no freeze overall. The mean annual precipitation is 7.4 inches, freezing index is 0 degree days below freezing, and there are 0 air freeze-thaw cycles per year.

9.2 SUMMARY OF RESULTS

9.2.1 Scenario 1: Dry No Freeze Rural State Highway (ADOT based M&R)

Design & Analysis Period

Parameter	Value	Units
Design Period	30	years
Analysis Period	50	years

Operational Context

Parameter	Value	Units
AADTT two Directions	1000	vehicles/day
Number of Total Lanes-two Directions	4	
AADTT Linear Annual Increase	3%	
Climate	Dry No Freeze – AZ	
Soil Type	A-4	
Total Trucks in Design Lane (50-yr Analysis Period)	14,258,400	No. of Trucks

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting (mean both wheel paths)	0.5	In
AC bottom-up (alligator) fatigue cracking	15	Percent lane area
Total cracking (alligator + reflection) at 50% reliability (for AC overlays)	10	Percent lane area
Thermal cracking	700	ft/mi

Performance Criteria – Portland Cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	15	Percent slabs
Faulting	0.20	In

Asphalt Concrete ADOT M&R Schedule

Year	Activity
New Construction	Place 7.5 in. AC over 4 in. crushed stone base material
15	Mill 2.5 in. of existing pavement and replace with 2.5 in. AC Overlay (patching of 0.011% lane area is required in the travel lane)
28	Mill 2.5 in. of existing pavement and replace with 2.5 in. AC Overlay (patching of 0.14% lane area is required in the travel lane)
41	Mill 2.5 in. of existing pavement and replace with 2.5 in. AC Overlay (patching of 1.18% lane area is required in the travel lane)
50	End of analysis period

Portland Cement Concrete ADOT M&R Schedule

Year	Activity
New construction	Place 8.5 in. PCC (with 1.25 in diameter dowel) over 4 in. crushed stone material
20	¼ inch diamond grinding and full depth repair (0.45% slab replacement is required in the travel lane)
40	¼ inch diamond grinding and full depth repair (3.7% slab replacement is required in the travel lane)
50	End of analysis period

9.2.2 Scenario 2: Dry No Freeze Rural State Highway (DARWin-ME based M&R)

Analysis Period

Parameter	Value	Units
Design Period	30	years
Analysis Period	50	years

Operational Context

Parameter	Value	Units
AADTT two Directions	1000	vehicles/day
Number of Total Lanes	4	
AADTT Linear Annual Increase	3%	
Climate	Dry No Freeze - AZ	
Soil Type	A-4	

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting	0.5	in
AC bottom-up (alligator) fatigue cracking	15	Percent lane area
Total cracking (alligator + reflection) at 50% reliability (for AC overlays)	10	Percent lane area
Thermal cracking	700	ft/mi

Performance Criteria – Portland Cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	15	percent
Faulting	0.20	in

Asphalt Concrete DARWin -ME M&R Schedule

Year	Activity
New Construction	Place 7.5 in. AC over 4 in. crushed stone base material
16	Mill 2.5 in. of existing pavement and replace with 2.5 in. AC Overlay (patching of 0.016% lane area is required in the travel lane)
29	Mill 2.5 in. of existing pavement and replace with 2.5 in. AC Overlay (patching of 0.18% lane area is required in the travel lane)
42	Mill 2.5 in. of existing pavement and replace with 2.5 in. AC Overlay (patching of 1.44% lane area is required in the travel lane)
Salvage at 50	5 years

Portland Cement Concrete DARWin-ME M&R Schedule

Year	Activity
New construction	Place 8.5 in. PCC (with 1.25 in diameter dowel) over 4 in. crushed stone material
30	¼ inch diamond grinding and full depth repair (slab replacement of 1.1% is required in the travel lane)
Salvage at 50	0 years

10 SUMMARY OF RESULTS FROM CELL 7 (DETAILED INFORMATION CAN BE FOUND IN SECTION 27): 30 YEAR DESIGN PERIOD, 50 YEAR ANALYSIS PERIOD

10.1 Site conditions:

- Rural State Highway
- Traffic loadings: The AADTT two directions for this section is 1,000 (class 4 through 13 vehicles).
- Soil support: AASHTO class is A-2-4, fine grained soil. The mean subgrade resilient modulus is 14,000 psi (optimum moisture) as determined from backcalculation and adjustment to optimum moisture content.
- Climate: The project site is located near Denver, CO. The climate is dry- freeze overall. The mean annual precipitation is 13.46 inches, freezing index is 559.91 degree days below freezing, and there are 71.41 air freeze-thaw cycles per year.

10.2 SUMMARY OF RESULTS

10.2.1 Scenario 1: Dry Freeze Rural State Highway (CDOT based M&R)

Design & Analysis Period

Parameter	Value	Units
Design Period	30	years
Analysis Period	50	years

Operational Context

Parameter	Value	Units
AADTT two Directions	1000	vehicles/day
Number of Total Lanes-two Directions	4	
AADTT Linear Annual Increase	3%	
Climate	Dry Freeze – CO	
Soil Type	A-2-4	
Total Trucks in Design Lane (50-yr Analysis Period)	14,258,400	No. of Trucks

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting (mean both wheel paths)	0.5	In
AC bottom-up (alligator) fatigue cracking	15	Percent lane area
Total cracking (alligator + reflection) at 50% reliability (for AC overlays)	10	Percent lane area
Thermal cracking	700	ft/mi

Performance Criteria – Portland Cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	15	Percent slabs
Faulting	0.20	In

Asphalt Concrete CDOT M&R Schedule

Year	Activity
New Construction	Place 9 in. AC over 12 in. crushed stone base material
13	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 0.008% lane area is required in the travel lane)
26	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 0.04% lane area is required in the travel lane)
38	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 0.12% lane area is required in the travel lane)
50	End of analysis period

Portland Cement Concrete CDOT M&R Schedule

Year	Activity
New construction	Place 7.5 in. PCC (with 1.0 in diameter dowel) over 4 in. crushed stone material
27	¼ inch diamond grinding and full depth repair (0.5% slab replacement is required in the travel lane)
50	End of analysis period

10.2.2 Scenario 2: Dry Freeze Rural State Highway (DARWin-ME based M&R)

Analysis Period

Parameter	Value	Units
Design Period	30	years
Analysis Period	50	years

Operational Context

Parameter	Value	Units
AADTT two Directions	1000	vehicles/day
Number of Total Lanes	4	
AADTT Linear Annual Increase	3%	
Climate	Dry Freeze - CO	
Soil Type	A-2-4	

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting	0.5	in
AC bottom-up (alligator) fatigue cracking	15	Percent lane area
Total cracking (alligator + reflection) at 50% reliability (for AC overlays)	10	Percent lane area
Thermal cracking	700	ft/mi

Performance Criteria – Portland Cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	15	percent
Faulting	0.20	In

Asphalt Concrete DARWin -ME M&R Schedule

Year	Activity
New Construction	Place 9 in. AC over 12 in. crushed stone base material
16	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 0.014% lane area is required in the travel lane)
33	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 0.09% lane area is required in the travel lane)
Salvage at 50	5 years

Portland Cement Concrete DARWin-ME M&R Schedule

Year	Activity
New construction	Place 7.5 in. PCC (with 1.0 in diameter dowel) over 4 in. crushed stone material
30	¼ inch diamond grinding and full depth repair (slab replacement of 0.27% is required in the travel lane)
Salvage at 50	5 years

11 SUMMARY OF RESULTS FROM CELL 8 (DETAILED INFORMATION CAN BE FOUND IN SECTION 29): 30 YEAR DESIGN PERIOD, 50 YEAR ANALYSIS PERIOD

11.1 Site conditions:

- Rural State Highway
- Traffic loadings: The AADTT two directions for this section is 1,000 (class 4 through 13 vehicles).
- Soil support: AASHTO class is A-2-4, fine grained soil. The mean subgrade resilient modulus is 12,000 psi (optimum moisture) as determined from backcalculation and adjustment to optimum moisture content.
- Climate: The project site is located near Gainesville, FL. The climate is wet- no freeze overall. The mean annual precipitation is 45.9 inches, freezing index is 54.2 degree days below freezing, and there are 11.8 air freeze-thaw cycles per year.

11.2 SUMMARY OF RESULTS

11.2.1 Scenario 1: Wet No Freeze Rural State Highway (FDOT based M&R)

Design & Analysis Period

Parameter	Value	Units
Design Period	30	years
Analysis Period	50	years

Operational Context

Parameter	Value	Units
AADTT two Directions	1000	vehicles/day
Number of Total Lanes-two Directions	4	
AADTT Linear Annual Increase	3%	
Climate	Wet No Freeze – FL	
Soil Type	A-2-4	
Total Trucks in Design Lane (50-yr Analysis Period)	14,258,400	No. of Trucks

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting (mean both wheel paths)	0.5	In
AC bottom-up (alligator) fatigue cracking	15	Percent lane area
Total cracking (alligator + reflection) at 50% reliability (for AC overlays)	10	Percent lane area
Thermal cracking	700	ft/mi

Performance Criteria – Portland Cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	15	Percent slabs
Faulting	0.20	In

Asphalt Concrete FDOT M&R Schedule

Year	Activity
New Construction	Place 6 in. AC over 6 in. limerock base material
14	Mill 2.5 in. of existing pavement and replace with 2.5 in. AC Overlay (patching of 0.891% lane area is required in the travel lane)
28	Mill 2.5 in. of existing pavement and replace with 2.5 in. AC Overlay (patching of 1.21% lane area is required in the travel lane)
40	Mill 2.5 in. of existing pavement and replace with 2.5 in. AC Overlay (patching of 1.58% lane area is required in the travel lane)
50	End of analysis period

Portland Cement Concrete FDOT M&R Schedule

Year	Activity
New construction	Place 9 in. PCC (with 1.25 in diameter dowel) over 6 in. limestone base material
20	¼ inch diamond grinding and full depth repair (3% slab replacement is required in the travel lane)
35	¼ inch diamond grinding and full depth repair (5% slab replacement is required in the travel lane)
50	End of analysis period

11.2.2 Scenario 2: Wet No Freeze Rural State Highway (DARWin-ME based M&R)

Analysis Period

Parameter	Value	Units
Design Period	30	years
Analysis Period	50	years

Operational Context

Parameter	Value	Units
AADTT two Directions	1000	vehicles/day
Number of Total Lanes	4	
AADTT Linear Annual Increase	3%	
Climate	Wet No Freeze – FL	
Soil Type	A-2-4	

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting	0.5	in
AC bottom-up (alligator) fatigue cracking	15	Percent lane area
Total cracking (alligator + reflection) at 50% reliability (for AC overlays)	10	Percent lane area
Thermal cracking	700	ft/mi

Performance Criteria – Portland Cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	15	percent
Faulting	0.20	In

Asphalt Concrete DARWin -ME M&R Schedule

Year	Activity
New Construction	Place 6 in. AC over 6 in. limerock base material
20	Mill 2.5 in. of existing pavement and replace with 2.5 in. AC Overlay (patching of 1.41% lane area is required in the travel lane)
37	Mill 2.5 in. of existing pavement and replace with 2.5 in. AC Overlay (patching of 1.89% lane area is required in the travel lane)
Salvage at 50	4 years

Portland Cement Concrete DARWin-ME M&R Schedule

Year	Activity
New construction	Place 9 in. PCC (with 1.25 in diameter dowel) over 6 in. limerock base material
30	¼ inch diamond grinding and full depth repair (slab replacement of 0.99% is required in the travel lane)
Salvage at 50	3 years

12 SUMMARY OF RESULTS FROM CELL 9A (DETAILED INFORMATION CAN BE FOUND IN SECTION 30): 20 YEAR DESIGN PERIOD, 30 YEAR ANALYSIS PERIOD

12.1 Site conditions:

- Urban Interstate Highway
- Traffic loadings: The AADTT two directions for this section is 8000 (class 4 through 13 vehicles).
- Soil support: AASHTO class is A-7-6, fine grained soil. The mean subgrade resilient modulus is 22,500 psi (optimum moisture) as determined from backcalculation and adjustment to optimum moisture content.
- Climate: The project site is located near Joplin, MO. The climate is wet-freeze overall. The mean precipitation is 41.01 inches, freezing index is 266.50 degree days below freezing, and there are 53.12 air freeze-thaw cycles per year.

12.2 SUMMARY OF RESULTS

12.2.1 Scenario 1: Wet Freeze Rural State Highway (MoDOT based M&R)

Design & Analysis Period

Parameter	Value	Units
Design Period	20	years
Analysis Period	30	years

Operational Context

Parameter	Value	Units
AADTT two Directions	8000	vehicles/day
Number of Total Lanes-two Directions	6	
AADTT Linear Annual Increase	3%	
Climate	Wet Freeze – MO	
Soil Type	A-7-6	
Total Trucks in Design Lane (30-yr Analysis Period)	50,316,800	No. of Trucks

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting (mean both wheel paths)	0.5	In
AC bottom-up (alligator) fatigue cracking	10	Percent lane area
Total cracking (alligator + reflection) at 50% reliability (for AC overlays)	5	Percent lane area
Thermal cracking	500	ft/mi

Performance Criteria – Portland Cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	10	Percent slabs
Faulting	0.15	In

Asphalt Concrete MoDOT M&R Schedule

Year	Activity
New Construction	Place 13.5 in. AC over 24 in. crushed stone base material
20	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 0.13% lane area is required in the travel lane)
30	End of analysis period

Portland Cement Concrete MoDOT M&R Schedule

Year	Activity
New construction	Place 10.5 in. PCC (with 1.5 in diameter dowel) over 6 in. crushed stone material
20	¼ inch diamond grinding and full depth repair (1.5% slab replacement is required in the travel lane)
30	End of analysis period

12.2.2 Scenario 2: Wet Freeze Rural State Highway (DARWin-ME based M&R)

Analysis Period

Parameter	Value	Units
Design Period	20	years
Analysis Period	30	years

Operational Context

Parameter	Value	Units
AADTT two Directions	8000	vehicles/day
Number of Total Lanes	6	
AADTT Linear Annual Increase	3%	
Climate	Wet Freeze – MO	
Soil Type	A-7-6	

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting	0.5	in
AC bottom-up (alligator) fatigue cracking	10	Percent lane area
Total cracking (alligator + reflection) at 50% reliability (for AC overlays)	5	Percent lane area
Thermal cracking	500	ft/mi

Performance Criteria – Portland Cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	10	percent
Faulting	0.15	in

Asphalt Concrete DARWin -ME M&R Schedule

Year	Activity
New Construction	Place 13.5 in. AC over 24 in. crushed stone base material
20	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 0.13% lane area is required in the travel lane)
Salvage at 30	7 years (maximum 17 years overlay life)

Portland Cement Concrete DARWin-ME M&R Schedule

Year	Activity
New construction	Place 10.5 in. PCC (with 1.5 in diameter dowel) over 6 in. crushed stone material
20	¼ inch diamond grinding and full depth repair (slab replacement of 0.14% is required in the travel lane)
Salvage at 30	15 years (maximum 25 years restoration life)

13 SUMMARY OF RESULTS FROM CELL 9B (DETAILED INFORMATION CAN BE FOUND IN SECTION 31): 30 YEAR DESIGN PERIOD, 50 YEAR ANALYSIS PERIOD

13.1 Site conditions:

- Urban Interstate Highway
- Traffic loadings: The AADTT two directions for this section is 8000 (class 4 through 13 vehicles).
- Soil support: AASHTO class is A-7-6, fine grained soil. The mean subgrade resilient modulus is 22,500 psi (optimum moisture) as determined from backcalculation and adjustment to optimum moisture content.
- Climate: The project site is located near Joplin, MO. The climate is wet-freeze overall. The mean precipitation is 41.01 inches, freezing index is 266.50 degree days below freezing, and there are 53.12 air freeze-thaw cycles per year.

13.2 SUMMARY OF RESULTS

13.2.1 Scenario 1: Wet Freeze Rural State Highway (MoDOT based M&R)

Design & Analysis Period

Parameter	Value	Units
Design Period	20	years
Analysis Period	50	years

Operational Context

Parameter	Value	Units
AADTT two Directions	8000	vehicles/day
Number of Total Lanes-two Directions	6	
AADTT Linear Annual Increase	3%	
Climate	Wet Freeze – MO	
Soil Type	A-7-6	
Total Trucks in Design Lane (50-yr Analysis Period)	101,393,000	No. of Trucks

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting (mean both wheel paths)	0.5	In
AC bottom-up (alligator) fatigue cracking	10	Percent lane area
Total cracking (alligator + reflection) at 50% reliability (for AC overlays)	5	Percent lane area
Thermal cracking	500	ft/mi

Performance Criteria – Portland Cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	10	Percent slabs
Faulting	0.15	In

Asphalt Concrete MoDOT M&R Schedule

Year	Activity
New Construction	Place 13.5 in. AC over 24 in. crushed stone base material
20	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 0.13% lane area is required in the travel lane)
35	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 0.26% lane area is required in the travel lane)
50	End of analysis period

Portland Cement Concrete MoDOT M&R Schedule

Year	Activity
New construction	Place 11 in. PCC (with 1.5 in diameter dowel) over 6 in. crushed stone material
20	¼ inch diamond grinding and full depth repair (1.5% slab replacement is required in the travel lane)
35	¼ inch diamond grinding and full depth repair (1.5% slab replacement is required in the travel lane)
50	End of analysis period

13.2.2 Scenario 2: Wet Freeze Rural State Highway (DARWin-ME based M&R)

Analysis Period

Parameter	Value	Units
Design Period	20	years
Analysis Period	50	years

Operational Context

Parameter	Value	Units
AADTT two Directions	8000	vehicles/day
Number of Total Lanes	6	
AADTT Linear Annual Increase	3%	
Climate	Wet Freeze – MO	
Soil Type	A-7-6	

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting	0.5	in
AC bottom-up (alligator) fatigue cracking	10	Percent lane area
Total cracking (alligator + reflection) at 50% reliability (for AC overlays)	5	Percent lane area
Thermal cracking	500	ft/mi

Performance Criteria – Portland Cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	10	percent
Faulting	0.15	in

Asphalt Concrete DARWin -ME M&R Schedule

Year	Activity
New Construction	Place 13.5 in. AC over 24 in. crushed stone base material
20	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 0.13% lane area is required in the travel lane)
37	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 0.18% lane area is required in the travel lane)
Salvage at 50	4 years (maximum 17 years overlay life)

Portland Cement Concrete DARWin-ME M&R Schedule

Year	Activity
New construction	Place 11 in. PCC (with 1.5 in diameter dowel) over 6 in. crushed stone material
20	¼ inch diamond grinding and full depth repair (slab replacement of 0.07% is required in the travel lane)
40	¼ inch diamond grinding and full depth repair (slab replacement of 0.02% is required in the travel lane)
Salvage at 50	10 years

14 SUMMARY OF RESULTS FROM CELL 10A (DETAILED INFORMATION CAN BE FOUND IN SECTION 32): 30 YEAR DESIGN PERIOD, 50 YEAR ANALYSIS PERIOD

14.1 Site conditions:

- Urban Interstate Highway
- Traffic loadings: The AADTT two directions for this section is high at 8,000 (class 4 through 13 vehicles).
- Soil support: AASHTO class is A-7-6, fine grained soil, but has a layer of bedrock within a few feet of the surface. The mean subgrade resilient modulus is high at 22,500 psi (optimum moisture) as determined from backcalculation (includes the bedrock) and adjustment to optimum moisture content.
- Climate: The project site is located near Joplin, MO. The climate is wet-freeze overall. The mean precipitation is 41 inches, freezing index is 266 degree days below freezing, and there are 53 air freeze-thaw cycles per year.

14.2 SUMMARY OF RESULTS

14.2.1 Wet Freeze Urban Interstate (MODOT based M&R)

Design & Analysis Period

Parameter	Value	Units
Design Period	30	years
Analysis Period	50	years

Operational Context

Parameter	Value	Units
AADTT two Directions	8,000	vehicles/day
Number of Total Lanes-two Directions	6	
AADTT Linear Annual Increase	3%	
Climate	Wet Freeze - MO	
Soil Type	A-7-6	

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting (mean both wheel paths)	0.5	in
AC bottom-up (alligator) fatigue cracking	10	Percent lane area
Thermal cracking	500	ft/mi

Performance Criteria – Portland Cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	10	Percent slabs
Faulting	0.15	In

Asphalt Concrete M&R Schedule (two schedules per design)

Year	Activity
New Construction	Place 13.5 in. AC over 24 in. rock base material
20	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay MODOT
35	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay MODOT
50	End of analysis period

Portland Cement Concrete M&R Schedule (two schedules per design)

Year	Activity
New construction	Place 11.0 in. PCC (with 1⅝ in diameter dowel) over 6 in. crushed stone material
25	Diamond grinding and full depth patching MODOT
50	End of analysis period

14.2.2 Wet Freeze Urban Interstate (MEPDG based M&R)

Analysis Period

Parameter	Value	Units
Design Period	30	years
Analysis Period	50	years

Operational Context

Parameter	Value	Units
AADTT two Directions	8,000	vehicles/day
Number of Total Lanes	6	
AADTT Linear Annual Increase	3%	
Climate	Wet Freeze - MO	
Soil Type	A-7-6	

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting	0.5	in
AC bottom-up (alligator) fatigue cracking	10	percent
Thermal cracking	500	ft/mi

Performance Criteria – Portland Cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	10	percent
Faulting	0.15	in

Asphalt Concrete M&R Schedule (two schedules per design)

Year	Activity
New Construction	Place 12 in. AC over 24 in. rock base material
12	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay
33	Mill 2 in. of existing pavement and replace with 3 in. AC Overlay
Salvage at 50	None

Portland Cement Concrete M&R Schedule (two schedules per design)

Year	Activity
New construction	Place 11.0 in. PCC (with 1⅜ in diameter dowel) over 6 in. crushed stone material
30	Diamond grinding and full depth patching
Salvage at 50	7 years

15 SUMMARY OF RESULTS FROM CELL 10b (DETAILED INFORMATION CAN BE FOUND IN CELL 33): MISSOURI 30 YEAR DESIGN PERIOD, 75 YEAR ANALYSIS PERIOD

15.1 Site conditions:

- Urban Interstate highway
- Traffic loadings: The AADTT two directions for this section is 8000 (class 4 through 13 vehicles).
- Soil support: AASHTO class is A-7-6, fine grained soil. The mean subgrade resilient modulus is 22,500 psi (optimum moisture) as determined from backcalculation and adjustment to optimum moisture content.
- Climate: The project site is located near Joplin, MO. The climate is wet-freeze overall. The mean precipitation is 41.01 inches, freezing index is 266.50 degree days below freezing, and there are 53.12 air freeze-thaw cycles per year.
- Long term environmental effects: This design requires use of the DARWin-ME over a 75-year period which is out of the scope of the calibration data used in its development. Therefore, some assumptions regarding long term impacts of the environment (e.g., climatic effects on AC and PCC durability, subgrade movements) on rehabilitation activities. Various assumptions for AC and PCC pavements are provided in the document.

15.2 SUMMARY OF RESULTS

15.2.1 Scenario 1: Wet Freeze Rural State Highway (MoDOT based M&R)

Design & Analysis Period

Parameter	Value	Units
Design Period	30	years
Analysis Period	75	years

Operational Context

Parameter	Value	Units
AADTT two Directions	8000	vehicles/day
Number of Total Lanes-two Directions	6	
AADTT Linear Annual Increase	3%	
Climate	Wet Freeze – MO	
Soil Type	A-7-6	
Total Trucks in Design Lane (75-yr Analysis Period)	184,963,000	No. of Trucks

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting (mean both wheel paths)	0.5	In
AC bottom-up (alligator) fatigue cracking	10	Percent lane area
Total cracking (alligator + reflection) at 50% reliability (for AC overlays)	5	Percent lane area
Thermal cracking	500	ft/mi

Performance Criteria – Portland Cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	10	Percent slabs
Faulting	0.15	In

Asphalt Concrete MoDOT M&R Schedule

Year	Activity
New Construction	Place 13.5 in. AC over 24 in. crushed stone base material
20	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 0.13% lane area is required in the travel lane)
35	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 0.26% lane area is required in the travel lane)
50	Mill 7 in existing asphalt materials and replace with 7 in. AC Overlay over existing asphalt
65	Mill 3 in. of existing pavement and replace with 3 in. AC Overlay (patching of 0.55% lane area is required in the travel lane)
75	End of analysis period

Portland Cement Concrete MoDOT M&R Schedule

Year	Activity
New construction	Place 11.5 in. PCC (with 1.625 in diameter dowel) over 6 in. crushed stone material
25	¼ inch diamond grinding and full depth repair (1.5% slab replacement is required in the travel lane)
50	¼ inch diamond grinding and full depth repair (10% slab replacement is required in the travel lane)*
65	¼ inch diamond grinding and full depth repair (15% slab replacement is required in the travel lane)*
75	End of analysis period

*Note that a higher amount of slab replacement is specified for the 50 and 65 year rehabilitations. This estimate is based on expected long term environmental impacts including PCC material durability factors and subgrade movements that would require the removal and replacement of cracked or deteriorated slabs (non-fatigue cracks).

15.2.2 Scenario 2: Wet Freeze Rural State Highway (DARWin-ME based M&R)

Analysis Period

Parameter	Value	Units
Design Period	30	years
Analysis Period	75	years

Operational Context

Parameter	Value	Units
AADTT two Directions	8000	vehicles/day
Number of Total Lanes	6	
AADTT Linear Annual Increase	3%	
Climate	Wet Freeze – MO	
Soil Type	A-7-6	

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting	0.5	in
AC bottom-up (alligator) fatigue cracking	10	Percent lane area
Total cracking (alligator + reflection) at 50% reliability (for AC overlays)	5	Percent lane area
Thermal cracking	500	ft/mi

Performance Criteria – Portland Cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	10	percent
Faulting	0.15	in

Asphalt Concrete DARWin -ME M&R Schedule

Year	Activity
New Construction	Place 13.5 in. AC over 24 in. crushed stone base material
20	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 0.13% lane area is required in the travel lane)
37	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 0.28% lane area is required in the travel lane)
50	Mill 7 in existing asphalt materials and replace with 7 in. AC Overlay over existing asphalt
63	Mill 3 in. of existing pavement and replace with 3 in. AC Overlay (patching of 0.52% lane area is required in the travel lane)
Salvage at 75	End of analysis period (no salvage)

Portland Cement Concrete DARWin-ME M&R Schedule

Year	Activity
New construction	Place 11.5 in. PCC (with 1.625 in diameter dowel) over 6 in. crushed stone material
30	¼ inch diamond grinding and full depth repair (6.2% slab replacement is required in the travel lane)
55	¼ inch diamond grinding and full depth repair (12% slab replacement is required in the travel lane)*
65	¼ inch diamond grinding and full depth repair (17% slab replacement is required in the travel lane)*
Salvage at 75	End of analysis period (no salvage)

*Note that a higher amount of slab replacement is specified for the 55 and 65 year rehabilitations. This estimate is based on expected long term environmental impacts including PCC material durability factors and subgrade movements that would require the removal and replacement of cracked or deteriorated slabs (non-fatigue cracks).

16 SUMMARY OF RESULTS FROM CELL 11a (DETAILED INFORMATION CAN BE FOUND IN CELL 34): MISSOURI 50 YEAR DESIGN PERIOD, 75 YEAR ANALYSIS PERIOD

16.1 Site conditions:

- Urban Interstate highway
- Traffic loadings: The AADTT two directions for this section is 8000 (class 4 through 13 vehicles).
- Soil support: AASHTO class is A-7-6, fine grained soil. The mean subgrade resilient modulus is 22,500 psi (optimum moisture) as determined from backcalculation and adjustment to optimum moisture content.
- Climate: The project site is located near Joplin, MO. The climate is wet-freeze overall. The mean precipitation is 41.01 inches, freezing index is 266.50 degree days below freezing, and there are 53.12 air freeze-thaw cycles per year.
- Long term environmental effects: This design requires use of the DARWin-ME over a 75-year period which is out of the scope of the calibration data used in its development. Therefore, some assumptions regarding long term impacts of the environment (e.g., climatic effects on AC and PCC durability, subgrade movements) on rehabilitation activities. Various assumptions for AC and PCC pavements are provided in the document.

16.2 SUMMARY OF RESULTS

16.2.1 Scenario 1: Wet Freeze Rural State Highway (MoDOT based M&R)

Design & Analysis Period

Parameter	Value	Units
Design Period	50	years
Analysis Period	75	years

Operational Context

Parameter	Value	Units
AADTT two Directions	8000	vehicles/day
Number of Total Lanes-two Directions	6	
AADTT Linear Annual Increase	3%	
Climate	Wet Freeze – MO	
Soil Type	A-7-6	
Total Trucks in Design Lane (75-yr Analysis Period)	184,963,000	No. of Trucks

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting (mean both wheel paths)	0.5	In
AC bottom-up (alligator) fatigue cracking	10	Percent lane area
Total cracking (alligator + reflection) at 50% reliability (for AC overlays)	5	Percent lane area
Thermal cracking	500	ft/mi

Performance Criteria – Portland Cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	10	Percent slabs
Faulting	0.15	In

Asphalt Concrete MoDOT M&R Schedule

Year	Activity
New Construction	Place 13.5 in. AC over 24 in. crushed stone base material
20	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 0.13% lane area is required in the travel lane)
35	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 0.26% lane area is required in the travel lane)
50	Mill 7 in existing asphalt materials and replace with 7 in. AC Overlay over existing asphalt
65	Mill 3 in. of existing pavement and replace with 3 in. AC Overlay (patching of 0.55% lane area is required in the travel lane)
75	End of analysis period

Portland Cement Concrete MoDOT M&R Schedule

Year	Activity
New construction	Place 11.5 in. PCC (with 1.625 in diameter dowel) over 6 in. crushed stone material
25	¼ inch diamond grinding and full depth repair (1.5% slab replacement is required in the travel lane)
50	¼ inch diamond grinding and full depth repair (10% slab replacement is required in the travel lane)*
65	¼ inch diamond grinding and full depth repair (15% slab replacement is required in the travel lane)*
75	End of analysis period

*Note that a higher amount of slab replacement is specified for the 50 and 65 year rehabilitations. This estimate is based on expected long term environmental impacts including PCC material durability factors and subgrade movements that would require the removal and replacement of cracked or deteriorated slabs (non-fatigue cracks).

16.2.2 Scenario 2: Wet Freeze Rural State Highway (DARWin-ME based M&R)

Analysis Period

Parameter	Value	Units
Design Period	50	years
Analysis Period	75	years

Operational Context

Parameter	Value	Units
AADTT two Directions	8000	vehicles/day
Number of Total Lanes	6	
AADTT Linear Annual Increase	3%	
Climate	Wet Freeze – MO	
Soil Type	A-7-6	

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting	0.5	in
AC bottom-up (alligator) fatigue cracking	10	Percent lane area
Total cracking (alligator + reflection) at 50% reliability (for AC overlays)	5	Percent lane area
Thermal cracking	500	ft/mi

Performance Criteria – Portland Cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	10	percent
Faulting	0.15	in

Asphalt Concrete DARWin -ME M&R Schedule

Year	Activity
New Construction	Place 13.5 in. AC over 24 in. crushed stone base material
20	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 0.13% lane area is required in the travel lane)
37	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 0.28% lane area is required in the travel lane)
50	Mill 7 in existing asphalt materials and replace with 7 in. AC Overlay over existing asphalt
63	Mill 3 in. of existing pavement and replace with 3 in. AC Overlay (patching of 0.52% lane area is required in the travel lane)
Salvage at 75	End of analysis period (no salvage)

Portland Cement Concrete DARWin-ME M&R Schedule

Year	Activity
New construction	Place 11.5 in. PCC (with 1.625 in diameter dowel) over 6 in. crushed stone material
35	¼ inch diamond grinding and full depth repair (6.2% slab replacement is required in the travel lane)
55	¼ inch diamond grinding and full depth repair (12% slab replacement is required in the travel lane)*
65	¼ inch diamond grinding and full depth repair (17% slab replacement is required in the travel lane)*
Salvage at 75	End of analysis period (no salvage)

*Note that a higher amount of slab replacement is specified for the 55 and 65 year rehabilitations. This estimate is based on expected long term environmental impacts including PCC material durability factors and subgrade movements that would require the removal and replacement of cracked or deteriorated slabs (non-fatigue cracks).

17 SUMMARY OF RESULTS FROM CELL 11b (DETAILED INFORMATION CAN BE FOUND IN SECTION 35): MISSOURI 50 YEAR DESIGN PERIOD, 100 YEAR ANALYSIS PERIOD

17.1 Site conditions:

- Urban Interstate Highway
- Traffic loadings: The AADTT two directions for this section is 8000 (class 4 through 13 vehicles).
- Soil support: AASHTO class is A-7-6, fine grained soil. The mean subgrade resilient modulus is 22,500 psi (optimum moisture) as determined from backcalculation and adjustment to optimum moisture content.
- Climate: The project site is located near Joplin, MO. The climate is wet-freeze overall. The mean precipitation is 41.01 inches, freezing index is 266.50 degree days below freezing, and there are 53.12 air freeze-thaw cycles per year.
- Long term environmental effects: This design requires use of the DARWin-ME over a 100-year period which is out of the scope of the calibration data used in its development. Therefore, some assumptions regarding long term impacts of the environment (e.g., climatic effects on AC and PCC durability, subgrade movements) on rehabilitation activities. Various assumptions for AC and PCC pavements are provided in the document.

17.2 SUMMARY OF RESULTS

17.2.1 Scenario 1: Wet Freeze Rural State Highway (MoDOT based M&R)

Design & Analysis Period

Parameter	Value	Units
Design Period	50	years
Analysis Period	100	years

Operational Context

Parameter	Value	Units
AADTT two Directions	8000	vehicles/day
Number of Total Lanes-two Directions	6	
AADTT Linear Annual Increase	3%	
Climate	Wet Freeze – MO	
Soil Type	A-7-6	
Total Trucks in Design Lane (100-yr Analysis Period)	286,975,800	No. of Trucks

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting (mean both wheel paths)	0.5	In
AC bottom-up (alligator) fatigue cracking	10	Percent lane area
Total cracking (alligator + reflection) at 50% reliability (for AC overlays)	5	Percent lane area
Thermal cracking	500	ft/mi

Performance Criteria – Portland Cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	10	Percent slabs
Faulting	0.15	In

Asphalt Concrete MoDOT M&R Schedule

Year	Activity
New Construction	Place 13.5 in. AC over 24 in. crushed stone base material
20	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 0.13% lane area is required in the travel lane)
35	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 0.26% lane area is required in the travel lane)
50	Mill 7 in existing asphalt materials and replace with 7 in. AC Overlay over existing asphalt
63	Mill 3 in. of existing pavement and replace with 3 in. AC Overlay (patching of 0.52% lane area is required in the travel lane)
75	Mill 8 in existing asphalt materials and replace with 8 in. AC Overlay over existing asphalt
90	Mill 4 in. of existing pavement and replace with 4 in. AC Overlay (patching of 0.77% lane area is required in the travel lane)
100	End of analysis period

Portland Cement Concrete MoDOT M&R Schedule

Year	Activity
New construction	Place 12 in. PCC (with 1.625 in diameter dowel) over 6 in. crushed stone material
25	¼ inch diamond grinding and full depth repair (1.5% slab replacement is required in the travel lane)
50	¼ inch diamond grinding and full depth repair (10% slab replacement is required in the travel lane)*
70	Removal & Replacement of JPCP
100	End of analysis period

*Note that a higher amount of slab replacement is specified for the 50 year rehabilitation. This estimate is based on expected long term environmental impacts including PCC material durability factors and subgrade movements that would require the removal and replacement of cracked or deteriorated slabs (non-fatigue cracks).

17.2.2 Scenario 2: Wet Freeze Rural State Highway (DARWin-ME based M&R)

Analysis Period

Parameter	Value	Units
Design Period	50	years
Analysis Period	100	years

Operational Context

Parameter	Value	Units
AADTT two Directions	8000	vehicles/day
Number of Total Lanes	6	
AADTT Linear Annual Increase	3%	
Climate	Wet Freeze – MO	
Soil Type	A-7-6	

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting	0.5	in
AC bottom-up (alligator) fatigue cracking	10	Percent lane area
Total cracking (alligator + reflection) at 50% reliability (for AC overlays)	5	Percent lane area
Thermal cracking	500	ft/mi

Performance Criteria – Portland Cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	10	percent
Faulting	0.15	in

Asphalt Concrete DARWin -ME M&R Schedule

Year	Activity
New Construction	Place 13.5 in. AC over 24 in. crushed stone base material
20	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 0.13% lane area is required in the travel lane)
37	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 0.28% lane area is required in the travel lane)
50	Mill 7 in existing asphalt materials and replace with 7 in. AC Overlay over existing asphalt
63	Mill 3 in. of existing pavement and replace with 3 in. AC Overlay (patching of 0.52% lane area is required in the travel lane)
75	Mill 8 in existing asphalt materials and replace with 8 in. AC Overlay over existing asphalt
90	Mill 4 in. of existing pavement and replace with 4 in. AC Overlay (patching of 0.77% lane area is required in the travel lane)
Salvage at 100	End of analysis period (no salvage)

Portland Cement Concrete DARWin-ME M&R Schedule

Year	Activity
New construction	Place 12 in. PCC (with 1.625 in diameter dowel) over 6 in. crushed stone material
40	¼ inch diamond grinding and full depth repair (10% slab replacement is required in the travel lane)
60	¼ inch diamond grinding and full depth repair (15% slab replacement is required in the travel lane)*
75	¼ inch diamond grinding and full depth repair (20% slab replacement is required in the travel lane)*
90	¼ inch diamond grinding and full depth repair (30 % slab replacement is required in the travel lane)*
Salvage at 100	End of analysis period (no salvage)

*Note that a higher amount of slab replacement is specified for the 60, 75, and 90 year rehabilitations. This estimate is based on expected long term environmental impacts including PCC material durability factors and subgrade movements that would require the removal and replacement of cracked or deteriorated slabs (non-fatigue cracks).

18 SUMMARY OF RESULTS FROM CELL 12 (DETAILED INFORMATION CAN BE FOUND IN SECTION 36): ARIZONA 30 YEAR DESIGN PERIOD, 50 YEAR ANALYSIS PERIOD

18.1 Site conditions:

- Urban Interstate Highway
- Traffic loadings: The AADTT two directions for this section is 8,000 (class 4 through 13 vehicles).
- Soil support: AASHTO class is A-2-4, coarse grained soil. The mean subgrade resilient modulus is 9,500 psi (optimum moisture) as determined from backcalculation and adjustment to optimum moisture content.
- Climate: The project site is located near Phoenix, AZ. The climate is dry-no freeze overall. The mean annual precipitation is 7.3 inches, freezing index is 0 degree days below freezing, and there are 0 air freeze-thaw cycles per year.

18.2 SUMMARY OF RESULTS

18.2.1 Scenario 1: Dry No Freeze Urban Interstate Highway (ADOT based M&R)

Design & Analysis Period

Parameter	Value	Units
Design Period	30	years
Analysis Period	50	years

Operational Context

Parameter	Value	Units
AADTT two Directions	8000	vehicles/day
Number of Total Lanes-two Directions	6	
AADTT Linear Annual Increase	3%	
Climate	Dry No Freeze – AZ	
Soil Type	A-2-4	
Total Trucks in Design Lane (50-yr Analysis Period)	101,393,000	No. of Trucks

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting (mean both wheel paths)	0.5	In
AC bottom-up (alligator) fatigue cracking	10	Percent lane area
Total cracking (alligator + reflection) at 50% reliability (for AC overlays)	5	Percent lane area
Thermal cracking	500	ft/mi

Performance Criteria – Portland Cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	10	Percent slabs
Faulting	0.15	In

Asphalt Concrete ADOT M&R Schedule

Year	Activity
New Construction	Place 13.5 in. AC over 12 in. crushed stone base material
15	Mill 2.5 in. of existing pavement and replace with 2.5 in. AC Overlay (patching of 0.01% lane area is required in the travel lane)
28	Mill 2.5 in. of existing pavement and replace with 2.5 in. AC Overlay (patching of 0.01% lane area is required in the travel lane)
41	Mill 2.5 in. of existing pavement and replace with 2.5 in. AC Overlay (patching of 0.02% lane area is required in the travel lane)
50	End of analysis period

Portland Cement Concrete ADOT M&R Schedule

Year	Activity
New construction	Place 11 in. PCC (with 1.5 in diameter dowel) over 6 in. crushed stone material
20	¼ inch diamond grinding and full depth repair (0.08% slab replacement is required in the travel lane)
40	¼ inch diamond grinding and full depth repair (0.23% slab replacement is required in the travel lane)
50	End of analysis period

18.2.2 Scenario 2: Dry No Freeze Urban Interstate Highway (DARWin-ME based M&R)

Analysis Period

Parameter	Value	Units
Design Period	30	years
Analysis Period	50	years

Operational Context

Parameter	Value	Units
AADTT two Directions	8000	vehicles/day
Number of Total Lanes	6	
AADTT Linear Annual Increase	3%	
Climate	Dry No Freeze - AZ	
Soil Type	A-2-4	

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting	0.5	in
AC bottom-up (alligator) fatigue cracking	10	Percent lane area
Total cracking (alligator + reflection) at 50% reliability (for AC overlays)	5	Percent lane area
Thermal cracking	500	ft/mi

Performance Criteria – Portland Cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	10	percent
Faulting	0.15	in

Asphalt Concrete DARWin -ME M&R Schedule

Year	Activity
New Construction	Place 13.5 in. AC over 12 in. crushed stone base material
16	Mill 2.5 in. of existing pavement and replace with 2.5 in. AC Overlay (patching of 0.01% lane area is required in the travel lane)
29	Mill 2.5 in. of existing pavement and replace with 2.5 in. AC Overlay (patching of 0.01% lane area is required in the travel lane)
42	Mill 2.5 in. of existing pavement and replace with 2.5 in. AC Overlay (patching of 0.02% lane area is required in the travel lane)
Salvage at 50	5 years (maximum 13 years overlay life)

Portland Cement Concrete DARWin-ME M&R Schedule

Year	Activity
New construction	Place 11 in. PCC (with 1.5 in diameter dowel) over 6 in. crushed stone material
30	¼ inch diamond grinding and full depth repair (slab replacement of 0.18% is required in the travel lane)
Salvage at 50	0 years (maximum 20 years restoration life)

19 SUMMARY OF RESULTS FROM CELL 13 (DETAILED INFORMATION CAN BE FOUND IN SECTION 37): COLORADO 30 YEAR DESIGN PERIOD, 50 YEAR ANALYSIS PERIOD

19.1 Site conditions:

- Urban Interstate Highway
- Traffic loadings: The AADTT two directions for this section is 8,000 (class 4 through 13 vehicles).
- Soil support: AASHTO class is A-2-4, coarse grained soil. The mean subgrade resilient modulus is 18,000 psi (optimum moisture) as determined from backcalculation and adjustment to optimum moisture content.
- Climate: The project site is located near Centennial, CO (near Denver-Aurora). The climate is dry- freeze overall. The mean annual precipitation is 19.4 inches, freezing index is 930.2 degree days below freezing, and there are 68.3 air freeze-thaw cycles per year.

19.2 SUMMARY OF RESULTS

19.2.1 Scenario 1: Dry Freeze Urban Interstate Highway (CDOT based M&R)

Design & Analysis Period

Parameter	Value	Units
Design Period	30	years
Analysis Period	50	years

Operational Context

Parameter	Value	Units
AADTT two Directions	8000	vehicles/day
Number of Total Lanes-two Directions	6	
AADTT Linear Annual Increase	3%	
Climate	Dry Freeze – CO	
Soil Type	A-2-4	
Total Trucks in Design Lane (50-yr Analysis Period)	101,393,000	No. of Trucks

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting (mean both wheel paths)	0.5	In
AC bottom-up (alligator) fatigue cracking	10	Percent lane area
Total cracking (alligator + reflection) at 50% reliability (for AC overlays)	5	Percent lane area
Thermal cracking	500	ft/mi

Performance Criteria – Portland Cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	10	Percent slabs
Faulting	0.15	In

Asphalt Concrete CDOT M&R Schedule

Year	Activity
New Construction	Place 14 in. AC over 4 in. aggregate base material
13	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 0.01% lane area is required in the travel lane)
26	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 0.01% lane area is required in the travel lane)
38	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 0.02% lane area is required in the travel lane)
50	End of analysis period

Portland Cement Concrete CDOT M&R Schedule

Year	Activity
New construction	Place 10 in. PCC (with 1.25 in diameter dowel) over 4 in. aggregate base material
27	¼ inch diamond grinding and full depth repair (0.5% slab replacement is required in the travel lane)
50	End of analysis period

19.2.2 Scenario 2: Dry Freeze Urban Interstate Highway (DARWin-ME based M&R)

Analysis Period

Parameter	Value	Units
Design Period	30	years
Analysis Period	50	years

Operational Context

Parameter	Value	Units
AADTT two Directions	8000	vehicles/day
Number of Total Lanes	6	
AADTT Linear Annual Increase	3%	
Climate	Dry Freeze - CO	
Soil Type	A-2-4	

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting	0.5	in
AC bottom-up (alligator) fatigue cracking	10	Percent lane area
Total cracking (alligator + reflection) at 50% reliability (for AC overlays)	5	Percent lane area
Thermal cracking	500	ft/mi

Performance Criteria – Portland Cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	10	percent
Faulting	0.15	In

Asphalt Concrete DARWin -ME M&R Schedule

Year	Activity
New Construction	Place 14 in. AC over 4 in. aggregate base material
13	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 0.01% lane area is required in the travel lane)
30	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 0.01% lane area is required in the travel lane)
40	Mill 2 in. of existing pavement and replace with 2 in. AC Overlay (patching of 0.02% lane area is required in the travel lane)
Salvage at 50	0 years

Portland Cement Concrete DARWin-ME M&R Schedule

Year	Activity
New construction	Place 10 in. PCC (with 1.25 in diameter dowel) over 4 in. aggregate base material
30	¼ inch diamond grinding and full depth repair (slab replacement of 0.08% is required in the travel lane)
Salvage at 50	5 years (maximum 25 years restoration life)

20 SUMMARY OF RESULTS FROM CELL 14 (DETAILED INFORMATION CAN BE FOUND IN SECTION 38): FLORIDA 30 YEAR DESIGN PERIOD, 50 YEAR ANALYSIS PERIOD

20.1 Site conditions:

- Urban Interstate Highway
- Traffic loadings: The AADTT two directions for this section is 8,000 (class 4 through 13 vehicles).
- Soil support: AASHTO class is A-3, coarse grained soil. The mean subgrade resilient modulus is 14,000 psi (optimum moisture) as determined from backcalculation and adjustment to optimum moisture content.
- Climate: The project site is located near West Palm Beach, FL. The climate is wet- no freeze overall. The mean annual precipitation is 60 inches, freezing index is 0 degree days below freezing, and there are 0 air freeze-thaw cycles per year.

20.2 SUMMARY OF RESULTS

20.2.1 Scenario 1: Wet No Freeze Urban Interstate Highway (FDOT based M&R)

Design & Analysis Period

Parameter	Value	Units
Design Period	30	years
Analysis Period	50	years

Operational Context

Parameter	Value	Units
AADTT two Directions	8000	vehicles/day
Number of Total Lanes-two Directions	6	
AADTT Linear Annual Increase	3%	
Climate	Wet No Freeze – FL	
Soil Type	A-3	
Total Trucks in Design Lane (50-yr Analysis Period)	101,393,000	No. of Trucks

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting (mean both wheel paths)	0.5	In
AC bottom-up (alligator) fatigue cracking	10	Percent lane area
Total cracking (alligator + reflection) at 50% reliability (for AC overlays)	5	Percent lane area
Thermal cracking	500	ft/mi

Performance Criteria – Portland Cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	10	Percent slabs
Faulting	0.15	In

Asphalt Concrete FDOT M&R Schedule

Year	Activity
New Construction	Place 12.5 in. AC over 6 in. limerock base material
14	Mill 2.5 in. of existing pavement and replace with 2.5 in. AC Overlay (patching of 0.161% lane area is required in the travel lane)
28	Mill 2.5 in. of existing pavement and replace with 2.5 in. AC Overlay (patching of 0.373% lane area is required in the travel lane)
40	Mill 2.5 in. of existing pavement and replace with 2.5 in. AC Overlay (patching of 0.58% lane area is required in the travel lane)
50	End of analysis period

Portland Cement Concrete FDOT M&R Schedule

Year	Activity
New construction	Place 9 in. PCC (with 1.25 in diameter dowel) over 4 in. asphalt treated base
20	¼ inch diamond grinding and full depth repair (3% slab replacement is required in the travel lane)
35	¼ inch diamond grinding and full depth repair (5% slab replacement is required in the travel lane)
50	End of analysis period

20.2.2 Scenario 2: Wet No Freeze Urban Interstate Highway (DARWin-ME based M&R)

Analysis Period

Parameter	Value	Units
Design Period	30	years
Analysis Period	50	years

Operational Context

Parameter	Value	Units
AADTT two Directions	8000	vehicles/day
Number of Total Lanes	6	
AADTT Linear Annual Increase	3%	
Climate	Wet No Freeze – FL	
Soil Type	A-3	

Performance Criteria – Asphalt Concrete

Parameter	Value	Units
IRI	160	In/mi
Total rutting	0.5	in
AC bottom-up (alligator) fatigue cracking	10	Percent lane area
Total cracking (alligator + reflection) at 50% reliability (for AC overlays)	5	Percent lane area
Thermal cracking	500	ft/mi

Performance Criteria – Portland Cement Concrete

Parameter	Value	Units
IRI	160	in/mi
Transverse Fatigue Cracking	10	percent
Faulting	0.15	In

Asphalt Concrete DARWin -ME M&R Schedule

Year	Activity
New Construction	Place 12.5 in. AC over 6 in. limerock base material
16	Mill 2.5 in. of existing pavement and replace with 2.5 in. AC Overlay (patching of 0.206% lane area is required in the travel lane)
33	Mill 2.5 in. of existing pavement and replace with 2.5 in. AC Overlay (patching of 0.48% lane area is required in the travel lane)
Salvage at 50	0 years

Portland Cement Concrete DARWin-ME M&R Schedule

Year	Activity
New construction	Place 9 in. PCC (with 1.25 in diameter dowel) over 4 in. asphalt treated base
30	¼ inch diamond grinding and full depth repair (slab replacement of 0.02% is required in the travel lane)
Salvage at 50	5 years (maximum 25 years restoration life)

21 Detailed Information for Cell 1

21.1 ASPHALT CONCRETE PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

21.1.1 MoDOT-Based Maintenance and Rehabilitation (M&R)

21.1.1.1 New Construction

21.1.1.1.1 Traffic Inputs

Design period	20
Initial two-way AADTT	300
Number of lanes in design direction	1
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	100.0
Number of trucks over design period (design lane)	1,408,040

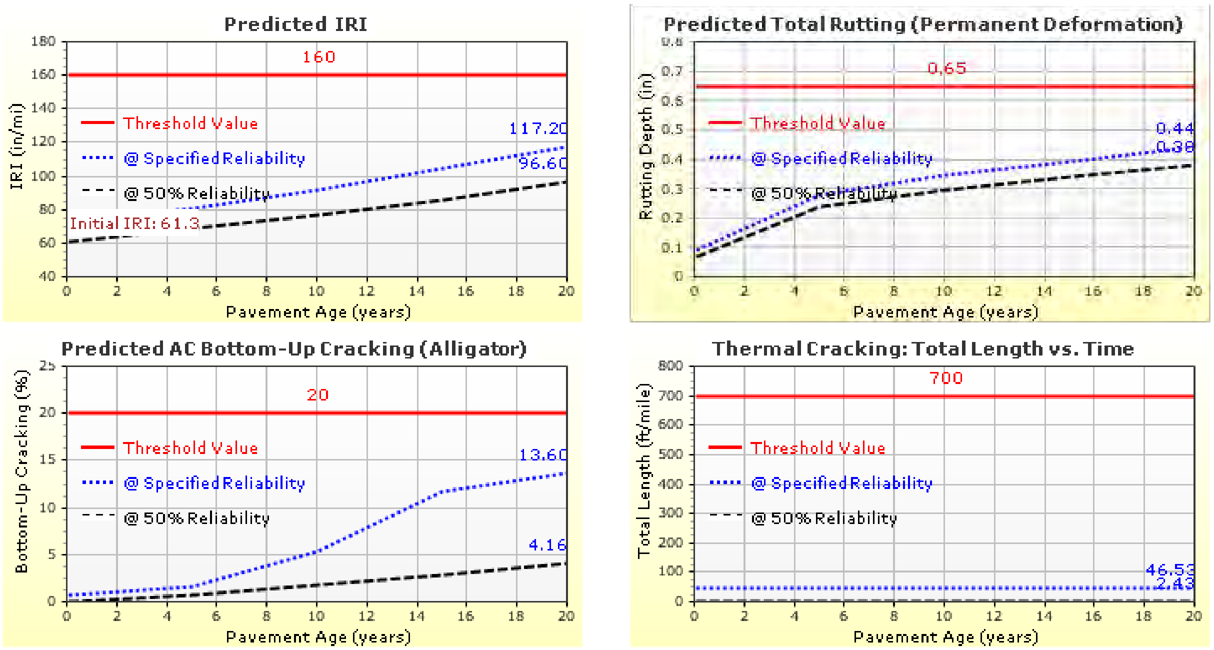
21.1.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	Material Type	Thickness (in)
AC Surface	HMA ½ in. mix with PG 64-22	1.75
AC Binder	HMA ¾ in. mix with PG 64-22	4
Granular Base	A-1-a	4
Subgrade	A-2-6	Semi-infinite

21.1.1.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	117.23	75.00	98.08	Pass
Permanent deformation - total pavement (in.)	0.65	0.44	75.00	99.88	Pass
AC bottom-up fatigue cracking (percent)	20.00	13.60	75.00	87.11	Pass
AC thermal fracture (ft/mile)	700.00	46.53	75.00	100.00	Pass
Permanent deformation - AC only (in.)	0.65	0.27	75.00	100.00	Pass

21.1.1.1.4 Distress Charts



21.1.1.2 MoDOT Rehabilitation – Mill & Overlay

The Missouri first rehabilitation is recommended at 20 years. The MoDOT expected life of the AC overlay is 15 years. This becomes the Design Period for the next overlay. The Missouri second rehabilitation was applied at 35 years with design period of 15 years.

21.1.1.3 Summary of Asphalt Pavement Design and Life Cycle Rehabilitation using MoDOT M&R

Pavement life cycle activities over a 50-year analysis period include the following as determined using the Missouri DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 5.75 in. AC over 4 in. crushed stone base material
20	AC overlay 1	Mill 1.75 in. and replace 1.75 in. AC OL (Patching of 4.16% lane area is required in the travel lane).
35	AC overlay 2	Mill 1.75 in. and replace 1.75 in. AC OL (Patching 8.37% lane area is required in the travel lane).
50	End of analysis period	

21.1.2 DARWin-ME-Based Maintenance and Rehabilitation (M&R)

21.1.2.1 New Construction

21.1.2.1.1 Traffic Inputs

Design period	20
Initial two-way AADTT	300
Number of lanes in design direction	1
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	100.0
Number of trucks over design period	1,408,040

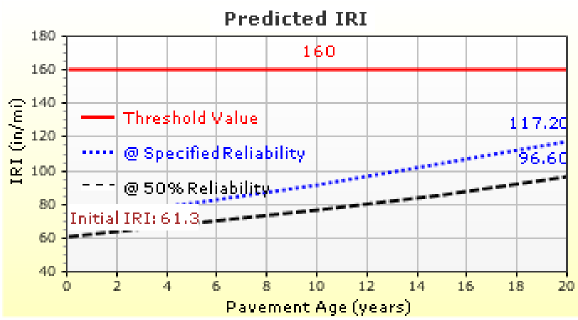
21.1.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

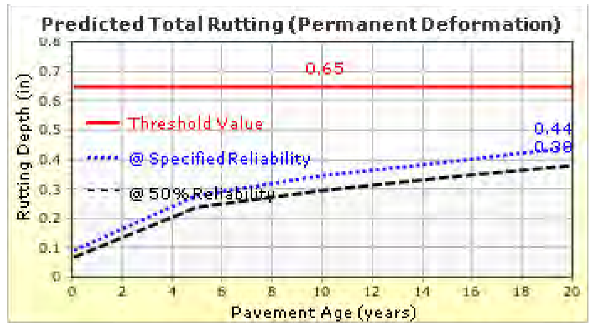
Layer Type	**Material Type**	**Thickness (in)**
AC Surface	HMA ½ in. mix with PG 64-22	1.75
AC Binder	HMA ¾ in. mix with PG 64-22	4
Granular Base	A-1-a	4
Subgrade	A-2-6	Semi-infinite

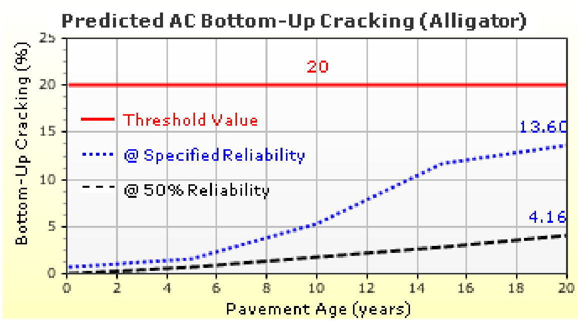
21.1.2.1.3 Distress Prediction & Reliability Summary

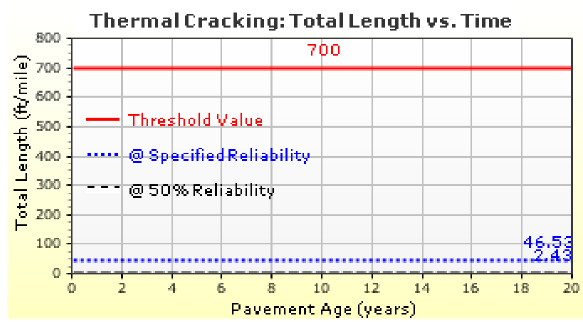
Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in./mile)	160.00	117.23	75.00	98.08	Pass
Permanent deformation - total pavement (in.)	0.65	0.44	75.00	99.88	Pass
AC bottom-up fatigue cracking (percent)	20.00	13.60	75.00	87.11	Pass
AC thermal fracture (ft/mile)	700.00	46.53	75.00	100.00	Pass
Permanent deformation - AC only (in.)	0.65	0.27	75.00	100.00	Pass

21.1.2.1.4 Distress Charts









21.1.2.2 First Rehabilitation – Mill & Overlay

The DARWin-ME based thresholds were used to establish future rehabilitation activities. A reasonable maximum service life of 20 years for new AC and 17 years for AC overlay was assumed for this climate since DARWin-ME does not consider all durability related distresses that develop over time. The first overlay project was then run for 17 years design period instead of typical MoDOT design life and the second overlay was run for 13 years. The mill and overlay then starts out rutting at 0 and IRI at 60 in/mile. Fatigue damage was low but is also determined and considered in the next overlay cracking prediction.

21.1.2.2.1 Rehabilitation Information

Rehabilitation strategy	Mill top 1.75 in. of AC surface course and place an AC overlay of 1.75 in. thick. Patching of 4.16% lane area is required in the travel lane.
Year of rehabilitation	20
Design period of rehab	17

21.1.2.2.2 Traffic Inputs

Design period (from year 20 to 37)	17
Initial two-way AADTT	480
Number of lanes in design direction	1
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	100.0
Number of trucks over design period	1,847,870

21.1.2.2.3

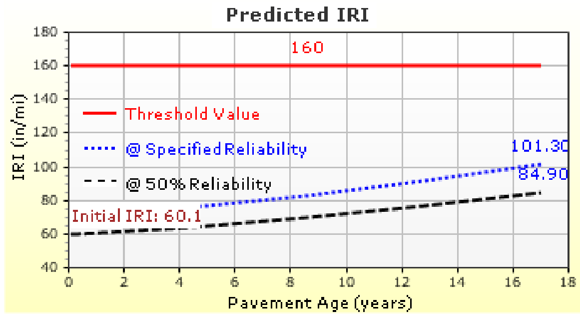
21.1.2.2.4 Pavement Structure

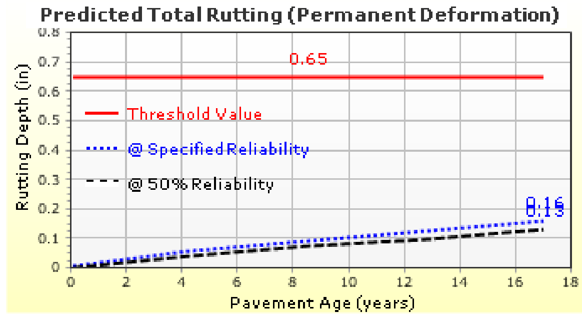
Layer Type	Material Type	Thickness (in)
AC Overlay (placed at 20 years)	HMA ½ in. mix with PG 64-22	1.75
AC Binder	HMA ¾ in. mix with PG 64-22	4
Granular Base	A-1-a	4
Subgrade	A-2-6	Semi-infinite

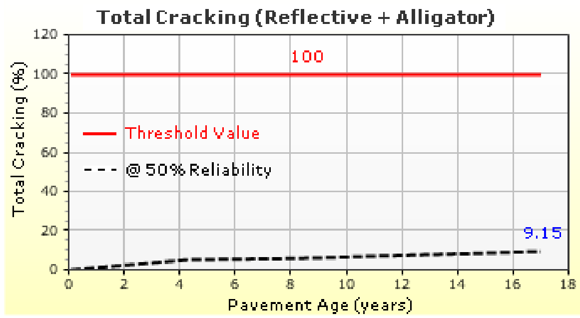
21.1.2.2.5 Distress Prediction & Reliability Summary

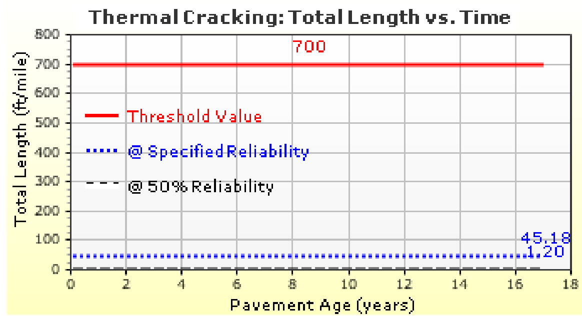
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	101.31	75.00	99.90	Pass
Permanent deformation - total pavement (in.)	0.65	0.16	75.00	100.00	Pass
Total Cracking (Reflective + Alligator) (percent)	15.00	9.15	50.00		Pass
AC thermal fracture (ft/mile)	700.00	45.18	75.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	20.00	0.76	75.00	100.00	Pass
Permanent deformation - AC only (in.)	0.65	0.16	75.00	100.00	Pass

21.1.2.2.6 Distress Charts









21.1.2.3 Second Rehabilitation – Mill & Overlay

The second rehabilitation was placed at 37 years with a design life of 13 years. Note that second rehabilitation has slightly greater than 3% linear traffic growth rate.

21.1.2.3.1 Rehabilitation Information

Rehabilitation strategy	Mill top 1.75 in. of AC surface course and place an AC overlay of 1.75 in. thick. Patching of 9.15% lane area is required in the travel lane.
Year of rehabilitation	37
Design period	13

21.1.2.3.2 Traffic Inputs

Design period (from year 37 to 50)	13
Initial two-way AADTT	725
Number of lanes in design direction	1
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	100.0
Number of trucks over design period	2,031,060

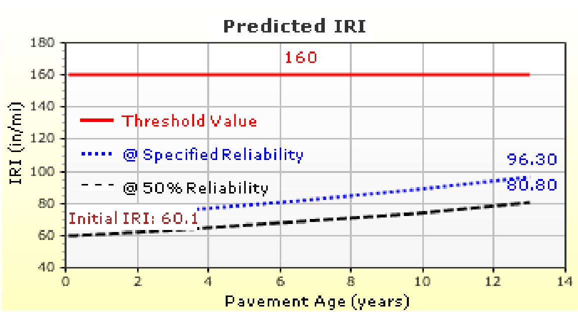
21.1.2.3.3 Pavement Structure

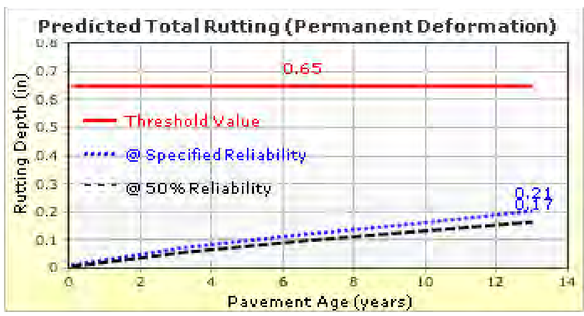
Layer Type	Material Type	Thickness (in)
AC Overlay (placed at 37 years)	HMA ½ in. mix with PG 64-22	1.75
AC Binder	HMA ¾ in. mix with PG 64-22	4
Granular Base	A-1-a	4
Subgrade	A-2-6	Semi-infinite

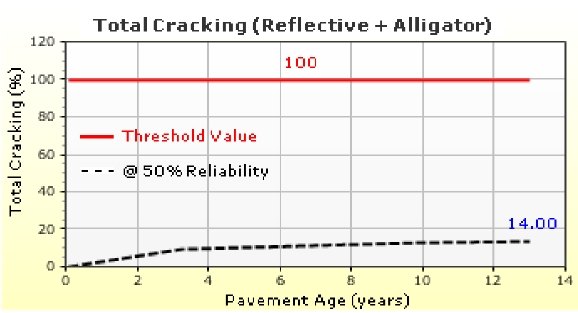
21.1.2.3.4 Distress Prediction & Reliability Summary

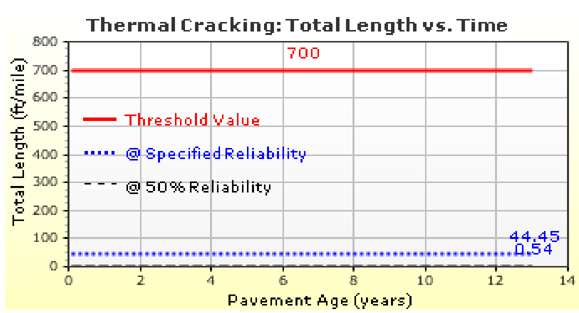
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	96.34	75.00	99.97	Pass
Permanent deformation - total pavement (in.)	0.65	0.21	75.00	100.00	Pass
Total Cracking (Reflective + Alligator) (percent)	15.00	14.00	50.00		Pass
AC thermal fracture (ft/mile)	700.00	44.45	75.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	20.00	0.76	75.00	100.00	Pass
Permanent deformation - AC only (in.)	0.65	0.21	75.00	100.00	Pass

21.1.2.3.5 Distress Charts









The pavement passes all of the criteria at 50 years. The overlay actually will last 15 years or 2 years longer than the 50-year analysis period and some salvage value can be considered in the LCCA.

21.1.2.4 Summary of Asphalt Pavement Design and Life Cycle Rehabilitation based on DARWin-ME Predictions

Pavement life cycle activities over a 50-year analysis period include the following as determined using the DARWin-ME threshold criteria:

Year	Activity	Description
0	New construction	Place 5.75 in. AC over 4 in. crushed stone base material
20	AC overlay 1	Mill 1.75 in. and replace 1.75 in. AC OL (Patching of 4.16% lane area is required in the travel lane).
37	AC overlay 2	Mill 1.75 in. and replace 1.75 in. AC OL (Patching of 9.15% lane area is required in the travel lane).
Salvage at 50	2 years	

21.2 PORTLAND CEMENT CONCRETE PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

The site conditions, design period and analysis period are exactly the same as that used for the AC design.

21.2.1 MoDOT-Based Maintenance and Rehabilitation (M&R)

The MoDOT M&R strategy is to perform concrete pavement restoration at 20 years. This includes 1.5% cracked slabs replacement in the travel lane and diamond grinding of the surface to restore IRI and remove faulting.

21.2.1.1 New Construction

21.2.1.1.1 Traffic Inputs

Design period	20
Initial two-way AADTT	300
Number of lanes in design direction	1
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	100.0
Number of trucks over design period	1,408,040

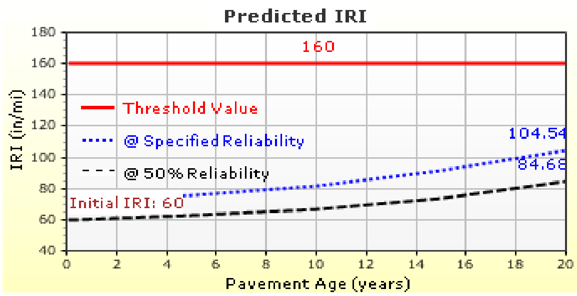
21.2.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

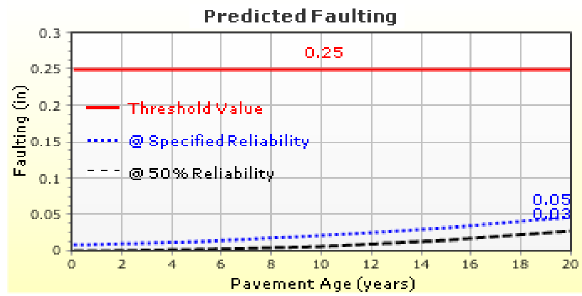
Layer Type	Material Type	Thickness (in)	Dowel Dia. (in)
JPCP-PCC	PCC	7.5	1.0
Granular Base	A-1-a	4	
Subgrade	A-2-6	Semi-infinite	

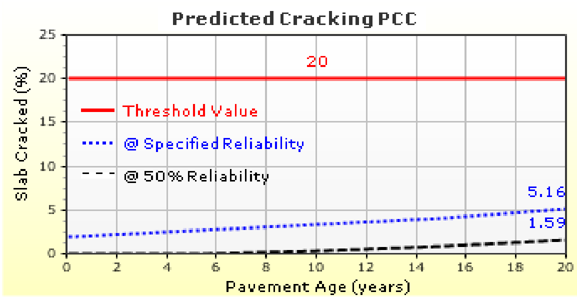
21.2.1.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	104.54	75.00	99.47	Pass
Mean joint faulting (in.)	0.25	0.05	75.00	100.00	Pass
JPCP transverse cracking (percent slabs)	20.00	5.16	75.00	99.97	Pass

21.2.1.1.4 Distress Charts







21.2.1.2 MoDOT Rehabilitation – Diamond Grinding and Full Depth Repair

The Missouri first rehabilitation is recommended at 20 years. The MoDOT expected life of the JPCP restoration is 15 years. This becomes the design period for the next restoration. The second restoration is recommended at 35 years with design period of 15 years.

21.2.1.3 Summary of MoDOT Concrete Pavement Design and Life Cycle Rehabilitation

Pavement life cycle activities over a 50-year analysis period include the following as determined using the Missouri DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 7.5 in. PCC (with 1 in diameter dowel) over 4 in. crushed stone material
20	PCC Rehabilitation 1	¼ in. Diamond grinding and full depth repair (1.5% slabs replacement is required in the travel lane as per MoDOT M&R strategy)
35	PCC Rehabilitation 2	¼ in. Diamond grinding and full depth repair (1.5% slabs replacement is required in the travel lane as per MoDOT M&R strategy)
50	End of analysis period	

21.2.2 DARWin-ME-Based Maintenance and Rehabilitation (M&R)

21.2.2.1 New Construction

21.2.2.1.1 Traffic Inputs

Design period	20
Initial two-way AADTT	300
Number of lanes in design direction	1
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	100.0
Number of trucks over design period	1,408,040

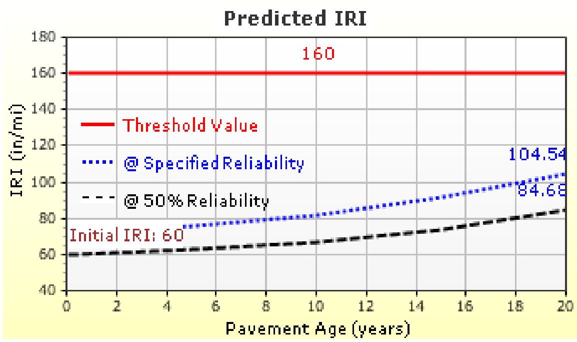
21.2.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

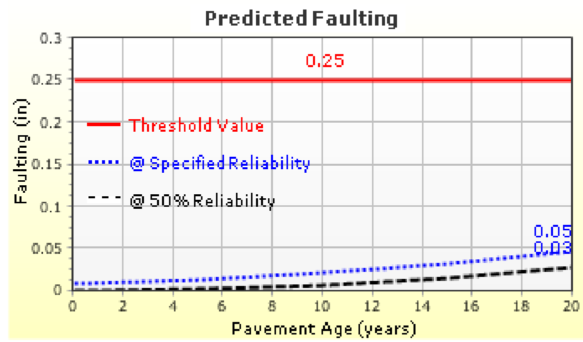
Layer Type	Material Type	Thickness (in)	Dowel Dia. (in)
JPCP-PCC	PCC	7.5	1.0
Granular Base	A-1-a	4	
Subgrade	A-2-6	Semi-infinite	

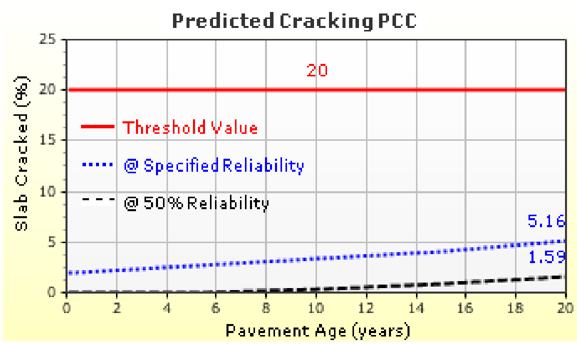
21.2.2.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	104.54	75.00	99.47	Pass
Mean joint faulting (in.)	0.25	0.05	75.00	100.00	Pass
JPCP transverse cracking (percent slabs)	20.00	5.16	75.00	99.97	Pass

21.2.2.1.4 Distress Charts







This design passes the DARWin-ME threshold criteria over 20 years. At 20 years, there is 5.16% fatigue cracking, 0.05 in faulting and 104.54 in/mile IRI at 75% reliability. Thus, diamond grinding and full depth repair are the most logical M&R treatment at 20 years.

21.2.2.2 First Rehabilitation –Full Depth Repair

At 20 years, all cracked slabs will be replaced. Past fatigue cracking damage will be considered in future cracking projections. A maximum JPCP restoration life of 25 years was assumed since DARWin-ME does not consider all durability related distresses that develop over time. The first restoration project was then run for 20 years design period instead of typical MoDOT design life and the second overlay was run for 10 years.

21.2.2.2.1 Traffic Inputs

Design period (from year 20 to 40)	20
Initial two-way AADTT	480
Number of lanes in design direction	1
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	100.0
Number of trucks over design period	2,252,860

21.2.2.2.2 Pavement Structure That Meets Performance & Reliability Requirements

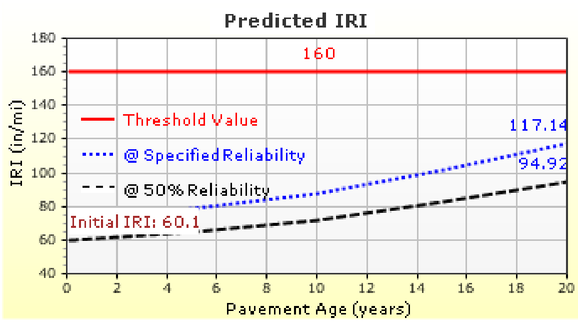
Layer Type	Material Type	Thickness (in)
JPCP-PCC	PCC	7.25*
Granular Base	A-1-a	4
Subgrade	A-2-6	Semi-infinite

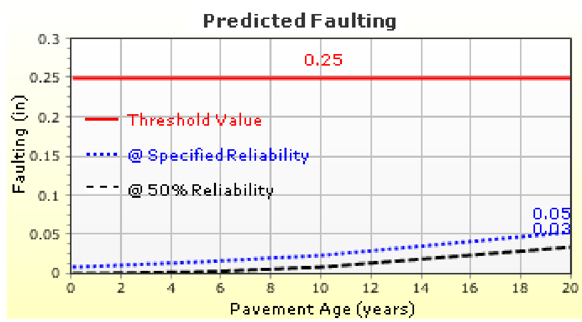
*Note: No diamond grinding is required.

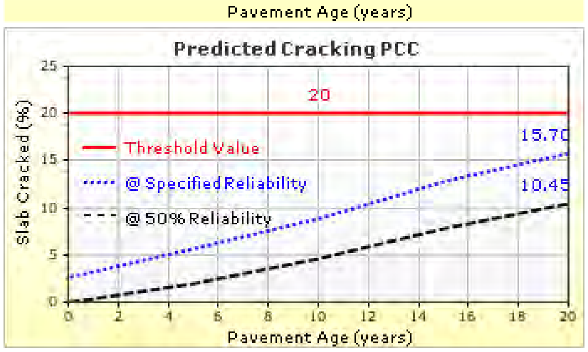
21.2.2.2.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	117.14	75.00	97.59	Pass
Mean joint faulting (in.)	0.25	0.05	75.00	100.00	Pass
JPCP transverse cracking (percent slabs)	20.00	15.70	75.00	89.00	Pass

21.2.2.2.4 Distress Charts







21.2.2.3 Second Rehabilitation –Full Depth Repair

The second rehabilitation was placed at 40 years with a design life of 10 years. Note that second rehabilitation has slightly greater than 3% linear traffic growth rate.

21.2.2.3.1 Traffic Inputs

Design period (from year 40 to 50)	10
Initial two-way AADTT	768
Number of lanes in design direction	1
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	100.0
Number of trucks over design period	1,591,910

21.2.2.3.2 Pavement Structure That Meets Performance & Reliability Requirements

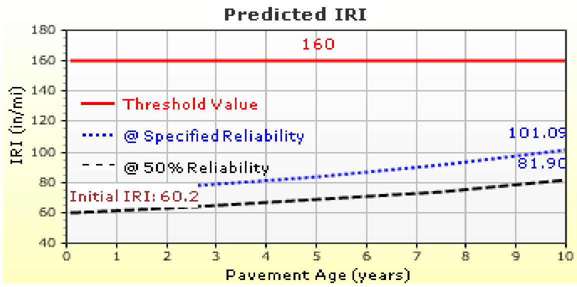
Layer Type	Material Type	Thickness (in)
JPCP-PCC	PCC	7.25*
Granular Base	A-1-a	4
Subgrade	A-2-6	Semi-infinite

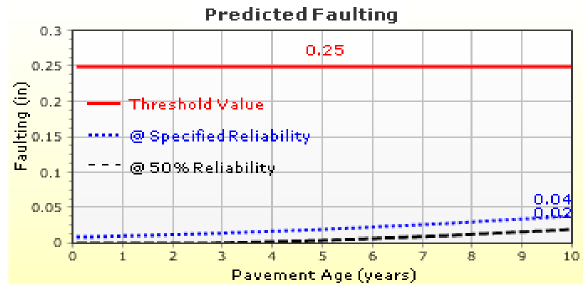
*Note: No diamond grinding is required.

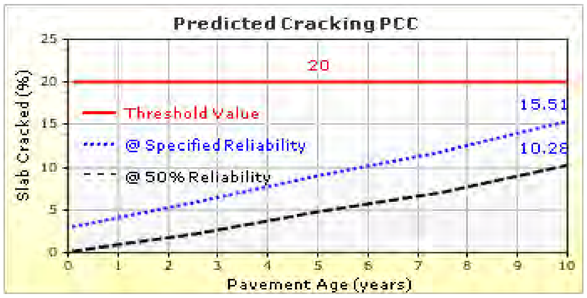
21.2.2.3.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	101.09	75.00	99.70	Pass
Mean joint faulting (in.)	0.25	0.04	75.00	100.00	Pass
JPCP transverse cracking (percent slabs)	20.00	15.51	75.00	89.50	Pass

Distress Charts







The pavement passes all of the criteria at 50 years. The restoration of the pavement actually will last 13 years (assuming texture depth does not wear down beyond critical level) or 3 years longer than the 50-year analysis period and some salvage value can be considered in the LCCA.

21.2.2.4 Summary of Concrete Pavement Design and Life Cycle Rehabilitation based on DARWin-ME Predictions

Pavement life cycle activities over a 50-year analysis period include the following as determined using the DARWin-ME based thresholds:

Year	Activity	Description
0	New construction	Place 7.5 in. PCC (with 1 in diameter dowel) over 4 in. crushed stone material
20	PCC Rehabilitation 1	Full depth repair DARWin-ME (slab replacement of 1.59% is required in the travel lane)
40	PCC Rehabilitation 2	Full depth repair DARWin-ME (slab replacement of 10.45% is required in the travel lane)
Salvage at 50	3 years	

22 Detailed Information for Cell 2

22.1 ASPHALT CONCRETE PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

22.1.1 MoDOT-Based Maintenance and Rehabilitation (M&R)

22.1.1.1 New Construction

22.1.1.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	300
Number of lanes in design direction	1
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	100.0
Number of trucks over design period (design lane)	2,358,600

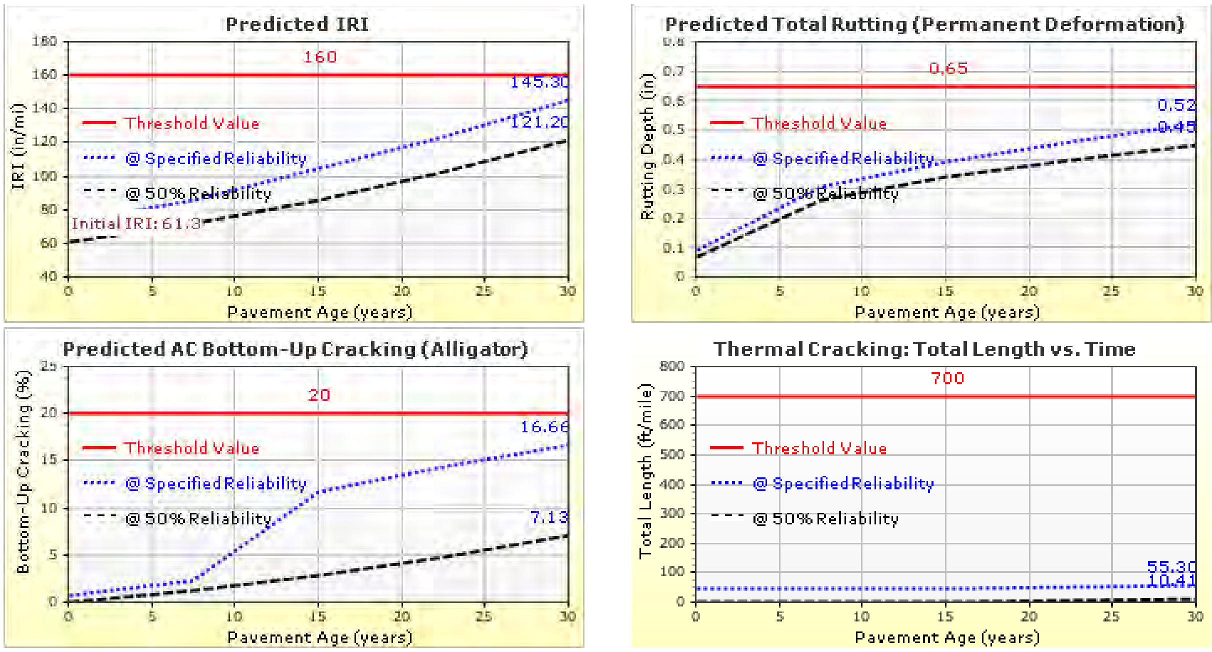
22.1.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	Material Type	Thickness (in)
AC Surface	HMA ½ in. mix with PG 64-22	1.75
AC Binder	HMA ¾ in. mix with PG 64-22	4
Granular Base	A-1-a	4
Subgrade	A-2-6	Semi-infinite

22.1.1.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	145.33	75.00	86.10	Pass
Permanent deformation - total pavement (in.)	0.65	0.52	75.00	97.30	Pass
AC bottom-up fatigue cracking (percent)	20.00	16.66	75.00	81.89	Pass
AC thermal fracture (ft/mile)	700.00	55.30	75.00	100.00	Pass
Permanent deformation - AC only (in.)	0.65	0.34	75.00	100.00	Pass

22.1.1.1.4 Distress Charts



22.1.1.2 MoDOT Rehabilitation – Mill & Overlay

The Missouri first rehabilitation is recommended at 20 years. The MoDOT expected life of the AC overlay is 15 years. This becomes the Design Period for the next overlay. The Missouri second rehabilitation was applied at 35 years with design period of 15 years.

22.1.1.3 Summary of Asphalt Pavement Design and Life Cycle Rehabilitation using MoDOT M&R

Pavement life cycle activities over a 50-year analysis period include the following as determined using the Missouri DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 5.75 in. AC over 4 in. crushed stone base material
20	AC overlay 1	Mill 1.75 in. and replace 1.75 in. AC OL (Patching of 4.16% is required in the travel lane).
35	AC overlay 2	Mill 1.75 in. and replace 1.75 in. AC OL (Patching of 8.37% is required in the travel lane).
50	End of analysis period	

22.1.2 DARWin-ME-Based Maintenance and Rehabilitation (M&R)

22.1.2.1 New Construction

22.1.2.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	300
Number of lanes in design direction	1
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	100.0
Number of trucks over design period	2,358,600

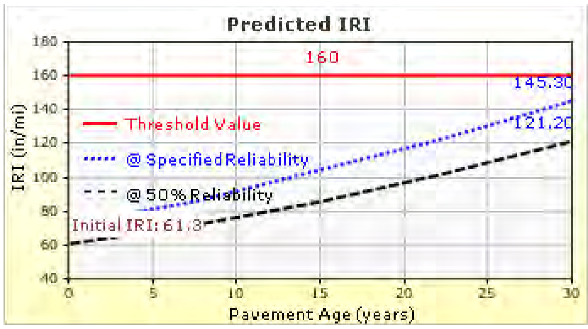
22.1.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

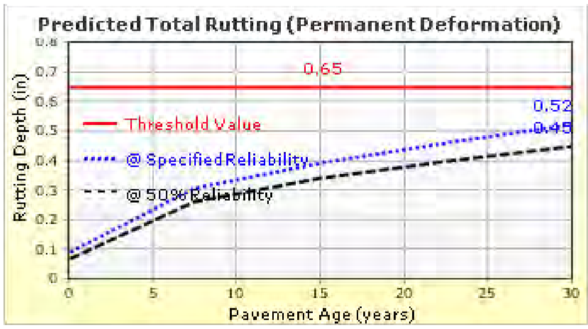
Layer Type	Material Type	Thickness (in)
AC Surface	HMA ½ in. mix with PG 64-22	1.75
AC Binder	HMA ¾ in. mix with PG 64-22	4
Granular Base	A-1-a	4
Subgrade	A-2-6	Semi-infinite

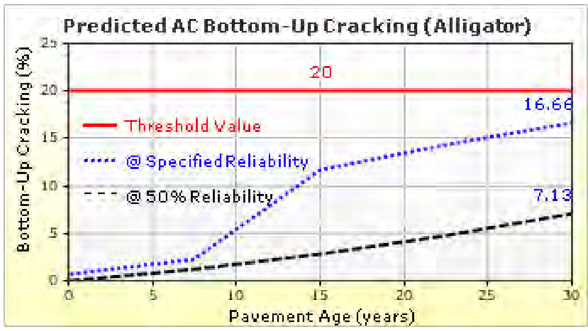
22.1.2.1.3 Distress Prediction & Reliability Summary

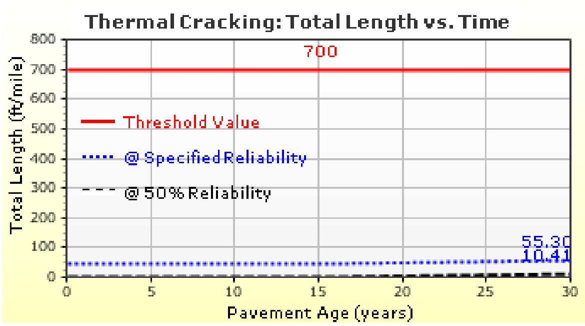
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	145.33	75.00	86.10	Pass
Permanent deformation - total pavement (in.)	0.65	0.52	75.00	97.30	Pass
AC bottom-up fatigue cracking (percent)	20.00	16.66	75.00	81.89	Pass
AC thermal fracture (ft/mile)	700.00	55.30	75.00	100.00	Pass
Permanent deformation - AC only (in.)	0.65	0.34	75.00	100.00	Pass

22.1.2.1.4 Distress Charts









22.1.2.2 First Rehabilitation – Mill & Overlay

The DARWin-ME based thresholds were used to establish future rehabilitation activities. A reasonable maximum service life of 20 years for new AC and 17 years for AC overlay was assumed for this climate since DARWin-ME does not consider all durability related distresses that develop over time. The first overlay project was then run for 17 years design period instead of typical MoDOT design life and the second overlay was run for 13 years. The mill and overlay then starts out rutting at 0 and IRI at 60 in/mile. Fatigue damage was low but is also determined and considered in the next overlay cracking prediction.

22.1.2.2.1 Rehabilitation Information

Rehabilitation strategy	Mill top 1.75 in. of AC surface course and place an AC overlay of 1.75 in. thick. Patching of 4.16% lane area is required in the travel lane.
Year of rehabilitation	20
Design period of rehab	17

22.1.2.2.2 Traffic Inputs

Design period (from year 20 to 37)	17
Initial two-way AADTT	480
Number of lanes in design direction	1
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	100.0
Number of trucks over design period	1,847,870

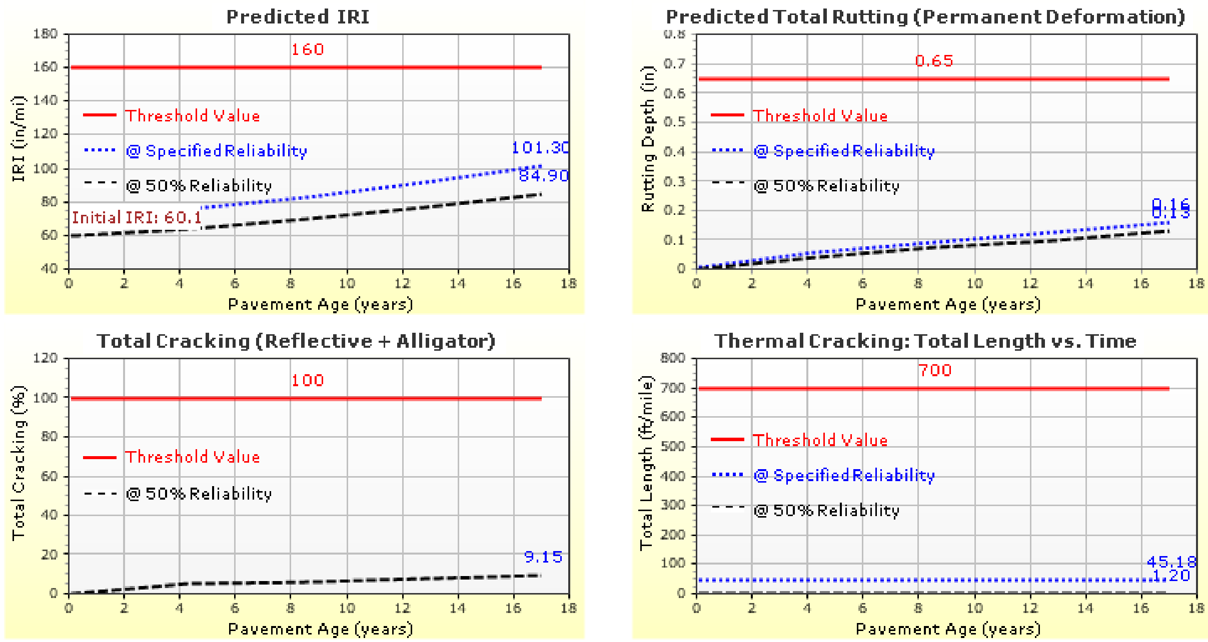
22.1.2.2.3 Pavement Structure

Layer Type	Material Type	Thickness (in)
AC Overlay (placed at 20 years)	HMA ½ in. mix with PG 64-22	1.75
AC Binder	HMA ¾ in. mix with PG 64-22	4
Granular Base	A-1-a	4
Subgrade	A-2-6	Semi-infinite

22.1.2.2.4 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	101.31	75.00	99.90	Pass
Permanent deformation - total pavement (in.)	0.65	0.16	75.00	100.00	Pass
Total Cracking (Reflective + Alligator) (percent)	15.00	9.15	50.00		Pass
AC thermal fracture (ft/mile)	700.00	45.18	75.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	20.00	0.76	75.00	100.00	Pass
Permanent deformation - AC only (in.)	0.65	0.16	75.00	100.00	Pass

22.1.2.2.5 Distress Charts



22.1.2.3 Second Rehabilitation – Mill & Overlay

The second rehabilitation was placed at 37 years with a design life of 13 years. Note that second rehabilitation has slightly greater than 3% linear traffic growth rate.

22.1.2.3.1 Rehabilitation Information

Rehabilitation strategy	Mill top 1.75 in. of AC surface course and place an AC overlay of 1.75 in. thick. Patching of 9.15% lane area is required in the travel lane.
Year of rehabilitation	37
Design period	13

22.1.2.3.2 Traffic Inputs

Design period (from year 37 to 50)	13
Initial two-way AADTT	725
Number of lanes in design direction	1
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	100.0
Number of trucks over design period	2,031,060

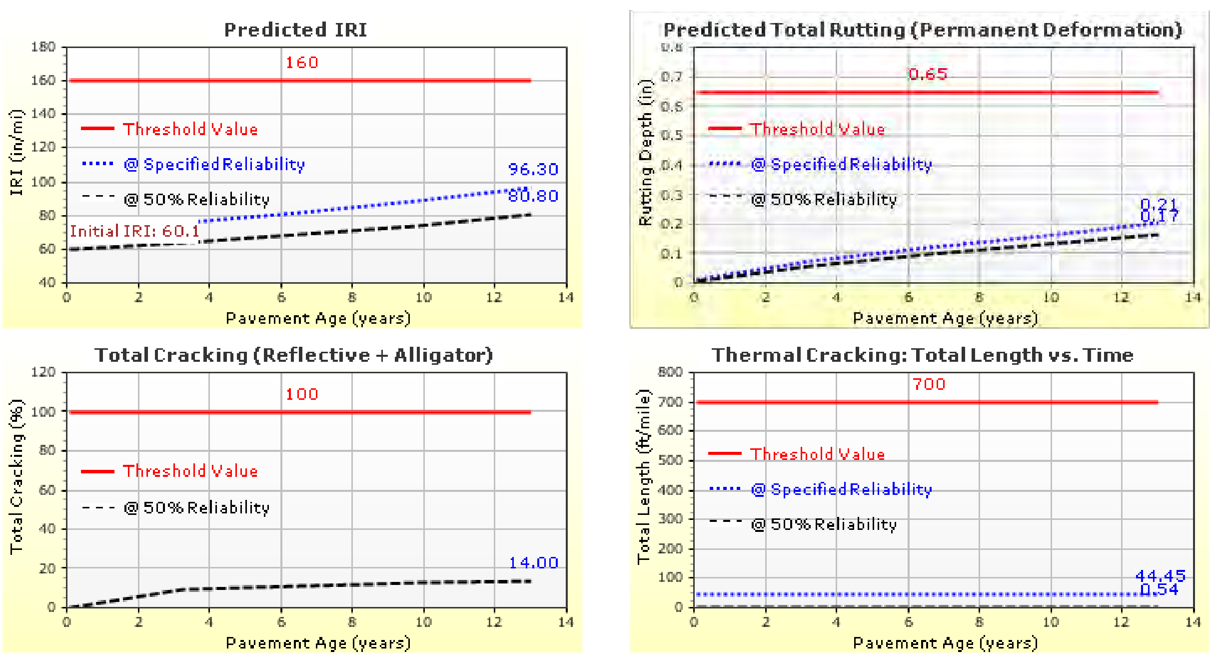
22.1.2.3.3 Pavement Structure

Layer Type	Material Type	Thickness (in)
AC Overlay (placed at 37 years)	HMA ½ in. mix with PG 64-22	1.75
AC Binder	HMA ¾ in. mix with PG 64-22	4
Granular Base	A-1-a	4
Subgrade	A-2-6	Semi-infinite

22.1.2.3.4 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	96.34	75.00	99.97	Pass
Permanent deformation - total pavement (in.)	0.65	0.21	75.00	100.00	Pass
Total Cracking (Reflective + Alligator) (percent)	15.00	14.00	50.00		Pass
AC thermal fracture (ft/mile)	700.00	44.45	75.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	20.00	0.76	75.00	100.00	Pass
Permanent deformation - AC only (in.)	0.65	0.21	75.00	100.00	Pass

22.1.2.3.5 Distress Charts



The pavement passes all of the criteria at 50 years. The overlay actually will last 15 years or 2 years longer than the 50-year analysis period and some salvage value can be considered in the LCCA.

22.1.2.4 *Summary of Asphalt Pavement Design and Life Cycle Rehabilitation based on DARWin-ME Predictions*

Pavement life cycle activities over a 50-year analysis period include the following as determined using the DARWin-ME threshold criteria:

Year	Activity	Description
0	New construction	Place 5.75 in. AC over 4 in. crushed stone base material
20	AC overlay 1	Mill 1.75 in. and replace 1.75 in. AC OL (Patching of 4.16% lane area is required in the travel lane).
37	AC overlay 2	Mill 1.75 in. and replace 1.75 in. AC OL (Patching of 9.15% lane area is required in the travel lane).
Salvage at 50	2 years	

22.2 PORTLAND CEMENT CONCRETE PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

The site conditions, Design period and analysis period are exactly the same as that used for the AC design.

22.2.1 MoDOT-Based Maintenance and Rehabilitation (M&R)

The MoDOT M&R strategy is to perform concrete pavement restoration at 25 years. This includes 1.5% cracked slabs replacement in the travel lane and diamond grinding of the surface to restore IRI and remove faulting.

22.2.1.1 New Construction

22.2.1.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	300
Number of lanes in design direction	1
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	100.0
Number of trucks over design period	2,358,600

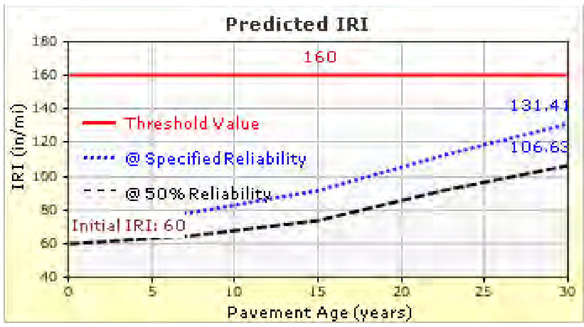
22.2.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

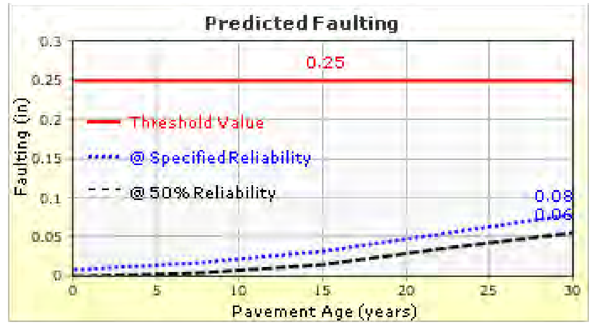
Layer Type	Material Type	Thickness (in)	Dowel Dia. (in)
JPCP-PCC	PCC	7.5	1.0
Granular Base	A-1-a	4	
Subgrade	A-2-6	Semi-infinite	

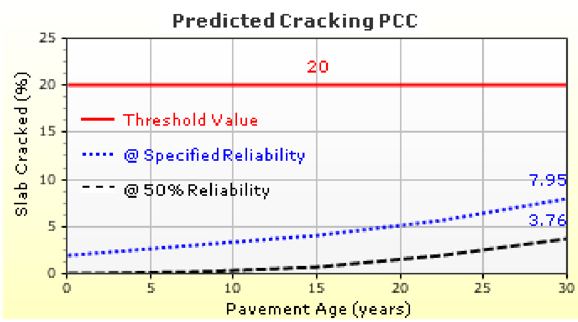
22.2.1.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	131.41	75.00	92.68	Pass
Mean joint faulting (in.)	0.25	0.08	75.00	100.00	Pass
JPCP transverse cracking (percent slabs)	20.00	7.95	75.00	99.56	Pass

22.2.1.1.4 Distress Charts







22.2.1.1.5 MoDOT Rehabilitation – Diamond Grinding and Full Depth Repair

The Missouri first rehabilitation is recommended at 25 years. The MoDOT expected life of the JPCP restoration is 25 years. This becomes the design period for the first restoration.

22.2.1.2 Summary of MoDOT Concrete Pavement Design and Life Cycle Rehabilitation

Pavement life cycle activities over a 50-year analysis period include the following as determined using the Missouri DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 7.5 in. PCC (with 1 in diameter dowel) over 4 in. crushed stone material
25	PCC Rehabilitation 1	¼ in. Diamond grinding and full depth repair (1.5% slabs replacement is required in the travel lane as per MoDOT M&R strategy)
50	End of analysis period	

22.2.2 DARWin-ME-Based Maintenance and Rehabilitation (M&R)

22.2.2.1 New Construction

22.2.2.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	300
Number of lanes in design direction	1
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	100.0
Number of trucks over design period	2,358,600

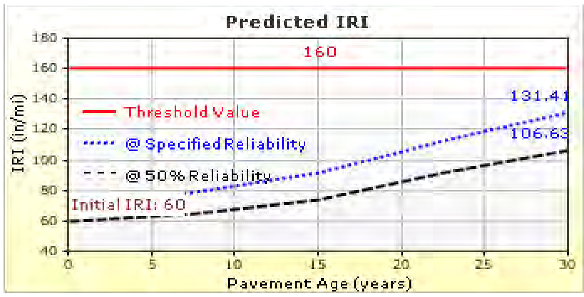
22.2.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

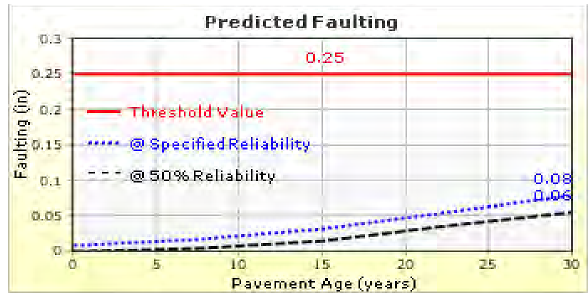
Layer Type	Material Type	Thickness (in)	Dowel Dia. (in)
JPCP-PCC	PCC	7.5	1.0
Granular Base	A-1-a	4	
Subgrade	A-2-6	Semi-infinite	

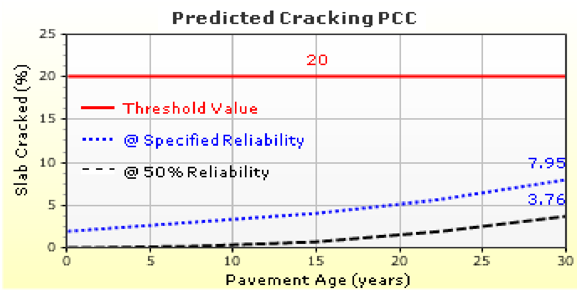
22.2.2.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	131.41	75.00	92.68	Pass
Mean joint faulting (in.)	0.25	0.08	75.00	100.00	Pass
JPCP transverse cracking (percent slabs)	20.00	7.95	75.00	99.56	Pass

22.2.2.1.4 Distress Charts







This design passes the DARWin-ME threshold criteria over 30 years. At 30 years, there is 7.95% fatigue cracking, 0.08 in faulting and 131.41 in/mile IRI at 75% reliability. Thus, diamond grinding and full depth repair are the most logical M&R treatment at 30 years.

22.2.2.2 First Rehabilitation –Diamond Grinding & Full Depth Repair

At 30 years, all cracked slabs will be replaced. Past fatigue cracking damage will be considered in future cracking projections. A maximum JPCP restoration life of 25 years was assumed since DARWin-ME does not consider all durability related distresses that develop over time. The first restoration project was then run for 20 years design period instead of typical MoDOT design life.

22.2.2.2.1 Traffic Inputs

Design period (from year 30 to 50)	20
Initial two-way AADTT	570
Number of lanes in design direction	1
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	100.0
Number of trucks over design period	2,675,270

22.2.2.2.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	Material Type	Thickness (in)
JPCP-PCC	PCC	7.25*

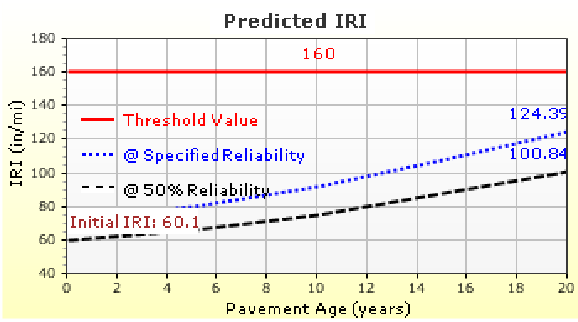
Granular Base	A-1-a	4
Subgrade	A-2-6	Semi-infinite

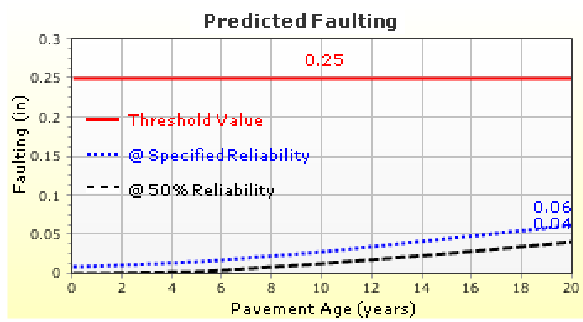
*Note: 0.25 inch slab thickness was removed by diamond grinding.

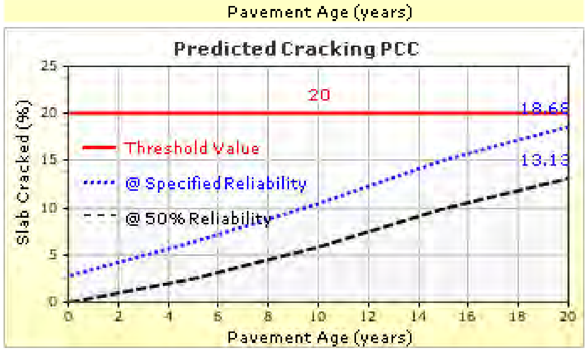
22.2.2.2.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	124.39	75.00	95.49	Pass
Mean joint faulting (in.)	0.25	0.06	75.00	100.00	Pass
JPCP transverse cracking (percent slabs)	20.00	18.68	75.00	79.80	Pass

22.2.2.2.4 Distress Charts







The pavement passes all of the criteria at 50 years. The restoration of the pavement actually will last 22 years (assuming texture depth does not wear down beyond critical level) or 2 years longer than the 50-year analysis period and some salvage value can be considered in the LCCA.

22.2.2.3 Summary of Concrete Pavement Design and Life Cycle Rehabilitation based on DARWin-ME Predictions

Pavement life cycle activities over a 50-year analysis period include the following as determined using the DARWin-ME based thresholds:

Year	Activity	Description

0	New construction	Place 7.5 in. PCC (with 1 in diameter dowel) over 4 in. crushed stone material
30	PCC Rehabilitation 1	¼ in. Diamond grinding & Full depth repair DARWin-ME (slab replacement of 3.76% is required in the travel lane)
Salvage at 50	2 years	

23 Detailed Information for Cell 3

23.1 ASPHALT CONCRETE PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

23.1.1 MoDOT-Based Maintenance and Rehabilitation (M&R)

23.1.1.1 New Construction

23.1.1.1.1 Traffic Inputs

Design period	20
Initial two-way AADTT	1000
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period (design lane)	4,224,120

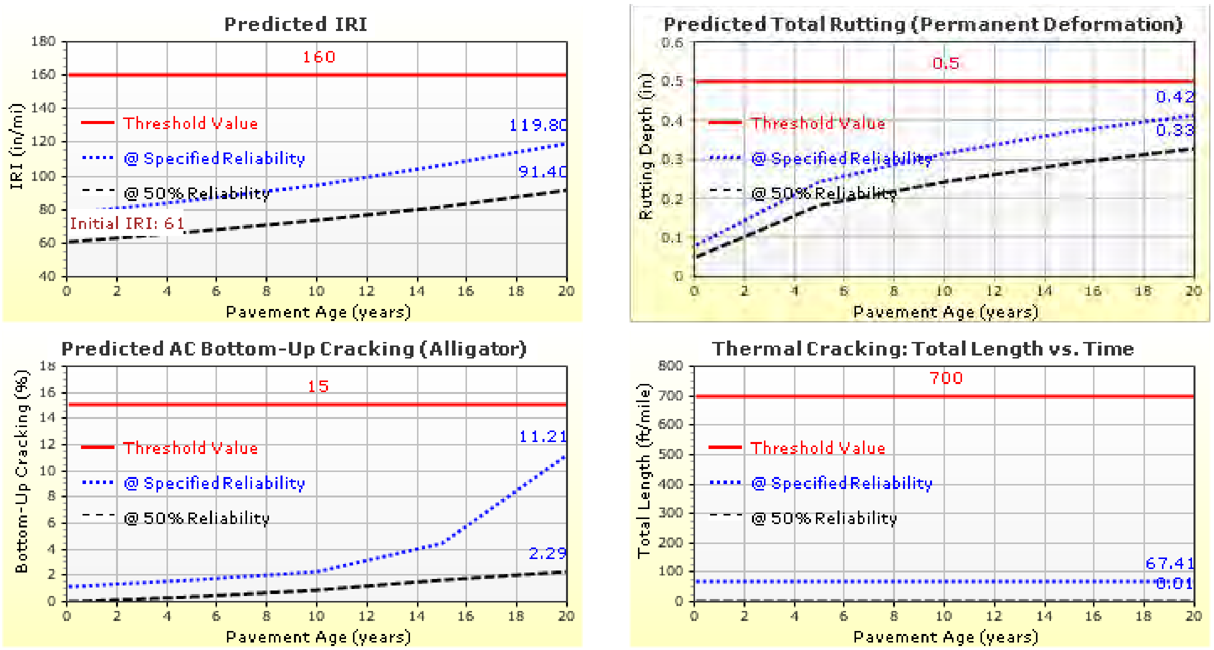
23.1.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	Material Type	Thickness (in)
AC Surface	HMA ½ in. mix with PG 70-22	2
AC Binder	HMA ¾ in. mix with PG 64-22	5
Granular Base	A-2-4	6
Subgrade	A-7-6	Semi-infinite

23.1.1.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.0	119.76	85.00	99.39	Pass
Permanent deformation - total pavement (in.)	0.5	0.42	85.00	97.86	Pass
AC bottom-up fatigue cracking (percent)	15.00	11.21	85.00	93.02	Pass
AC thermal fracture (ft/mile)	700.0	67.41	85.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.30	85.00	99.99	Pass

23.1.1.1.4 Distress Charts



23.1.1.2 MoDOT Rehabilitation – Mill & Overlay

The Missouri first rehabilitation is recommended at 20 years. The MoDOT expected life of the AC overlay is 15 years. This becomes the Design Period for the next overlay. The Missouri second rehabilitation was applied at 35 years with design period of 15 years.

23.1.1.3 Summary of Asphalt Pavement Design and Life Cycle Rehabilitation using MoDOT M&R

Pavement life cycle activities over a 50-year analysis period include the following as determined using the Missouri DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 7 in. AC over 6 in. crushed stone base material
20	AC overlay 1	Mill 2 in. and replace 2 in. AC OL (Patching of 2.29% lane area is required in the travel lane)
35	AC overlay 2	Mill 2 in. and replace 2 in. AC OL (Patching of 4.56% lane area is required in the travel lane)
50	End of analysis period	

23.1.2 DARWin-ME-Based Maintenance and Rehabilitation (M&R)

23.1.2.1 New Construction

23.1.2.1.1 Traffic Inputs

Design period	20
Initial two-way AADTT	1000
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	4,224,120

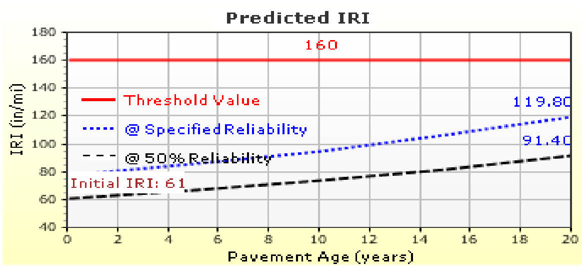
23.1.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

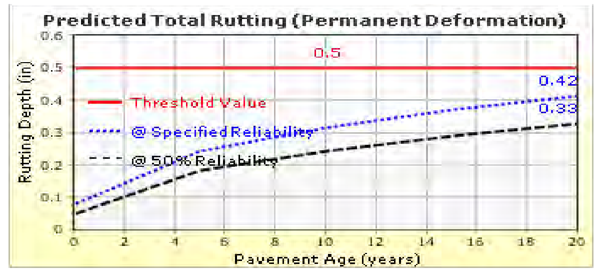
Layer Type	**Material Type**	**Thickness (in)**
AC Surface	HMA ½ in. mix with PG 70-22	2
AC Binder	HMA ¾ in. mix with PG 64-22	5
Granular Base	A-2-4	6
Subgrade	A-7-6	Semi-infinite

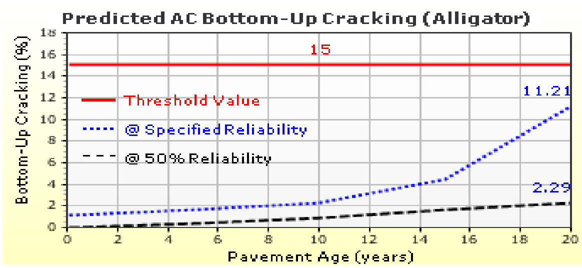
23.1.2.1.3 Distress Prediction & Reliability Summary

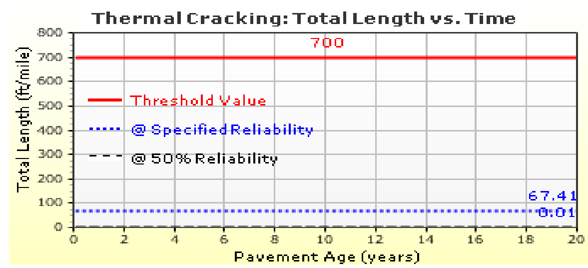
Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in./mile)	160.0	119.76	85.00	99.39	Pass
Permanent deformation - total pavement (in.)	0.5	0.42	85.00	97.86	Pass
AC bottom-up fatigue cracking (percent)	15.00	11.21	85.00	93.02	Pass
AC thermal fracture (ft/mile)	700.0	67.41	85.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.30	85.00	99.99	Pass

23.1.2.1.4 Distress Charts









23.1.2.2 First Rehabilitation – Mill & Overlay

The DARWin-ME based thresholds were used to establish future rehabilitation activities. A reasonable maximum service life of 20 years for new AC and 17 years for AC overlay was assumed for this climate since DARWin-ME does not consider all durability related distresses that develop over time. The first overlay project was then run for 17 years design period instead of typical MoDOT design life and the second overlay was run for 13 years. The mill and overlay then starts out rutting at 0 and IRI at 60 in/mile. Fatigue damage was low but is also determined and considered in the next overlay cracking prediction.

23.1.2.2.1 Rehabilitation Information

Rehabilitation strategy	Mill top 2 in. of AC surface course and place an AC overlay of 2 in. thick. Patching of 2.29% lane area is required in the travel lane.
Year of rehabilitation	20
Design period	17

23.1.2.2.2 Traffic Inputs

Design period (from year 20 to 37)	17
Initial two-way AADTT	1600
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	5,543,620

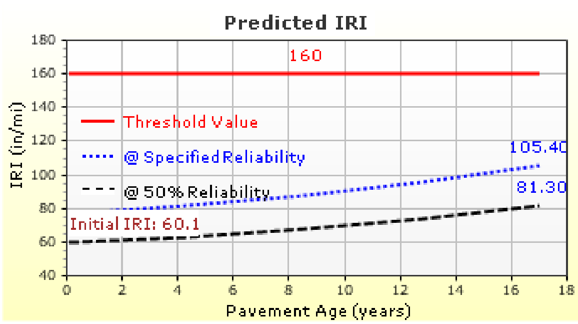
23.1.2.2.3 Pavement Structure

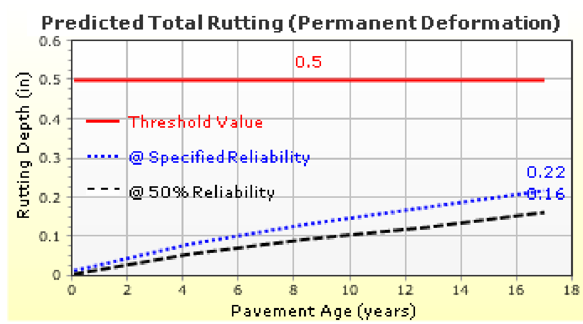
Layer Type	Material Type	Thickness (in)
AC Overlay (placed at 20 years)	HMA ½ in. mix with PG 70-22	2
AC Binder	HMA ¾ in. mix with PG 64-22	5
Granular Base	A-2-4	6
Subgrade	A-7-6	Semi-infinite

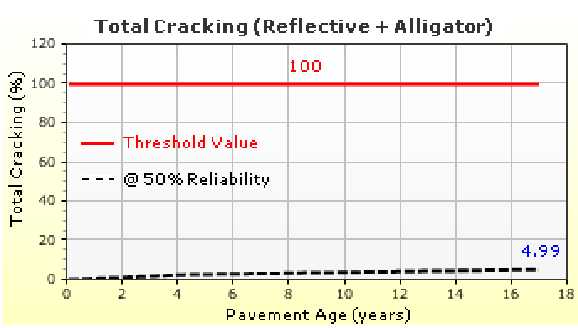
23.1.2.2.4 Distress Prediction & Reliability Summary

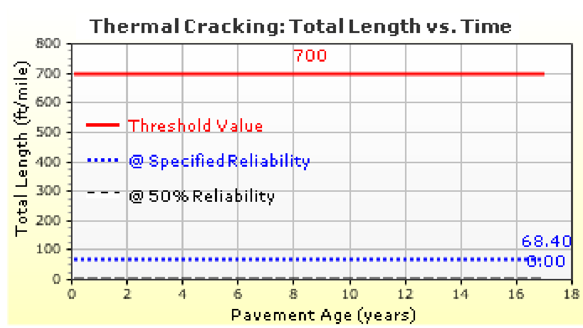
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	105.43	85.00	99.96	Pass
Permanent deformation - total pavement (in.)	0.5	0.22	85.00	100.00	Pass
Total Cracking (Reflective + Alligator) (percent)	10.00	4.99	50.00		Pass
AC thermal fracture (ft/mile)	700.00	68.40	85.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	15.00	1.17	85.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.22	85.00	100.00	Pass

23.1.2.2.5 Distress Charts









23.1.2.3 Second Rehabilitation – Mill & Overlay

The second rehabilitation was placed at 37 years with a design life of 13 years. Note that second rehabilitation has slightly greater than 3% linear traffic growth rate.

23.1.2.3.1 Rehabilitation Information

Rehabilitation strategy	Mill top 2 in. of AC surface course and place an AC overlay of 2 in. thick. Patching of 4.99% lane area is required in the travel lane.
Year of rehabilitation	37
Design period	13

23.1.2.3.2 Traffic Inputs

Design period (from year 37 to 50)	13
Initial two-way AADTT	2416
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	6,091,510

23.1.2.3.3 Pavement Structure

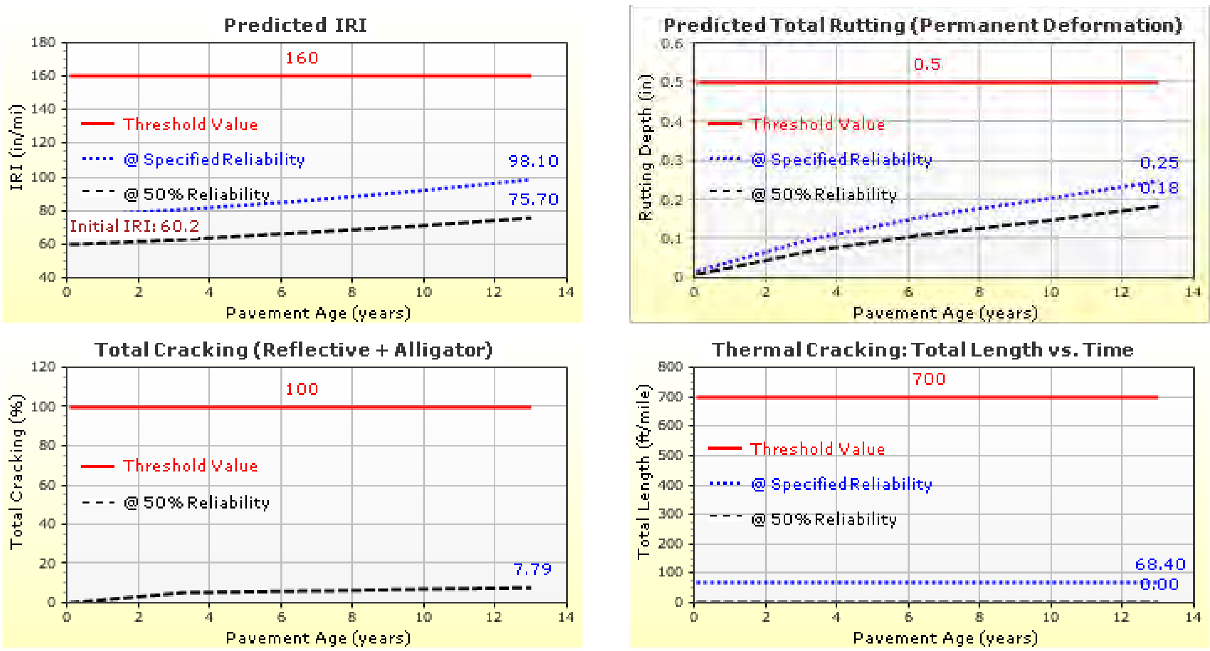
Layer Type	**Material Type**	**Thickness (in)**
AC Overlay (placed at 37 years)	HMA ½ in. mix with PG 70-22	2
AC Binder	HMA ¾ in. mix with PG 64-22	5
Granular Base	A-2-4	6
Subgrade	A-7-6	Semi-infinite

23.1.2.3.4 Distress Prediction & Reliability Summary

Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in./mile)	160.00	98.07	85.00	100.00	Pass
Permanent deformation - total pavement (in.)	0.5	0.25	85.00	100.00	Pass

Total Cracking (Reflective + Alligator) (percent)	10.00	7.79	50.00		Pass
AC thermal fracture (ft/mile)	700.00	68.40	85.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	15.00	1.17	85.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.25	85.00	100.00	Pass

23.1.2.3.5 Distress Charts



The pavement passes all of the criteria at 50 years. The overlay actually will last 17 years or 4 years longer than the 50-year analysis period and some salvage value can be considered in the LCCA.

23.1.2.4 Summary of Asphalt Pavement Design and Life Cycle Rehabilitation based on DARWin-ME Predictions

Pavement life cycle activities over a 50-year analysis period include the following as determined using the DARWin-ME threshold criteria:

Year	Activity	Description
0	New construction	Place 7 in. AC over 6 in. crushed stone base material
20	AC overlay 1	Mill 2 in. and replace 2 in. AC OL (Patching of 2.29% lane area is required in the travel lane).

37	AC overlay 2	Mill 2 in. and replace 2 in. AC OL (Patching of 4.99% lane area is required in the travel lane).
Salvage at 50	4 years	

23.2 PORTLAND CEMENT CONCRETE PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

The site conditions, Design period and analysis period are exactly the same as that used for the AC design.

23.2.1 MoDOT-Based Maintenance and Rehabilitation (M&R)

The MoDOT M&R strategy is to perform concrete pavement restoration at 20 years. This includes 1.5% cracked slabs replacement in the travel lane and diamond grinding of the surface to restore IRI and remove faulting.

23.2.1.1 New Construction

23.2.1.1.1 Traffic Inputs

Design period	20
Initial two-way AADTT	1000
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	4,224,120

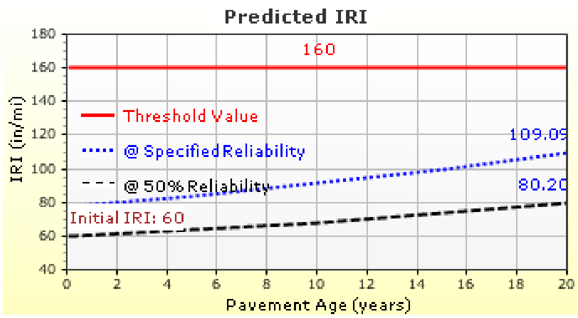
23.2.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

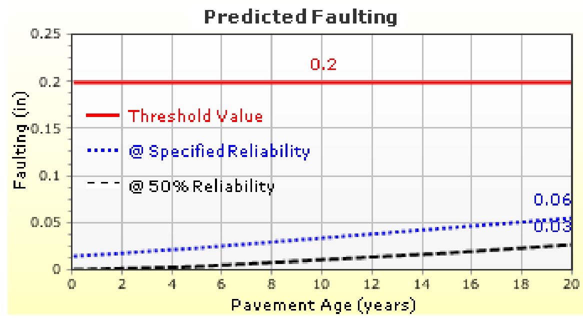
Layer Type	Material Type	Thickness (in)	Dowel Dia. (in)
JPCP-PCC	PCC	8	1.25
Granular Base	A-2-4	4	
Subgrade	A-7-6	Semi-infinite	

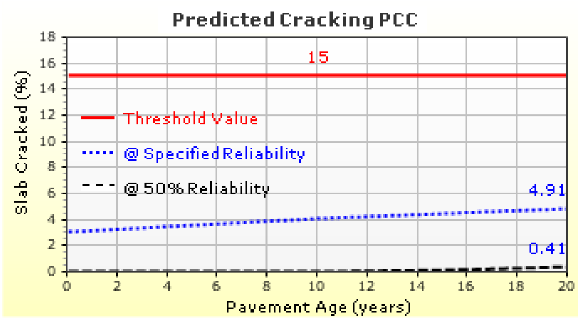
23.2.1.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	109.09	85.00	99.79	Pass
Mean joint faulting (in.)	0.20	0.06	85.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	4.91	85.00	99.96	Pass

23.2.1.1.4 Distress Charts







23.2.1.2 Summary of MoDOT Concrete Pavement Design and Life Cycle Rehabilitation

Pavement life cycle activities over a 50-year analysis period include the following as determined using the Missouri DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 8 in. PCC (with 1.25 in diameter dowel) over 4 in. crushed stone material
20	PCC Rehabilitation 1	¼ in. Diamond grinding and full depth repair (1.5% slabs repaired in the travel lane as per MoDOT M&R strategy)
35	PCC Rehabilitation 2	¼ in. Diamond grinding and full depth repair (1.5% slabs repaired in the travel lane as per MoDOT M&R strategy)
50	End of analysis period	

23.2.2 DARWin-ME-Based Maintenance and Rehabilitation (M&R)

23.2.2.1 New Construction

23.2.2.1.1 Traffic Inputs

Design period	20
Initial two-way AADTT	1000
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	4,224,120

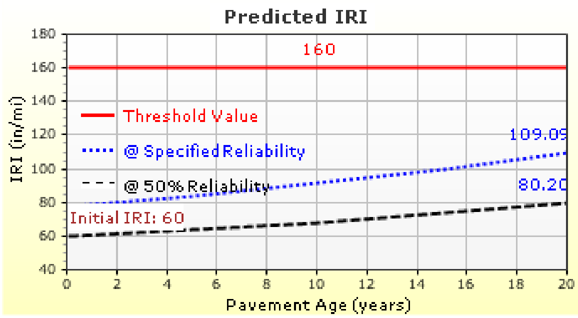
23.2.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

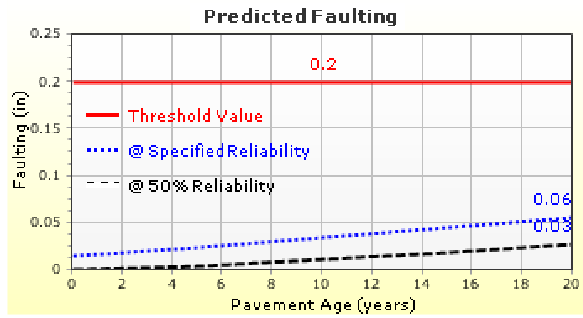
Layer Type	Material Type	Thickness (in)	Dowel Dia. (in)
JPCP-PCC	PCC	8	1.25
Granular Base	A-2-4	4	
Subgrade	A-7-6	Semi-infinite	

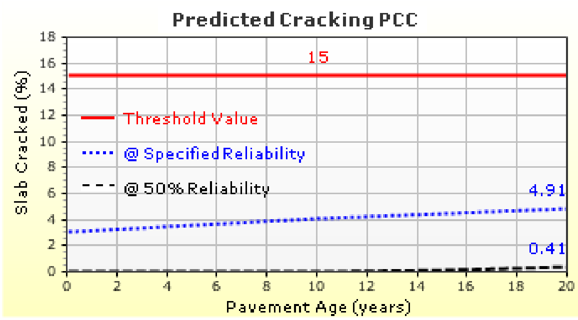
23.2.2.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	109.09	85.00	99.79	Pass
Mean joint faulting (in.)	0.20	0.06	85.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	4.91	85.00	99.96	Pass

23.2.2.1.4 Distress Charts







This design passes the DARWin-ME threshold criteria over 20 years. At 20 years, there is 4.91% fatigue cracking, 0.06 in faulting and 109.09 in/mile IRI at 85% reliability. Thus, diamond grinding and full depth repair are the most logical M&R treatment at 20 years.

23.2.2.2 First Rehabilitation –Diamond Grinding & Full Depth Repair

At 20 years, all cracked slabs will be replaced. Past fatigue cracking damage will be considered in future cracking projections. A maximum JPCP restoration life of 25 years was assumed since DARWin-ME does not consider all durability related distresses that develop over time. The first restoration project was then run for 20 years design period instead of typical MoDOT design life and the second overlay was run for 10 years.

23.2.2.2.1 Traffic Inputs

Design period (from year 20 to 40)	20
Initial two-way AADTT	1600
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	6,758,590

23.2.2.2.2 Pavement Structure That Meets Performance & Reliability Requirements

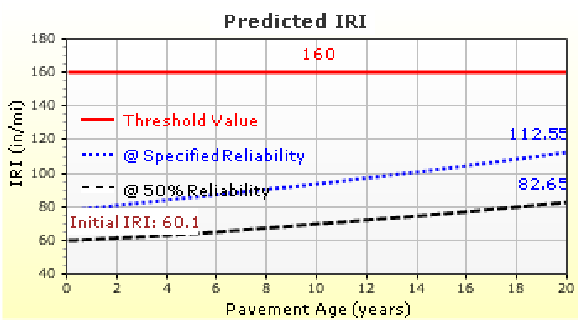
Layer Type	Material Type	Thickness (in)
JPCP-PCC	PCC	7.75*
Granular Base	A-2-4	4
Subgrade	A-7-6	Semi-infinite

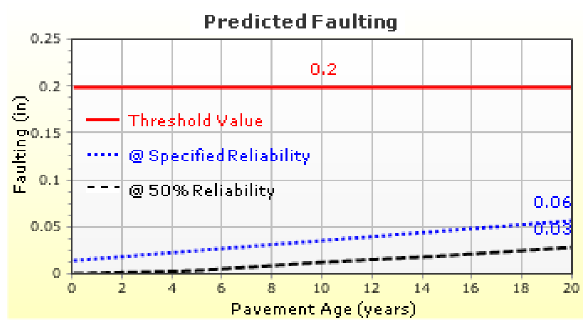
*Note: 0.25 inch slab thickness was removed by diamond grinding.

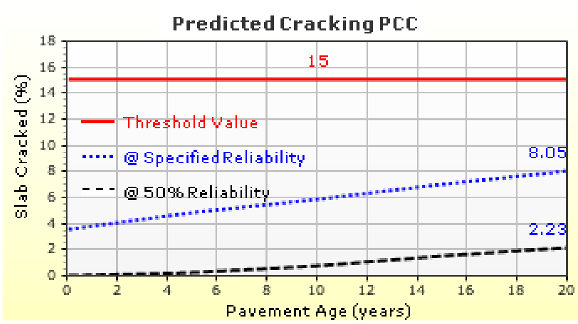
23.2.2.2.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	112.55	85.00	99.63	Pass
Mean joint faulting (in.)	0.20	0.06	85.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	8.05	85.00	98.85	Pass

23.2.2.2.4 Distress Charts







23.2.2.3 Second Rehabilitation –Diamond Grinding & Full Depth Repair

The second rehabilitation was placed at 40 years with a design life of 10 years. Note that second rehabilitation has slightly greater than 3% linear traffic growth rate.

23.2.2.3.1 Traffic Inputs

Design period (from year 40 to 50)	10
Initial two-way AADTT	2560
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	4,775,720

23.2.2.3.2 Pavement Structure That Meets Performance & Reliability Requirements

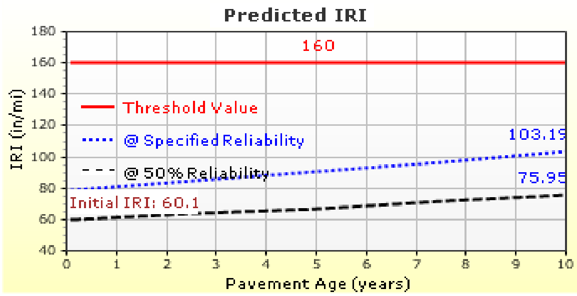
Layer Type	Material Type	Thickness (in)
JPCP-PCC	PCC	7.5*
Granular Base	A-2-4	4
Subgrade	A-7-6	Semi-infinite

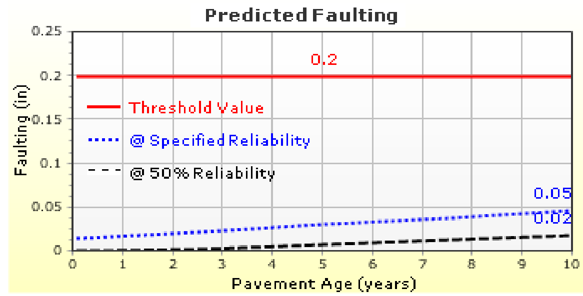
*Note: 0.25 inch slab thickness was removed by diamond grinding.

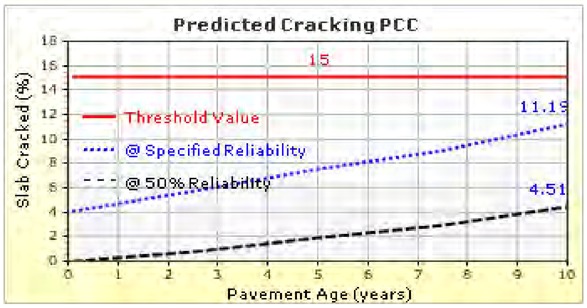
23.2.2.3.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	103.19	85.00	99.93	Pass
Mean joint faulting (in.)	0.20	0.05	85.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	11.19	85.00	94.82	Pass

23.2.2.3.4 Distress Charts







The pavement passes all of the criteria at 50 years. The restoration of the pavement actually will last 14 years (assuming texture depth does not wear down beyond critical level) or 4 years longer than the 50-year analysis period and some salvage value can be considered in the LCCA.

23.2.2.4 Summary of Concrete Pavement Design and Life Cycle Rehabilitation based on DARWin-ME Predictions

Pavement life cycle activities over a 50-year analysis period include the following as determined using the DARWin-ME based thresholds:

Year	Activity	Description
0	New construction	Place 8 in. PCC (with 1.25 in diameter dowel) over 4 in. crushed stone material
20	PCC Rehabilitation 1	¼ in. Diamond grinding & Full depth repair (0.41% slabs repaired in the travel lane)
40	PCC Rehabilitation 2	¼ in. Diamond grinding & Full depth repair (2.23% slabs repaired in the travel lane)
Salvage at 50	4 years	

24 Detailed Information for Cell 4

24.1 ASPHALT CONCRETE PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

24.1.1 MoDOT-Based Maintenance and Rehabilitation (M&R)

24.1.1.1 New Construction

24.1.1.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	1000
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period (design lane)	7,075,810

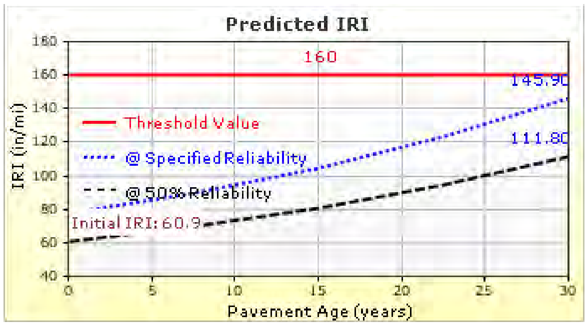
24.1.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

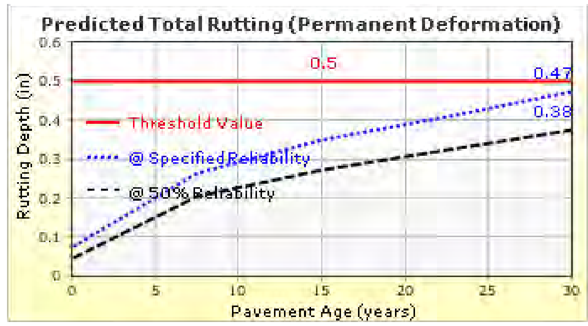
Layer Type	Material Type	Thickness (in)
AC Surface	HMA ½ in. mix with PG 70-22	2
AC Binder	HMA ¾ in. mix with PG 64-22	5.5
Granular Base	A-2-4	6
Subgrade	A-7-6	Semi-infinite

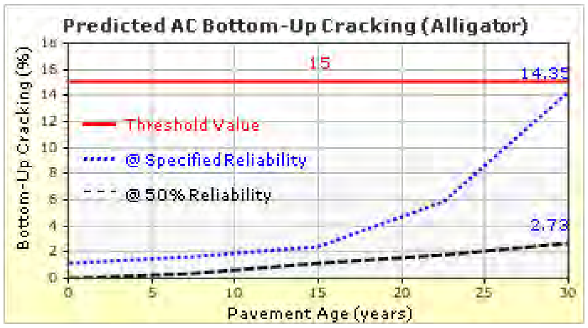
24.1.1.1.3 Distress Prediction & Reliability Summary

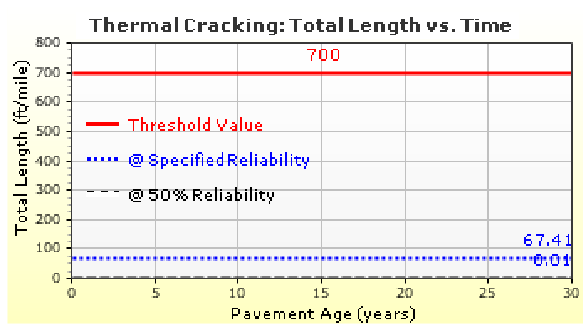
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.0	145.94	85.00	92.83	Pass
Permanent deformation - total pavement (in.)	0.5	0.47	85.00	90.47	Pass
AC bottom-up fatigue cracking (percent)	15.00	14.34	85.00	86.32	Pass
AC thermal fracture (ft/mile)	700.0	67.41	85.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.36	85.00	99.64	Pass

24.1.1.1.4 Distress Charts









24.1.1.2 MoDOT Rehabilitation – Mill & Overlay

The Missouri first rehabilitation is recommended at 20 years. The MoDOT expected life of the AC overlay is 15 years. This becomes the Design Period for the next overlay. The Missouri second rehabilitation was applied at 35 years with design period of 15 years.

24.1.1.3 Summary of Asphalt Pavement Design and Life Cycle Rehabilitation using MoDOT M&R

Pavement life cycle activities over a 50-year analysis period include the following as determined using the Missouri DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 7.5 in. AC over 6 in. crushed stone base material
20	AC overlay 1	Mill 2 in. and replace 2 in. AC OL (Patching of 1.6% lane area is required in the travel lane)
35	AC overlay 2	Mill 2 in. and replace 2 in. AC OL (Patching of 3.17% lane area is required in the travel lane)
50	End of analysis period	

24.1.2 DARWin-ME-Based Maintenance and Rehabilitation (M&R)

24.1.2.1 New Construction

24.1.2.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	1000
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	7,075,810

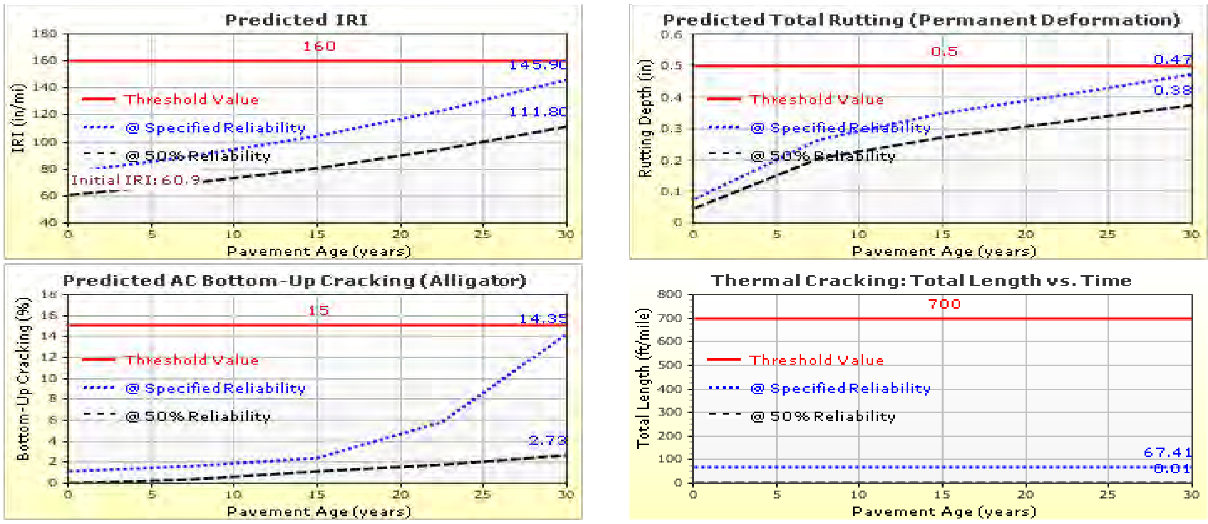
24.1.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	Material Type	Thickness (in)
AC Surface	HMA ½ in. mix with PG 70-22	2
AC Binder	HMA ¾ in. mix with PG 64-22	5.5
Granular Base	A-2-4	6
Subgrade	A-7-6	Semi-infinite

24.1.2.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.0	145.94	85.00	92.83	Pass
Permanent deformation - total pavement (in.)	0.5	0.47	85.00	90.47	Pass
AC bottom-up fatigue cracking (percent)	15.00	14.34	85.00	86.32	Pass
AC thermal fracture (ft/mile)	700.0	67.41	85.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.36	85.00	99.64	Pass

24.1.2.1.4 Distress Charts



24.1.2.2 4. First Rehabilitation – Mill & Overlay

The DARWin-ME based thresholds were used to establish future rehabilitation activities. A reasonable maximum service life of 20 years for new AC and 17 years for AC overlay was assumed for this climate since DARWin-ME does not consider all durability related distresses that develop over time. The first overlay project was then run for 17 years design period instead of typical MoDOT design life and the second overlay was run for 13 years. The mill and overlay then starts out rutting at 0 and IRI at 60 in/mile. Fatigue damage was low but is also determined and considered in the next overlay cracking prediction.

24.1.2.2.1 Rehabilitation Information

Rehabilitation strategy	Mill top 2 in. of AC surface course and place an AC overlay of 2 in. thick. Patching of 1.6% lane area is required in the travel lane.
Year of rehabilitation	20
Design period	17

24.1.2.2.2 Traffic Inputs

Design period (from year 20 to 37)	17
Initial two-way AADTT	1600
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0

Percent of trucks in design lane (%)	90.0
Number of trucks over design period	5,543,620

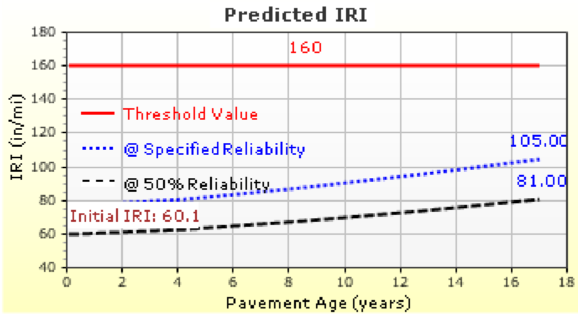
24.1.2.2.3 Pavement Structure

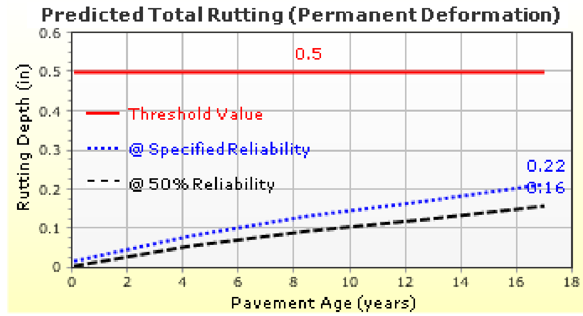
Layer Type	Material Type	Thickness (in)
AC Overlay (placed at 20 years)	HMA ½ in. mix with PG 70-22	2
AC Binder	HMA ¾ in. mix with PG 64-22	5.5
Granular Base	A-2-4	6
Subgrade	A-7-6	Semi-infinite

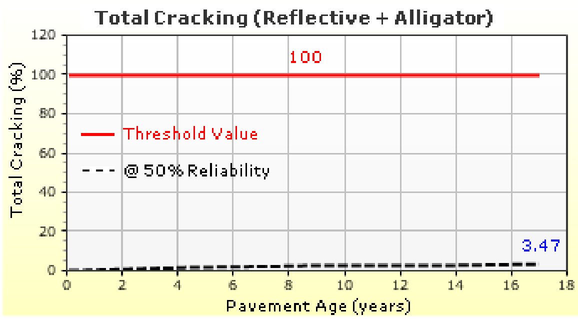
24.1.2.2.4 Distress Prediction & Reliability Summary

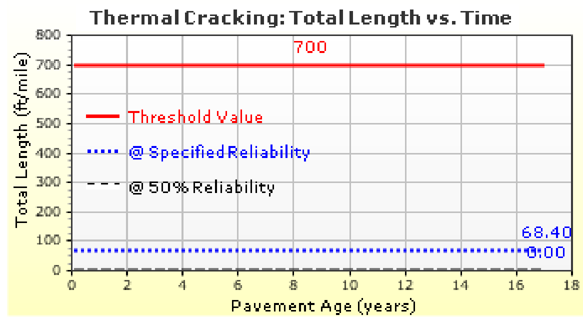
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	105.02	85.00	99.97	Pass
Permanent deformation - total pavement (in.)	0.5	0.22	85.00	100.00	Pass
Total Cracking (Reflective + Alligator) (percent)	10.00	3.47	50.00		Pass
AC thermal fracture (ft/mile)	700.00	68.40	85.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	15.00	1.17	85.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.22	85.00	100.00	Pass

24.1.2.2.5 Distress Charts









24.1.2.3 Second Rehabilitation – Mill & Overlay

The second rehabilitation was placed at 37 years with a design life of 13 years. Note that second rehabilitation has slightly greater than 3% linear traffic growth rate.

24.1.2.3.1 Rehabilitation Information

Rehabilitation strategy	Mill top 2 in. of AC surface course and place an AC overlay of 2 in. thick. Patching of 3.47% lane area is required in the travel lane.
Year of rehabilitation	37
Design period	13

24.1.2.3.2 Traffic Inputs

Design period (from year 37 to 50)	13
Initial two-way AADTT	2416
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	6,091,510

24.1.2.3.3 Pavement Structure

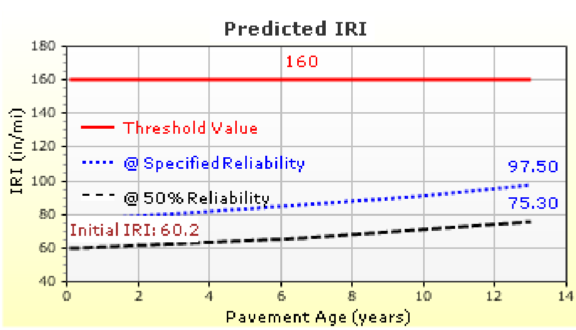
Layer Type	**Material Type**	**Thickness (in)**

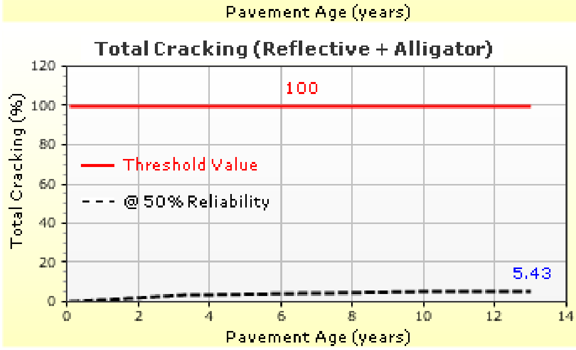
AC Overlay (placed at 37 years)	HMA ½ in. mix with PG 70-22	2
AC Binder	HMA ¾ in. mix with PG 64-22	5.5
Granular Base	A-2-4	6
Subgrade	A-7-6	Semi-infinite

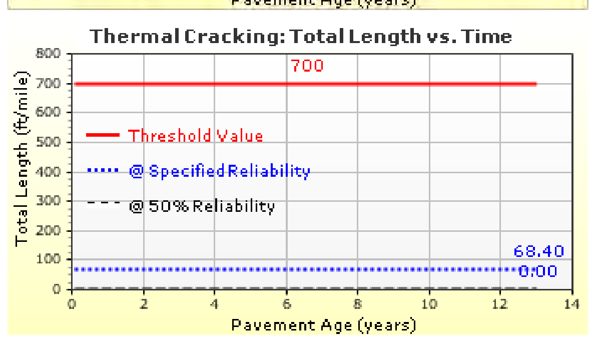
24.1.2.4 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	97.52	85.00	100.00	Pass
Permanent deformation - total pavement (in.)	0.5	0.24	85.00	100.00	Pass
Total Cracking (Reflective + Alligator) (percent)	10.00	5.43	50.00		Pass
AC thermal fracture (ft/mile)	700.00	68.40	85.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	15.00	1.17	85.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.24	85.00	100.00	Pass

24.1.2.5 Distress Charts







The pavement passes all of the criteria at 50 years. The overlay actually will last 17 years or 4 years longer than the 50-year analysis period and some salvage value can be considered in the LCCA.

24.1.2.6 Summary of Asphalt Pavement Design and Life Cycle Rehabilitation based on DARWin-ME Predictions

Pavement life cycle activities over a 50-year analysis period include the following as determined using the DARWin-ME threshold criteria:

Year	Activity	Description
0	New construction	Place 7 in. AC over 6 in. crushed stone base material
20	AC overlay 1	Mill 2 in. and replace 2 in. AC OL (Patching of 1.6% lane area is required in the travel lane).
37	AC overlay 2	Mill 2 in. and replace 2 in. AC OL (Patching of 3.47% lane area is required in the travel lane).
Salvage at 50	4 years	

24.2 PORTLAND CEMENT CONCRETE PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

The site conditions, Design period and analysis period are exactly the same as that used for the AC design.

24.2.1 MoDOT-Based Maintenance and Rehabilitation (M&R)

The MoDOT M&R strategy is to perform concrete pavement restoration at 25 years. This includes 1.5% cracked slabs replacement in the travel lane and diamond grinding of the surface to restore IRI and remove faulting.

24.2.1.1 New Construction

24.2.1.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	1000
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	7,075,810

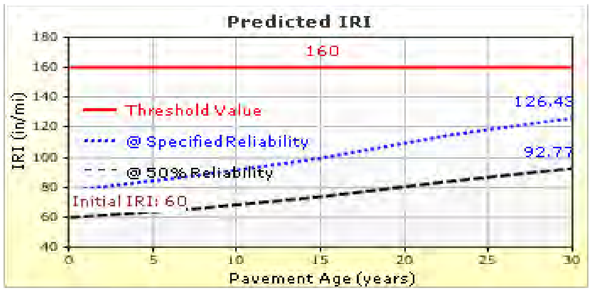
24.2.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

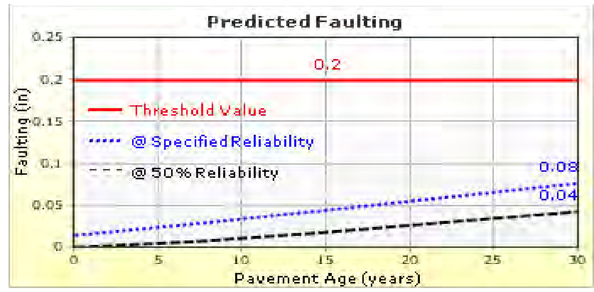
Layer Type	Material Type	Thickness (in)	Dowel Dia. (in)
JPCP-PCC	PCC	8	1.25
Granular Base	A-2-4	4	
Subgrade	A-7-6	Semi-infinite	

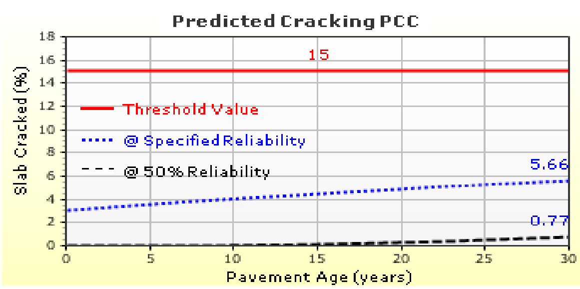
24.2.1.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	126.43	85.00	98.08	Pass
Mean joint faulting (in.)	0.20	0.08	85.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	5.66	85.00	99.87	Pass

24.2.1.1.4 Distress Charts







24.2.1.1.5 Summary of MoDOT Concrete Pavement Design and Life Cycle Rehabilitation

Pavement life cycle activities over a 50-year analysis period include the following as determined using the Missouri DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 8 in. PCC (with 1.25 in diameter dowel) over 4 in. crushed stone material
20	PCC Rehabilitation 1	¼ in. Diamond grinding and full depth repair (1.5% slabs repaired in the travel lane as per MoDOT M&R strategy)
35	PCC Rehabilitation 2	¼ in. Diamond grinding and full depth repair (1.5% slabs repaired in the travel lane as per MoDOT M&R strategy)
50	End of analysis period	

24.2.2 DARWin-ME-Based Maintenance and Rehabilitation (M&R)

24.2.2.1 New Construction

24.2.2.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	1000
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	7,075,810

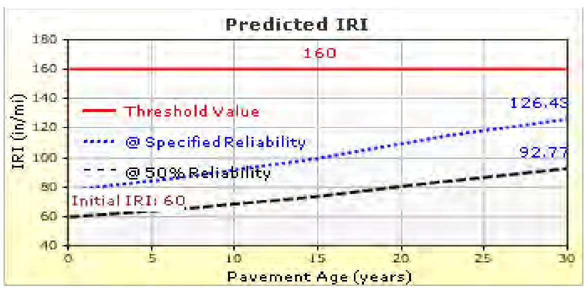
24.2.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

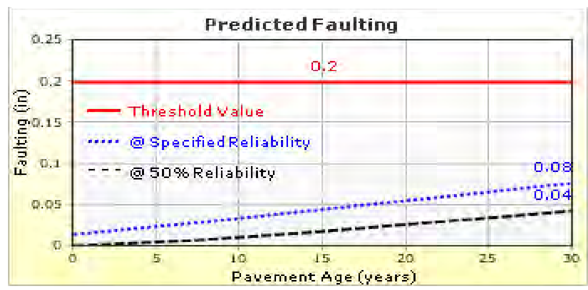
Layer Type	Material Type	Thickness (in)	Dowel Dia. (in)
JPCP-PCC	PCC	8	1.25
Granular Base	A-2-4	4	
Subgrade	A-7-6	Semi-infinite	

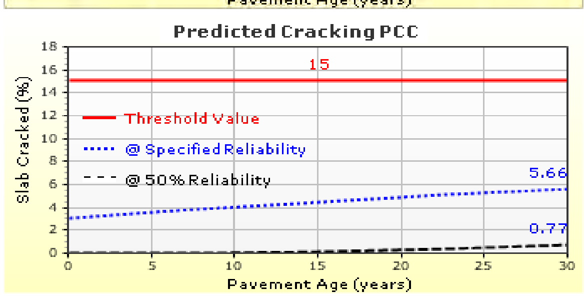
24.2.2.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	126.43	85.00	98.08	Pass
Mean joint faulting (in.)	0.20	0.08	85.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	5.66	85.00	99.87	Pass

24.2.2.1.4 Distress Charts







This design passes the DARWin-ME threshold criteria over 30 years. At 30 years, there is 5.66% fatigue cracking, 0.08 in faulting and 126.43 in/mile IRI at 85% reliability. Thus, diamond grinding and full depth repair are the most logical M&R treatment at 30 years.

24.2.2.2 First Rehabilitation –Diamond Grinding & Full Depth Repair

At 30 years, all cracked slabs will be replaced. Past fatigue cracking damage will be considered in future cracking projections. A maximum JPCP restoration life of 25 years was assumed since DARWin-ME does not consider all durability related distresses that develop over time. The first restoration project was then run for 20 years design period instead of typical MoDOT design life.

24.2.2.2.1 Traffic Inputs

Design period (from year 30 to 50)	20
Initial two-way AADTT	1900
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	8,025,820

24.2.2.2.2 Pavement Structure That Meets Performance & Reliability Requirements

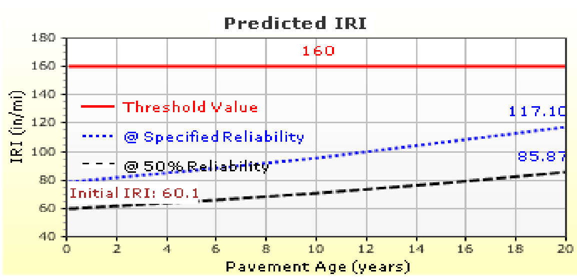
Layer Type	Material Type	Thickness (in)
JPCP-PCC	PCC	7.75*
Granular Base	A-2-4	4
Subgrade	A-7-6	Semi-infinite

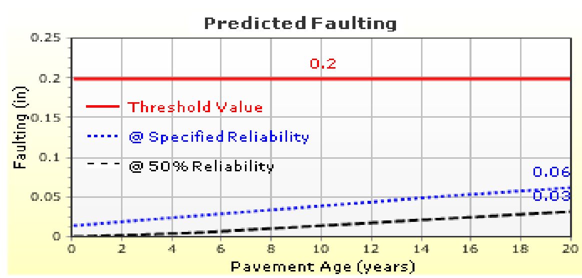
*Note: 0.25 inch slab thickness was removed by diamond grinding.

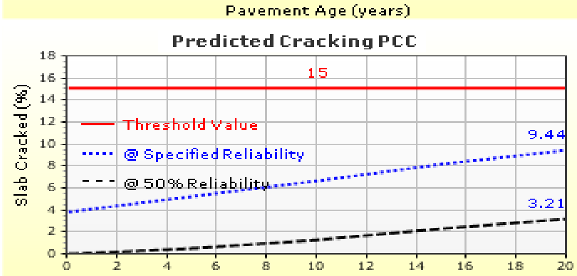
24.2.2.2.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	117.10	85.00	99.30	Pass
Mean joint faulting (in.)	0.20	0.06	85.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	9.44	85.00	97.50	Pass

24.2.2.2.4 Distress Charts







The pavement passes all of the criteria at 50 years. The restoration of the pavement actually will last 25 years (assuming texture depth does not wear down beyond critical level) or 5 years longer than the 50-year analysis period and some salvage value can be considered in the LCCA.

24.2.2.3 Summary of Concrete Pavement Design and Life Cycle Rehabilitation based on DARWin-ME Predictions

Pavement life cycle activities over a 50-year analysis period include the following as determined using the DARWin-ME based thresholds:

Year	Activity	Description
0	New construction	Place 8 in. PCC (with 1.25 in diameter dowel) over 4 in. crushed stone material
30	PCC Rehabilitation 1	¼ in. Diamond grinding & Full depth repair (0.77% slabs repaired in the travel lane)
Salvage at 50	5 years	

25 Detailed Information for Cell 5

25.1 ASPHALT CONCRETE PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

25.1.1 MoDOT-Based Maintenance and Rehabilitation (M&R)

25.1.1.1 New Construction

25.1.1.1.1 Traffic Inputs

Design period	40
Initial two-way AADTT	1000
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period (design lane)	10,420,600

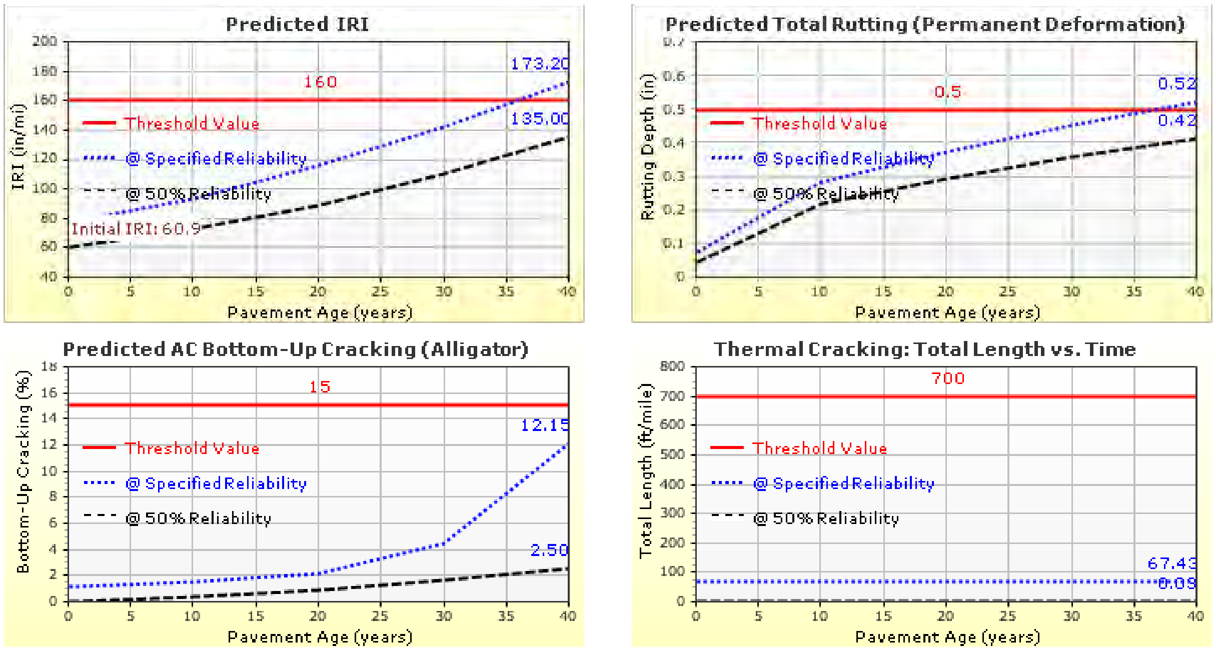
25.1.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	Material Type	Thickness (in)
AC Surface	HMA ½ in. mix with PG 70-22	2
AC Binder	HMA ¾ in. mix with PG 64-22	6.25
Granular Base	A-2-4	6
Subgrade	A-7-6	Semi-infinite

25.1.1.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.0	173.16	85.00	75.15	Fail
Permanent deformation - total pavement (in.)	0.5	0.52	85.00	79.34	Fail
AC bottom-up fatigue cracking (percent)	15.00	12.15	85.00	91.04	Pass
AC thermal fracture (ft/mile)	700.0	67.43	85.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.41	85.00	97.72	Pass

25.1.1.1.4 Distress Charts



25.1.1.2 MoDOT Rehabilitation – Mill & Overlay

The Missouri first rehabilitation is recommended at 20 years. The MoDOT expected life of the AC overlay is 15 years. This becomes the Design Period for the next overlay. The Missouri second rehabilitation was applied at 35 years with design period of 15 years.

25.1.1.3 Summary of Asphalt Pavement Design and Life Cycle Rehabilitation using MoDOT M&R

Pavement life cycle activities over a 50-year analysis period include the following as determined using the Missouri DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 8.25 in. AC over 6 in. crushed stone base material
20	AC overlay 1	Mill 2 in. and replace 2 in. AC OL (Patching of 0.985% lane area is required in the travel lane)
35	AC overlay 2	Mill 2 in. and replace 2 in. AC OL (Patching of 1.96% lane area is required in the travel lane)
50	End of analysis period	

25.1.2 DARWin-ME-Based Maintenance and Rehabilitation (M&R)

25.1.2.1 New Construction

25.1.2.1.1 Traffic Inputs

Design period	40
Initial two-way AADTT	1000
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	10,420,600

25.1.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	Material Type	Thickness (in)
AC Surface	HMA ½ in. mix with PG 70-22	2
AC Binder	HMA ¾ in. mix with PG 64-22	6.25
Granular Base	A-2-4	6
Subgrade	A-7-6	Semi-infinite

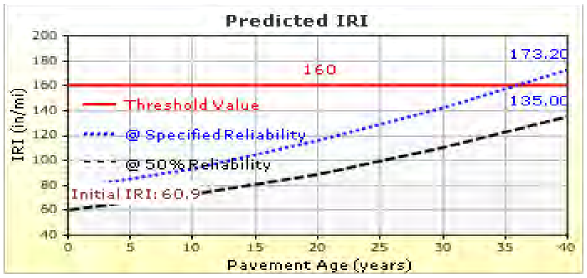
25.1.2.1.3 Distress Prediction & Reliability Summary

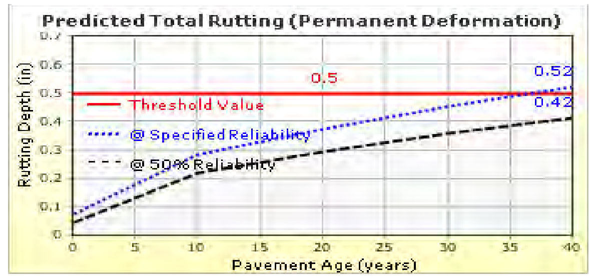
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.0	173.16	85.00	75.15	Fail
Permanent deformation - total pavement (in.)	0.5	0.52	85.00	79.34	Fail
AC bottom-up fatigue cracking (percent)	15.00	12.15	85.00	91.04	Pass
AC thermal fracture (ft/mile)	700.0	67.43	85.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.41	85.00	97.72	Pass

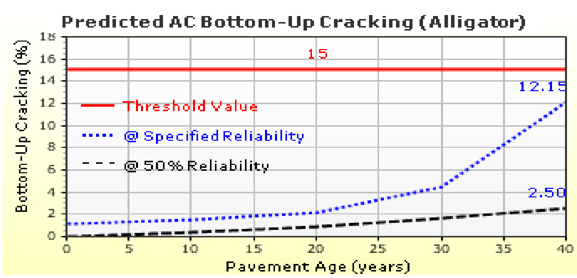
Note: * Predicted IRI at specified reliability is within 160 in/mile threshold until 35 years.

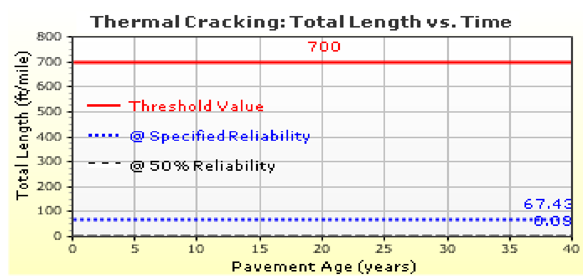
** Predicted permanent deformation at specified reliability is within 0.5 in. threshold until 35 years.

25.1.2.1.4 Distress Charts









25.1.2.2 First Rehabilitation – Mill & Overlay

The DARWin-ME based thresholds were used to establish future rehabilitation activities. A reasonable maximum service life of 20 years for new AC and 17 years for AC overlay was assumed for this climate since DARWin-ME does not consider all durability related distresses that develop over time. The first overlay project was then run for 17 years design period instead of typical MoDOT design life and the second overlay was run for 13 years. The mill and overlay then starts out rutting at 0 and IRI at 60 in/mile. Fatigue damage was low but is also determined and considered in the next overlay cracking prediction.

25.1.2.2.1 Rehabilitation Information

Rehabilitation strategy	Mill top 2 in. of AC surface course and place an AC overlay of 2 in. thick. Patching of 0.985% lane area is required in the travel lane.
Year of rehabilitation	20
Design period	17

25.1.2.2.2 Traffic Inputs

Design period (from year 20 to 37)	17
Initial two-way AADTT	1600
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	5,543,620

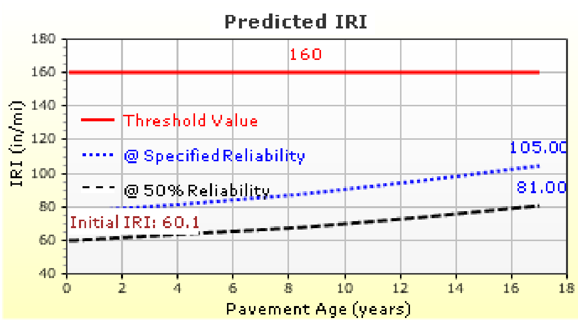
25.1.2.2.3 Pavement Structure

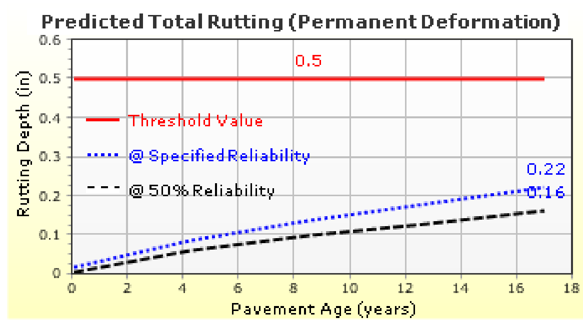
Layer Type	Material Type	Thickness (in)
AC Overlay (placed at 20 years)	HMA ½ in. mix with PG 70-22	2
AC Binder	HMA ¾ in. mix with PG 64-22	6.25
Granular Base	A-2-4	6
Subgrade	A-7-6	Semi-infinite

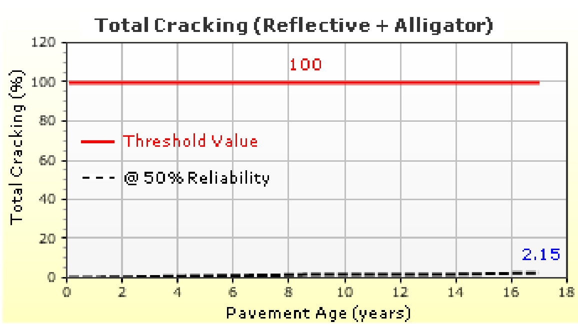
25.1.2.2.4 Distress Prediction & Reliability Summary

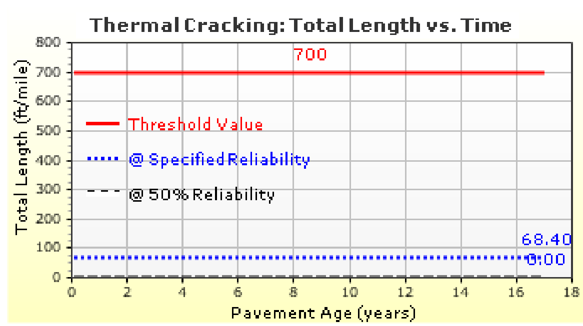
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	104.99	85.00	99.97	Pass
Permanent deformation - total pavement (in.)	0.5	0.22	85.00	100.00	Pass
Total Cracking (Reflective + Alligator) (percent)	10.00	2.15	50.00		Pass
AC thermal fracture (ft/mile)	700.00	68.40	85.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	15.00	1.17	85.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.22	85.00	100.00	Pass

25.1.2.2.5 Distress Charts









25.1.2.3 Second Rehabilitation – Mill & Overlay

The second rehabilitation was placed at 37 years with a design life of 13 years. Note that second rehabilitation has slightly greater than 3% linear traffic growth rate.

25.1.2.3.1 Rehabilitation Information

Rehabilitation strategy	Mill top 2 in. of AC surface course and place an AC overlay of 2 in. thick. Patching of 0.985% lane area is required in the travel lane.
Year of rehabilitation	37
Design period	13

25.1.2.3.2 Traffic Inputs

Design period (from year 37 to 50)	13
Initial two-way AADTT	2416
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	6,091,510

25.1.2.3.3 Pavement Structure

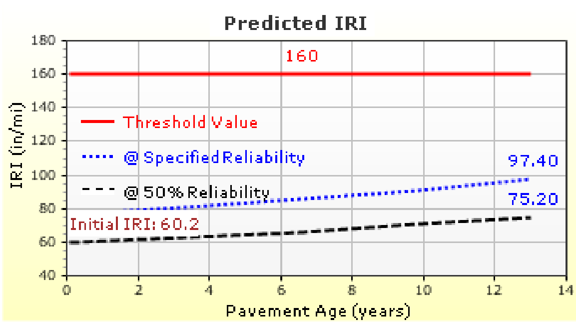
Layer Type	**Material Type**	**Thickness (in)**
AC Overlay (placed at 20 years)	HMA ½ in. mix with PG 70-22	2
AC Binder	HMA ¾ in. mix with PG 64-22	6.25
Granular Base	A-2-4	6
Subgrade	A-7-6	Semi-infinite

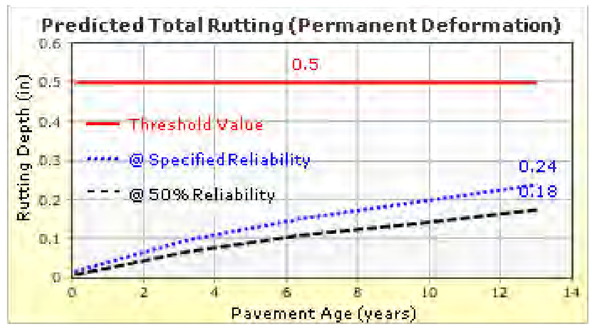
25.1.2.3.4 Distress Prediction & Reliability Summary

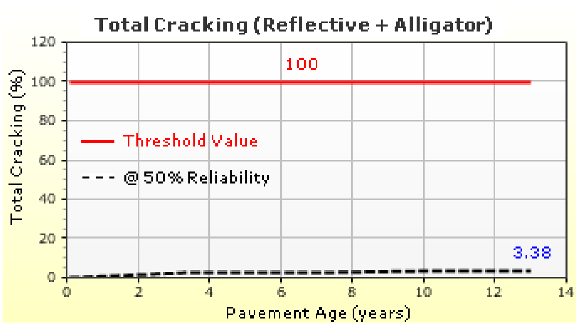
Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in./mile)	160.00	97.38	85.00	100.00	Pass
Permanent deformation - total pavement (in.)	0.5	0.24	85.00	100.00	Pass

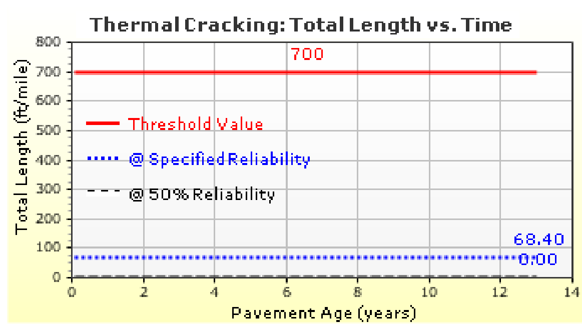
Total Cracking (Reflective + Alligator) (percent)	10.00	3.38	50.00		Pass
AC thermal fracture (ft/mile)	700.00	68.40	85.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	15.00	1.17	85.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.24	85.00	100.00	Pass

25.1.2.3.5 Distress Charts









The pavement passes all of the criteria at 50 years. The overlay actually will last 17 years or 4 years longer than the 50-year analysis period and some salvage value can be considered in the LCCA.

25.1.2.4 Summary of Asphalt Pavement Design and Life Cycle Rehabilitation based on DARWin-ME Predictions

Pavement life cycle activities over a 50-year analysis period include the following as determined using the DARWin-ME threshold criteria:

Year	Activity	Description
0	New construction	Place 8.25 in. AC over 6 in. crushed stone base material
20	AC overlay 1	Mill 2 in. and replace 2 in. AC OL (Patching of 0.985% lane area is required in the travel lane).

37	AC overlay 2	Mill 2 in. and replace 2 in. AC OL (Patching of 2.15% lane area is required in the travel lane).
Salvage at 50	4 years	

25.2 PORTLAND CEMENT CONCRETE PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

The site conditions, Design period and analysis period are exactly the same as that used for the AC design.

25.2.1 MoDOT-Based Maintenance and Rehabilitation (M&R)

The MoDOT M&R strategy is to perform concrete pavement restoration at 25 years. This includes 1.5% cracked slabs replacement in the travel lane and diamond grinding of the surface to restore IRI and remove faulting.

25.2.1.1 New Construction

25.2.1.1.1 Traffic Inputs

Design period	40
Initial two-way AADTT	1000
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	10,420,600

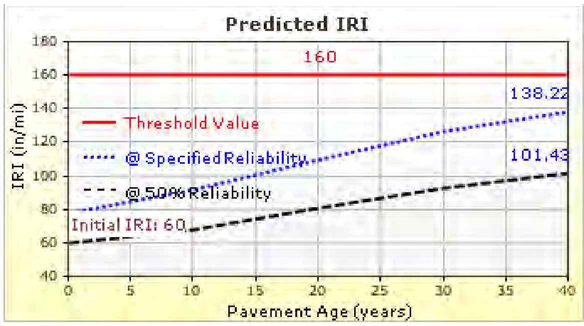
25.2.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

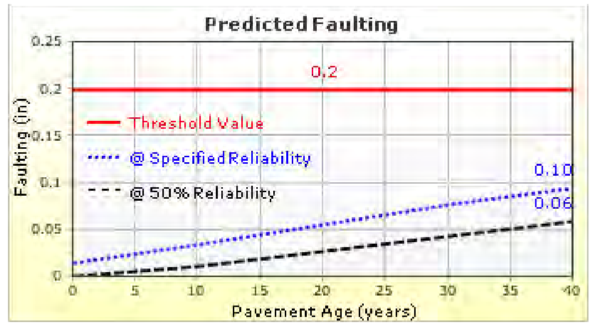
Layer Type	Material Type	Thickness (in)	Dowel Dia. (in)
JPCP-PCC	PCC	8	1.25
Granular Base	A-2-4	4	
Subgrade	A-7-6	Semi-infinite	

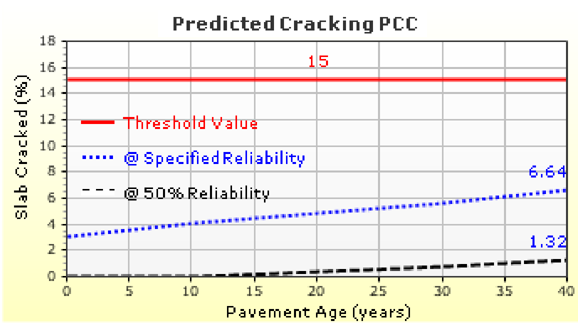
25.2.1.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	138.22	85.00	95.05	Pass
Mean joint faulting (in.)	0.20	0.10	85.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	6.64	85.00	99.62	Pass

25.2.1.1.4 Distress Charts







25.2.1.2 Summary of MoDOT Concrete Pavement Design and Life Cycle Rehabilitation

Pavement life cycle activities over a 50-year analysis period include the following as determined using the Missouri DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 8 in. PCC (with 1.25 in diameter dowel) over 4 in. crushed stone material
20	PCC Rehabilitation 1	¼ in. Diamond grinding and full depth repair (1.5% slabs repaired in the travel lane as per MoDOT M&R strategy)
35	PCC Rehabilitation 2	¼ in. Diamond grinding and full depth repair (1.5% slabs repaired in the travel lane as per MoDOT M&R strategy)
50	End of analysis period	

25.2.2 DARWin-ME-Based Maintenance and Rehabilitation (M&R)

25.2.2.1 5. PCC.B1 New Construction

25.2.2.1.1 Traffic Inputs

Design period	40
Initial two-way AADTT	1000
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	10,420,600

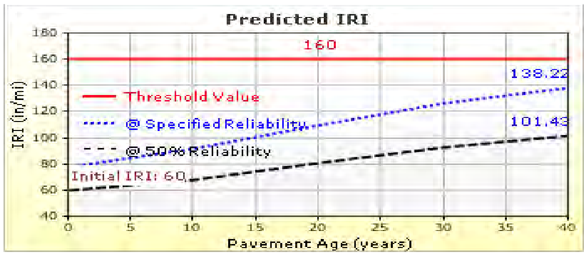
25.2.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

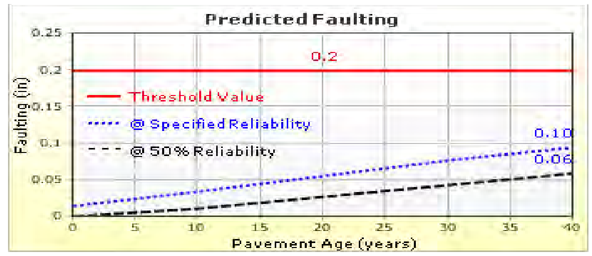
Layer Type	Material Type	Thickness (in)	Dowel Dia. (in)
JPCP-PCC	PCC	8	1.25
Granular Base	A-2-4	4	
Subgrade	A-7-6	Semi-infinite	

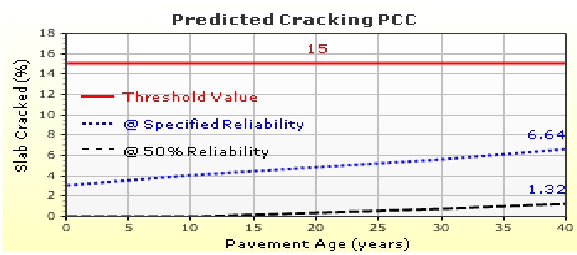
25.2.2.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	138.22	85.00	95.05	Pass
Mean joint faulting (in.)	0.20	0.10	85.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	6.64	85.00	99.62	Pass

25.2.2.1.4 Distress Charts







This design passes the DARWin-ME threshold criteria over 30 years. At 40 years, there is 6.64% fatigue cracking, 0.10 in faulting and 138.22 in/mile IRI at 85% reliability. Thus, diamond grinding and full depth repair are the most logical M&R treatment at 40 years.

25.2.2.2 First Rehabilitation –Diamond Grinding & Full Depth Repair

At 40 years, all cracked slabs will be replaced. Past fatigue cracking damage will be considered in future cracking projections. A maximum JPCP restoration life of 25 years was assumed since DARWin-ME does not consider all durability related distresses that develop over time. The first restoration project was then run for 10 years design period instead of typical MoDOT design life.

25.2.2.2.1 Traffic Inputs

Design period (from year 40 to 50)	10
Initial two-way AADTT	2200
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	4,104,130

25.2.2.2.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	Material Type	Thickness (in)
JPCP-PCC	PCC	7.75*

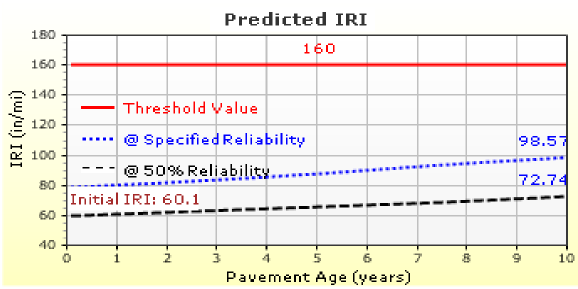
Granular Base	A-2-4	4
Subgrade	A-7-6	Semi-infinite

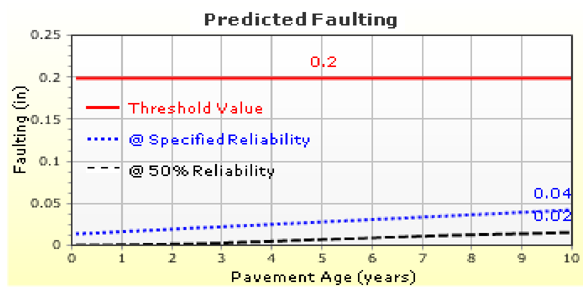
*Note: 0.25 inch slab thickness was removed by diamond grinding.

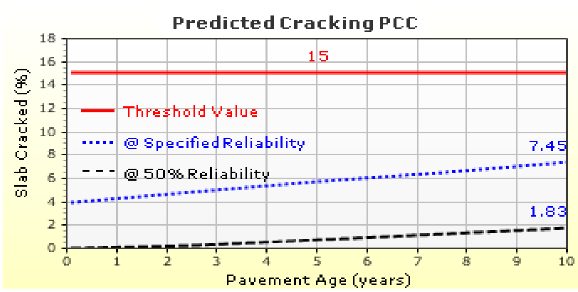
25.2.2.2.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	98.57	85.00	99.98	Pass
Mean joint faulting (in.)	0.20	0.04	85.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	7.45	85.00	99.25	Pass

25.2.2.2.4 Distress Charts







The pavement passes all of the criteria at 50 years. The restoration of the pavement actually will last 20 years (assuming texture depth does not wear down beyond critical level) or 10 years longer than the 50-year analysis period and some salvage value can be considered in the LCCA.

25.2.2.3 Summary of Concrete Pavement Design and Life Cycle Rehabilitation based on DARWin-ME Predictions

Pavement life cycle activities over a 50-year analysis period include the following as determined using the DARWin-ME based thresholds:

Year	Activity	Description

0	New construction	Place 8 in. PCC (with 1.25 in diameter dowel) over 4 in. crushed stone material
40	PCC Rehabilitation 1	¼ in. Diamond grinding & Full depth repair (1.32% slabs repaired in the travel lane)
Salvage at 50	10 years	

26 Detailed Information for Cell 6

26.1 ASPHALT CONCRETE PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

26.1.1 ADOT-Based Maintenance and Rehabilitation (M&R)

26.1.1.1 New Construction

26.1.1.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	1000
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period (design lane)	7,075,810

26.1.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	Material Type	Thickness (in)
AC Surface	HMA ½ in. mix with Asphalt Rubber (ARAC)	2.5
AC Binder	HMA ¾ in. mix with PG 64-22	5
Granular Base	A-1-a	4
Subgrade	A-4	Semi-infinite

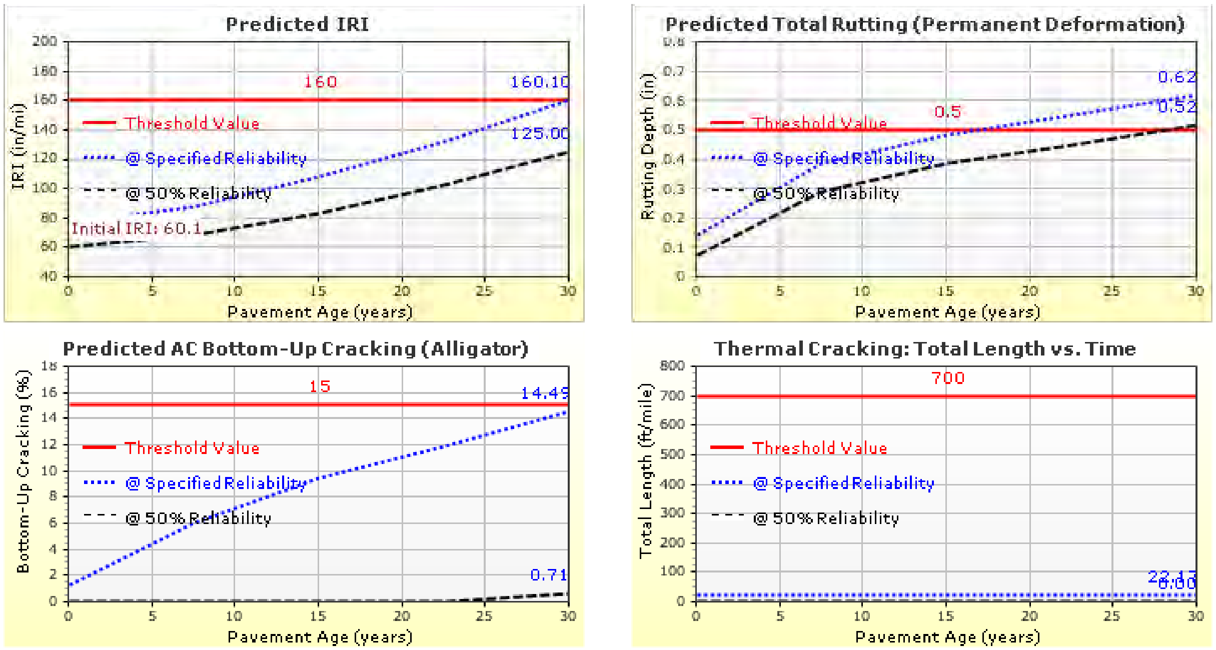
26.1.1.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.0	160.07	85.00	84.95*	Fail
Permanent deformation - total pavement (in.)	0.5	0.62	85.00	42.66**	Fail
AC bottom-up fatigue cracking (percent)	15.00	14.49	85.00	85.88	Pass
AC thermal fracture (ft/mile)	700.0	22.17	85.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.45	85.00	94.40	Pass

Note: * Predicted IRI at specified reliability is within 160 in/mile threshold until the placement of first rehabilitation overlay at 15 years.

** Predicted permanent deformation at specified reliability is within 0.5 in. threshold until the placement of first rehabilitation overlay at 15 years.

26.1.1.1.4 Distress Charts



26.1.1.2 ADOT Rehabilitation – Mill & Overlay

The Arizona first rehabilitation is recommended at 15 years. The ADOT expected life of the AC overlay is 13 years. This becomes the Design Period for the next overlay. The Arizona second rehabilitation was applied at 28 years with design period of 13 years and third overlay was placed at 41 years with design period of 9 years.

26.1.1.3 Summary of Asphalt Pavement Design and Life Cycle Rehabilitation using ADOT M&R

Pavement life cycle activities over a 50-year analysis period include the following as determined using the Arizona DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 7.5 in. AC over 4 in. crushed stone base material
15	AC overlay 1	Mill 2.5 in. and replace 2.5 in. AC OL (Patching of 0.011% lane area is required in the travel lane)
28	AC overlay 2	Mill 2.5 in. and replace 2.5 in. AC OL (Patching of 0.14% lane area is required in the travel lane)
41	AC overlay 3	Mill 2.5 in. and replace 2.5 in. AC OL (Patching of 1.18% lane area is required in the travel lane)
50	End of analysis period	

26.1.2 DARWin-ME-Based Maintenance and Rehabilitation (M&R)

26.1.2.1 New Construction

26.1.2.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	1000
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	7,075,810

26.1.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	Material Type	Thickness (in)
AC Surface	HMA ½ in. mix with Asphalt Rubber (ARAC)	2.5
AC Binder	HMA ¾ in. mix with PG 64-22	5
Granular Base	A-1-a	4
Subgrade	A-4	Semi-infinite

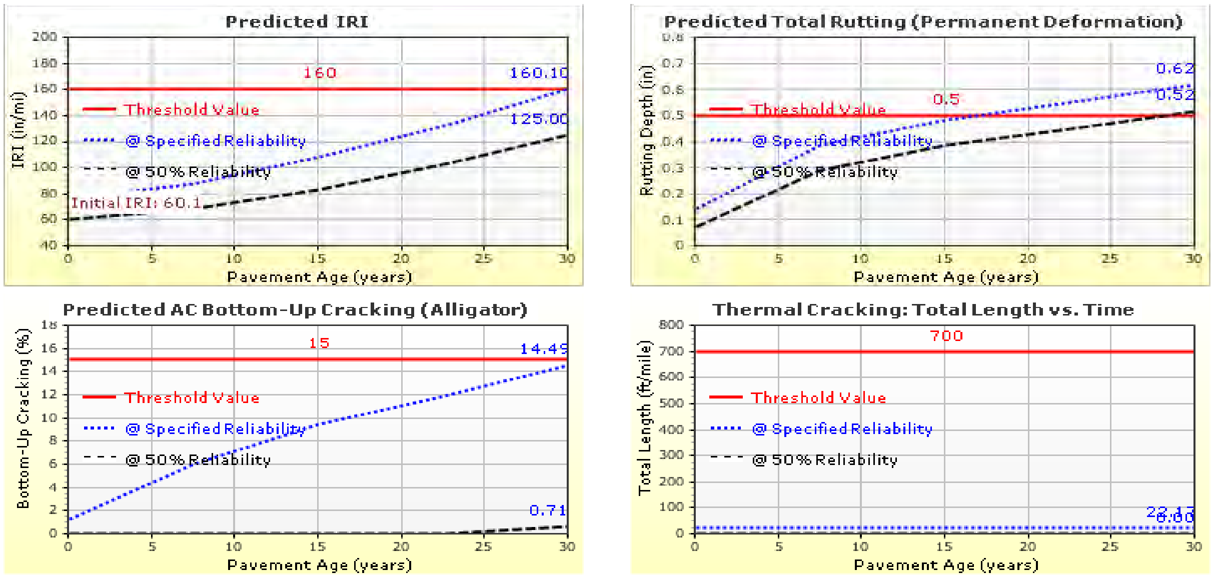
26.1.2.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.0	160.07	85.00	84.95*	Fail
Permanent deformation - total pavement (in.)	0.5	0.62	85.00	42.66**	Fail
AC bottom-up fatigue cracking (percent)	15.00	14.49	85.00	85.88	Pass
AC thermal fracture (ft/mile)	700.0	22.17	85.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.45	85.00	94.40	Pass

Note: * Predicted IRI at specified reliability is within 160 in/mile threshold until the placement of first rehabilitation overlay at 16 years.

** Predicted permanent deformation at specified reliability is within 0.5 in. threshold until the placement of first rehabilitation overlay at 16 years.

26.1.2.1.4 Distress Charts



26.1.2.2 First Rehabilitation – Mill & Overlay

The DARWin-ME based thresholds were used to establish future rehabilitation activities. A reasonable maximum service life of 20 years for new AC (the Arizona survival shows a mean life ranging from 17 to 24 years for this climate) and 13 years for AC overlay (the Arizona survival shows a mean life of 13 years for this climate) was assumed for this climate since DARWin-ME does not consider all durability related distresses that develop over time. The first overlay project was then run for 13 years design period. The mill and overlay then starts out rutting at 0 and IRI at 60 in/mile. Fatigue damage was low but is also determined and considered in the next overlay cracking prediction.

26.1.2.2.1 Rehabilitation Information

Rehabilitation strategy	Mill top 2.5 in. of AC surface course and place an AC overlay of 2.5 in. thick. Patching of 0.016% lane area is required in the travel lane.
Year of rehabilitation	16
Design period	13

26.1.2.2.2 Traffic Inputs

Design period (from year 16 to 29)	13
Initial two-way AADTT	1480
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	3,727,720

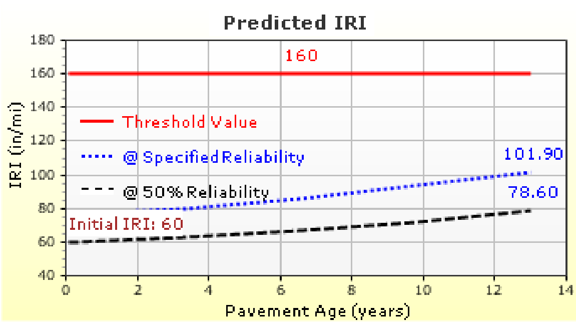
26.1.2.2.3 Pavement Structure

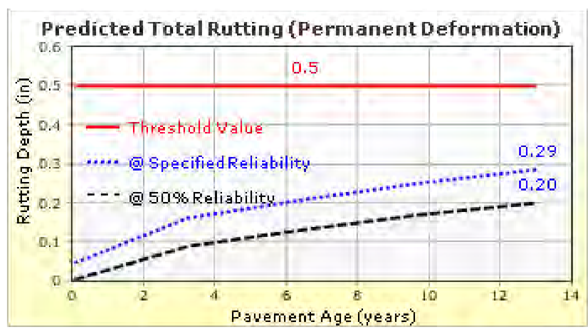
Layer Type	Material Type	Thickness (in)
AC Overlay (placed at 16 years)	HMA ½ in. mix with Asphalt Rubber (ARAC)	2.5
AC Existing	HMA ¾ in. mix with PG 64-22	5
Granular Base	A-1-a	4
Subgrade	A-4	Semi-infinite

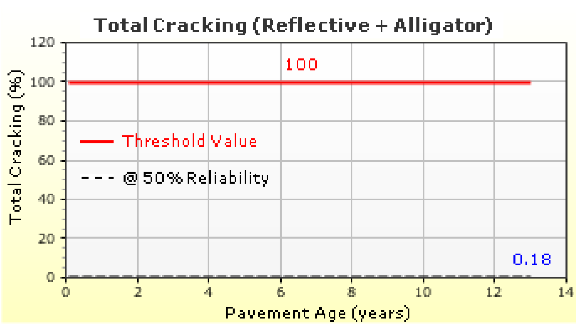
26.1.2.2.4 Distress Prediction & Reliability Summary

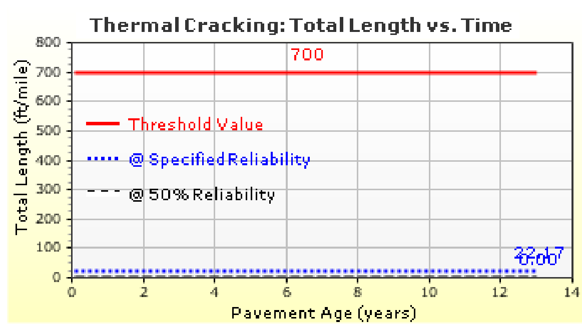
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	101.93	85.00	99.99	Pass
Permanent deformation - total pavement (in.)	0.5	0.29	85.00	99.99	Pass
Total Cracking (Reflective + Alligator) (percent)	10.00	0.18	50.00		Pass
AC thermal fracture (ft/mile)	700.00	22.17	85.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	15.00	1.18	85.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.28	85.00	99.99	Pass

26.1.2.2.5 Distress Charts









26.1.2.3 Second Rehabilitation – Mill & Overlay

The second rehabilitation was placed at 29 years with a design life of 13 years. Note that second rehabilitation has slightly greater than 3% linear traffic growth rate.

26.1.2.3.1 Rehabilitation Information

Rehabilitation strategy	Mill top 2.5 in. of AC surface course and place an AC overlay of 2.5 in. thick. Patching of 0.18% lane area is required in the travel lane.
Year of rehabilitation	29
Design period	13

26.1.2.3.2 Traffic Inputs

Design period (from year 29 to 42)	13
Initial two-way AADTT	2057
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	5,181,020

26.1.2.3.3 Pavement Structure

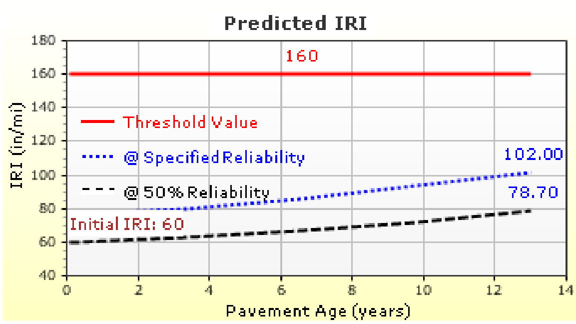
Layer Type	**Material Type**	**Thickness (in)**
AC Overlay (placed at 29 years)	HMA ½ in. mix with Asphalt Rubber (ARAC)	2.5
AC Existing	HMA ¾ in. mix with PG 64-22	5
Granular Base	A-1-a	6
Subgrade	A-4	Semi-infinite

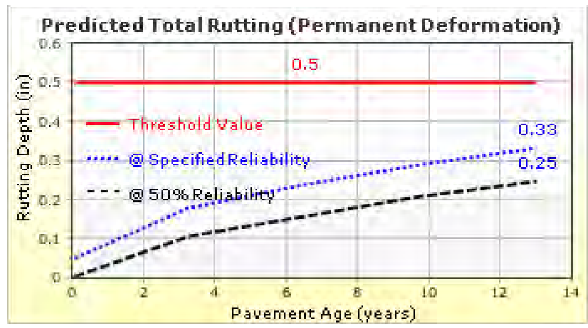
26.1.2.3.4 Distress Prediction & Reliability Summary

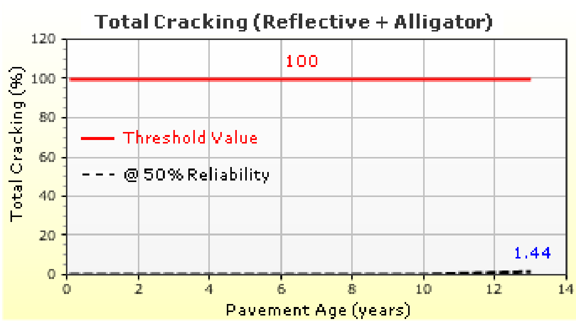
Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in./mile)	160.00	102.01	85.00	99.99	Pass
Permanent deformation - total pavement (in.)	0.5	0.33	85.00	99.89	Pass

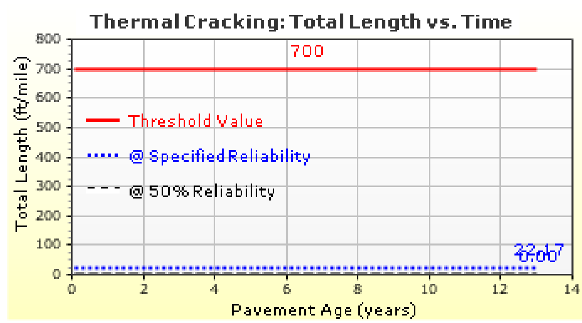
Total Cracking (Reflective + Alligator) (percent)	10.00	1.44	50.00		Pass
AC thermal fracture (ft/mile)	700.00	22.17	85.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	15.00	1.18	85.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.33	85.00	99.93	Pass

26.1.2.3.5 Distress Charts









26.1.2.4 Third Rehabilitation – Mill & Overlay

The second rehabilitation was placed at 42 years with a design life of 8 years. Note that third rehabilitation has slightly greater than 3% linear traffic growth rate.

26.1.2.4.1 Rehabilitation Information

Rehabilitation strategy	Mill top 2.5 in. of AC surface course and place an AC overlay of 2.5 in. thick. Patching of 1.44% lane area is required in the travel lane.
Year of rehabilitation	42
Design period	8

26.1.2.4.2 Traffic Inputs

Design period (from year 42 to 50)	8
Initial two-way AADTT	2860

Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	4,151,210

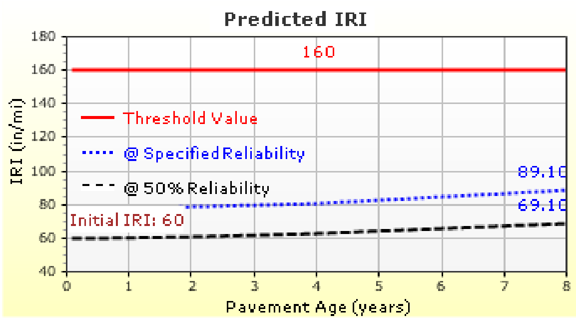
26.1.2.4.3 Pavement Structure

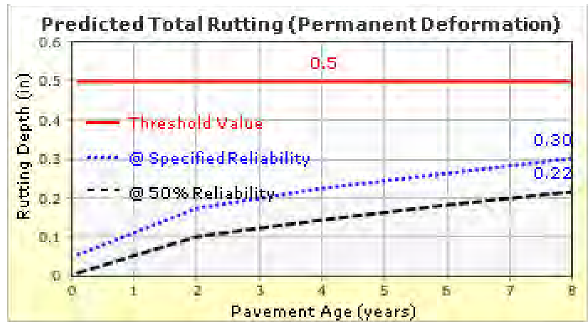
Layer Type	Material Type	Thickness (in)
AC Overlay (placed at 42 years)	HMA ½ in. mix with Asphalt Rubber (ARAC)	2.5
AC Existing	HMA ¾ in. mix with PG 64-22	5
Granular Base	A-1-a	6
Subgrade	A-4	Semi-infinite

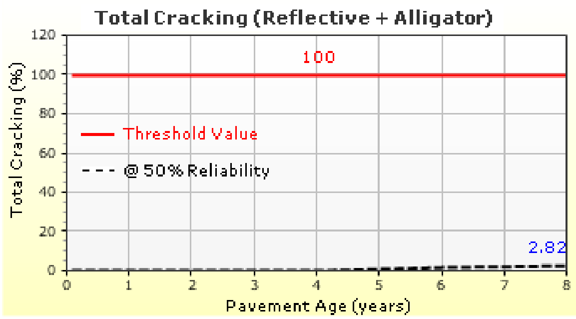
26.1.2.4.4 Distress Prediction & Reliability Summary

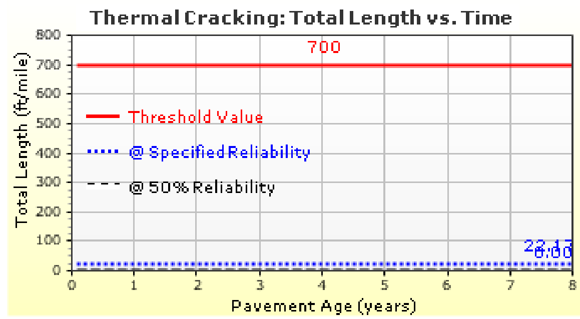
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	89.15	85.00	100.00	Pass
Permanent deformation - total pavement (in.)	0.5	0.30	85.00	99.97	Pass
Total Cracking (Reflective + Alligator) (percent)	10.00	2.82	50.00		Pass
AC thermal fracture (ft/mile)	700.00	22.17	85.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	15.00	1.17	85.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.30	85.00	99.98	Pass

26.1.2.4.5 Distress Charts









26.1.2.5 Summary of Asphalt Pavement Design and Life Cycle Rehabilitation based on DARWin-ME Predictions

Pavement life cycle activities over a 50-year analysis period include the following as determined using the DARWin-ME threshold criteria:

Year	Activity	Description
0	New construction	Place 7.5 in. AC over 4 in. crushed stone base material
16	AC overlay 1	Mill 2.5 in. and replace 2.5 in. AC OL (Patching of 0.016% lane area is required in the travel lane).
29	AC overlay 2	Mill 2.5 in. and replace 2.5 in. AC OL (Patching of 0.18% lane area is required in the travel lane).
42	AC overlay 3	Mill 2.5 in. and replace 2.5 in. AC OL (Patching of 1.44% lane area is required in the travel lane).
Salvage at 50	5 years	

26.2 PORTLAND CEMENT CONCRETE PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

The site conditions, design period and analysis period are exactly the same as that used for the AC design.

26.2.1 ADOT-Based Maintenance and Rehabilitation (M&R)

The ADOT M&R strategy is to perform concrete pavement restoration at 20 years. This includes cracked slabs replacement in the travel lane and diamond grinding of the surface to restore IRI and remove faulting.

26.2.1.1 New Construction

26.2.1.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	1000
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	7,075,810

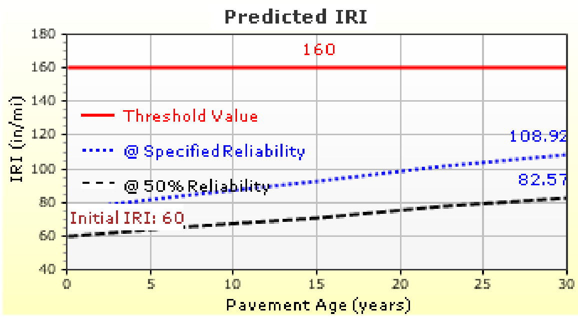
26.2.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

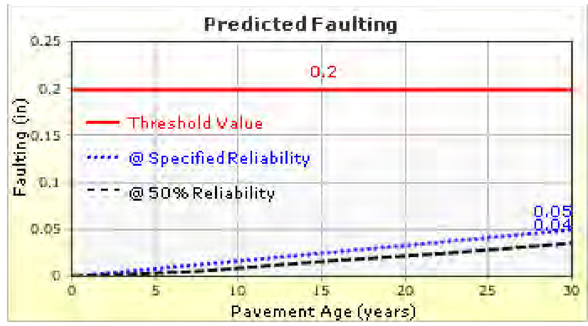
Layer Type	**Material Type**	**Thickness (in)**	**Dowel Dia. (in)**
JPCP-PCC	PCC	8.5	1.25
Granular Base	A-1-a	4	
Subgrade	A-4	Semi-infinite	

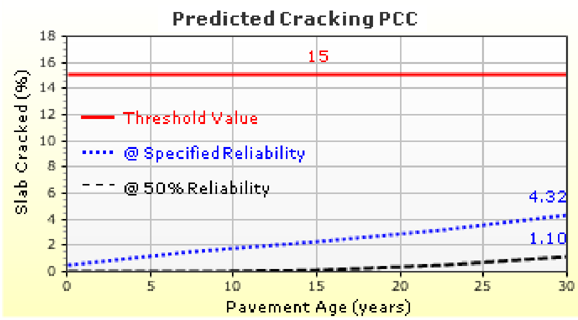
26.2.1.1.3 Distress Prediction & Reliability Summary

Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in./mile)	160.00	108.92	85.00	99.88	Pass
Mean joint faulting (in.)	0.20	0.05	85.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	4.32	85.00	100.00	Pass

26.2.1.1.4 Distress Charts







26.2.1.2 Summary of ADOT Concrete Pavement Design and Life Cycle Rehabilitation

Pavement life cycle activities over a 50-year analysis period include the following as determined using the Arizona DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 8.5 in. PCC (with 1.25 in diameter dowel) over 4 in. crushed stone material
20	PCC Rehabilitation 1	¼ in. Diamond grinding and full depth repair (0.45% slabs repaired in the travel lane as per ADOT M&R strategy)
40	PCC Rehabilitation 2	¼ in. Diamond grinding and full depth repair (3.7% slabs repaired in the travel lane as per ADOT M&R strategy)
50	End of analysis period	

26.2.2 DARWin-ME-Based Maintenance and Rehabilitation (M&R)

26.2.2.1 New Construction

26.2.2.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	1000
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	7,075,810

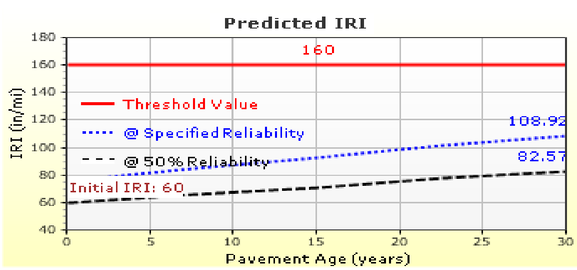
26.2.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

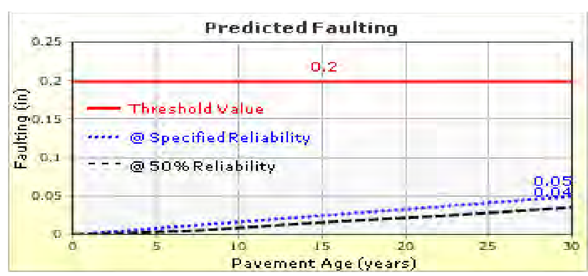
Layer Type	Material Type	Thickness (in)	Dowel Dia. (in)
JPCP-PCC	PCC	8.5	1.25
Granular Base	A-1-a	4	
Subgrade	A-4	Semi-infinite	

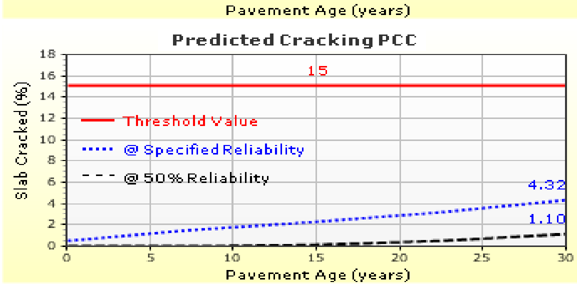
26.2.2.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	108.92	85.00	99.88	Pass
Mean joint faulting (in.)	0.20	0.05	85.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	4.32	85.00	100.00	Pass

26.2.2.1.4 Distress Charts







This design passes the DARWin-ME threshold criteria over 30 years. At 30 years, there is 4.32% fatigue cracking, 0.05 in faulting and 108.92 in/mile IRI at 85% reliability. Thus, diamond grinding and full depth repair are the most logical M&R treatment at 30 years.

26.2.2.2 First Rehabilitation –Diamond Grinding & Full Depth Repair

At 30 years, all cracked slabs will be replaced. Past fatigue cracking damage will be considered in future cracking projections. A maximum JPCP restoration life of 25 years was assumed since DARWin-ME does not consider all durability related distresses that develop over time. The first restoration project was then run for 20 years design period.

26.2.2.2.1 Traffic Inputs

Design period (from year 30 to 50)	20
Initial two-way AADTT	1900
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	8,025,820

26.2.2.2.2 Pavement Structure That Meets Performance & Reliability Requirements

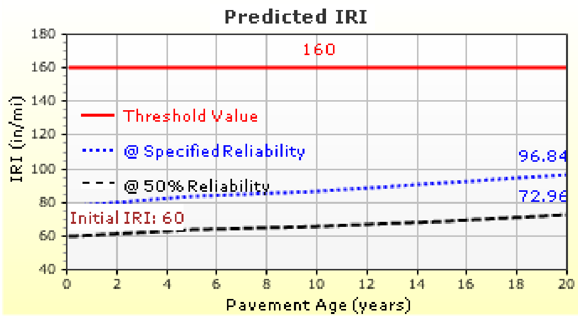
Layer Type	Material Type	Thickness (in)
JPCP-PCC	PCC	8.25*
Granular Base	A-1-a	4
Subgrade	A-4	Semi-infinite

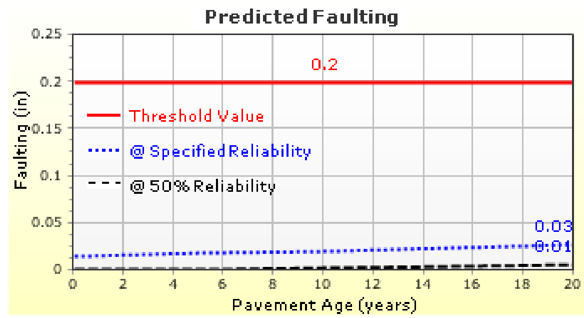
*Note: 0.25 inch slab thickness was removed by diamond grinding.

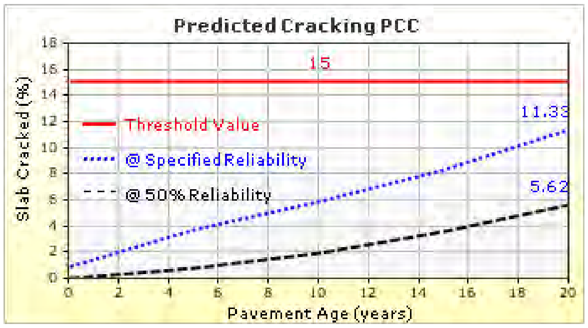
26.2.2.2.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	96.84	85.00	99.99	Pass
Mean joint faulting (in.)	0.20	0.03	85.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	11.33	85.00	95.57	Pass

26.2.2.2.4 Distress Charts







26.2.2.3 Summary of Concrete Pavement Design and Life Cycle Rehabilitation based on DARWin-ME Predictions

Pavement life cycle activities over a 50-year analysis period include the following as determined using the DARWin-ME based thresholds:

Year	Activity	Description
0	New construction	Place 8.5 in. PCC (with 1.25 in diameter dowel) over 4 in. crushed stone material
30	PCC Rehabilitation 1	¼ in. Diamond grinding & Full depth repair (1.1% slabs repaired in the travel lane)
Salvage at 50	0 years	

27 Detailed Information for Cell 7

27.1 ASPHALT CONCRETE PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

27.1.1 CDOT-Based Maintenance and Rehabilitation (M&R)

27.1.1.1 New Construction

27.1.1.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	1000
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period (design lane)	7,075,810

27.1.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	Material Type	Thickness (in)
AC Surface	HMA ½ in. mix (SX 100) with PG 64-28	2
AC Binder	HMA ¾ in. mix (S 100) with PG 64-22	7
Granular Base	A-1-a	12
Subgrade	A-2-4	Semi-infinite

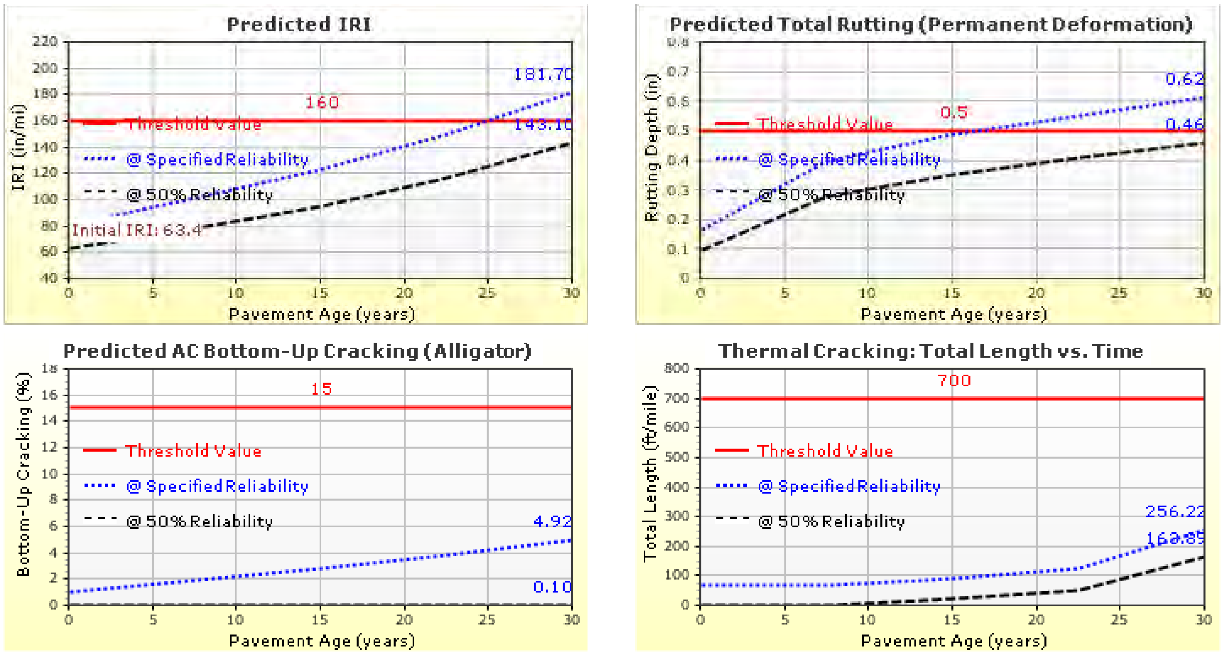
27.1.1.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.0	181.71	85.00	67.51*	Fail
Permanent deformation - total pavement (in.)	0.5	0.62	85.00	59.74**	Fail
AC bottom-up fatigue cracking (percent)	15.00	4.92	85.00	99.93	Pass
AC thermal fracture (ft/mile)	700.0	256.22	85.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.41	85.00	95.93	Pass

Note: * Predicted IRI at specified reliability is within 160 in/mile threshold until the placement of first rehabilitation overlay at 13 years.

** Predicted permanent deformation at specified reliability is within 0.5 in. threshold until the placement of first rehabilitation overlay at 13 years.

27.1.1.1.4 Distress Charts



27.1.1.2 CDOT Rehabilitation – Mill & Overlay

The Colorado first rehabilitation is recommended at 13 years. The CDOT expected life of the AC overlay is 13 years. This becomes the Design Period for the next overlay. The Colorado second rehabilitation was applied at 26 years with design period of 12 years and third overlay was placed at 38 years with design period of 12 years.

27.1.1.3 Summary of Asphalt Pavement Design and Life Cycle Rehabilitation using CDOT M&R

Pavement life cycle activities over a 50-year analysis period include the following as determined using the Colorado DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 9 in. AC over 12 in. crushed stone base material
13	AC overlay 1	Mill 2 in. and replace 2 in. AC OL (Patching of 0.008% lane area is required in the travel lane)
26	AC overlay 2	Mill 2 in. and replace 2 in. AC OL (Patching of 0.04% lane area is required in the travel lane)
38	AC overlay 3	Mill 2 in. and replace 2 in. AC OL (Patching of 0.12% lane area is required in the travel lane)
50	End of analysis period	

27.1.2 DARWin-ME-Based Maintenance and Rehabilitation (M&R)

27.1.2.1 New Construction

27.1.2.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	1000
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	7,075,810

27.1.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	**Material Type**	**Thickness (in)**
AC Surface	HMA ½ in. mix (SX 100) with PG 64-28	2
AC Binder	HMA ¾ in. mix (S 100) with PG 64-22	7
Granular Base	A-1-a	12
Subgrade	A-2-4	Semi-infinite

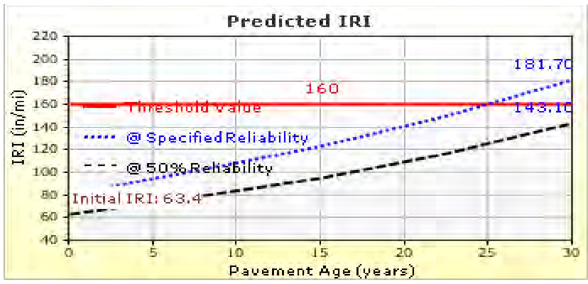
27.1.2.1.3 Distress Prediction & Reliability Summary

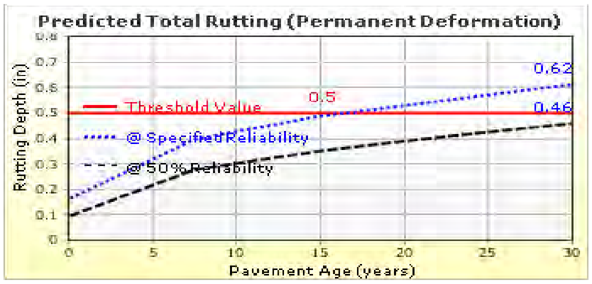
Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in./mile)	160.0	181.71	85.00	67.51*	Fail
Permanent deformation - total pavement (in.)	0.5	0.62	85.00	59.74**	Fail
AC bottom-up fatigue cracking (percent)	15.00	4.92	85.00	99.93	Pass
AC thermal fracture (ft/mile)	700.0	256.22	85.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.41	85.00	95.93	Pass

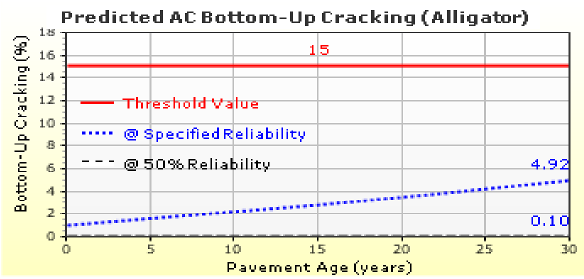
Note: * Predicted IRI at specified reliability is within 160 in/mile threshold until the placement of first rehabilitation overlay at 16 years.

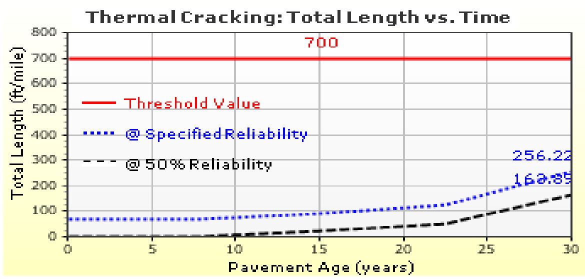
** Predicted permanent deformation at specified reliability is within 0.5 in. threshold until the placement of first rehabilitation overlay at 16 years.

27.1.2.1.4 Distress Charts









27.1.2.2 First Rehabilitation – Mill & Overlay

The DARWin-ME based thresholds were used to establish future rehabilitation activities. A reasonable maximum service life of 20 years for new AC and 17 years for AC overlay was assumed for this climate since DARWin-ME does not consider all durability related distresses that develop over time. The first overlay project was then run for 17 years design period instead of typical CDOT design life and the second overlay was run for 17 years. The mill and overlay then starts out rutting at 0 and IRI at 60 in/mile. Fatigue damage was low but is also determined and considered in the next overlay cracking prediction.

27.1.2.2.1 Rehabilitation Information

Rehabilitation strategy	Mill top 2 in. of AC surface course and place an AC overlay of 2 in. thick. Patching of 0.014% lane area is required in the travel lane.
Year of rehabilitation	16
Design period	17

27.1.2.2.2 Traffic Inputs

Design period (from year 16 to 33)	17
Initial two-way AADTT	1480
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	5,127,850

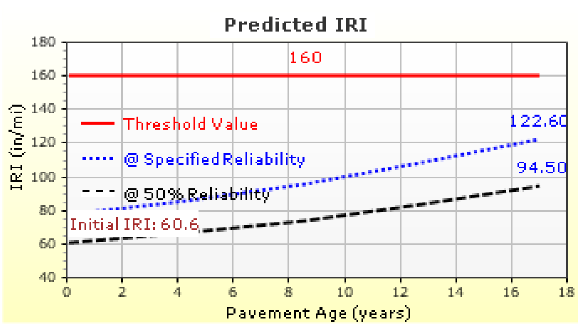
27.1.2.2.3 Pavement Structure

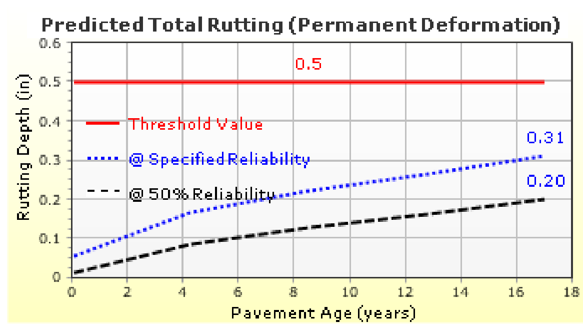
Layer Type	Material Type	Thickness (in)
AC Overlay (placed at 16 years)	HMA ½ in. mix (SX 100) with PG 64-28	2
AC Existing	HMA ¾ in. mix (S 100) with PG 64-22	7
Granular Base	A-1-a	12
Subgrade	A-2-4	Semi-infinite

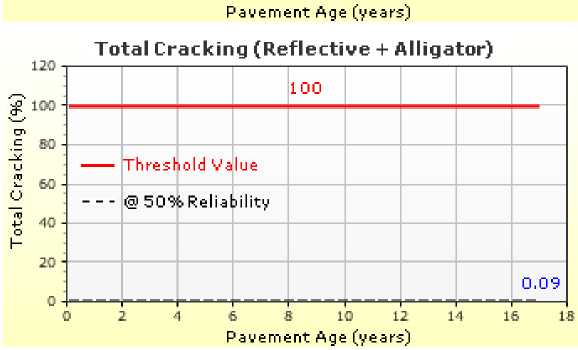
27.1.2.2.4 Distress Prediction & Reliability Summary

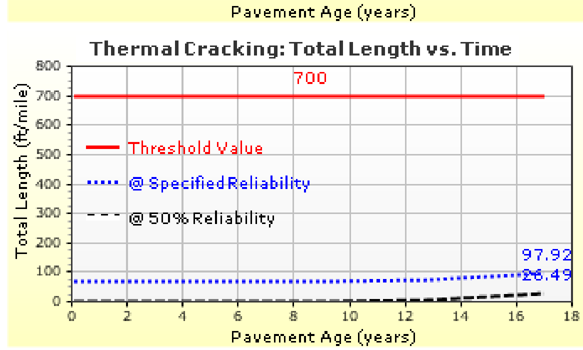
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	122.58	85.00	99.22	Pass
Permanent deformation - total pavement (in.)	0.5	0.31	85.00	99.70	Pass
Total Cracking (Reflective + Alligator) (percent)	10.00	0.09	50.00		Pass
AC thermal fracture (ft/mile)	700.00	97.92	85.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	15.00	1.04	85.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.31	85.00	99.72	Pass

27.1.2.2.5 Distress Charts









27.1.2.3 Second Rehabilitation – Mill & Overlay

The second rehabilitation was placed at 33 years with a design life of 17 years. Note that second rehabilitation has slightly greater than 3% linear traffic growth rate.

27.1.2.3.1 Rehabilitation Information

Rehabilitation strategy	Mill top 2 in. of AC surface course and place an AC overlay of 2 in. thick. Patching of 0.09% lane area is required in the travel lane.
Year of rehabilitation	33
Design period	17

27.1.2.3.2 Traffic Inputs

Design period (from year 33 to 50)	17
Initial two-way AADTT	2235
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	7,743,740

27.1.2.3.3 Pavement Structure

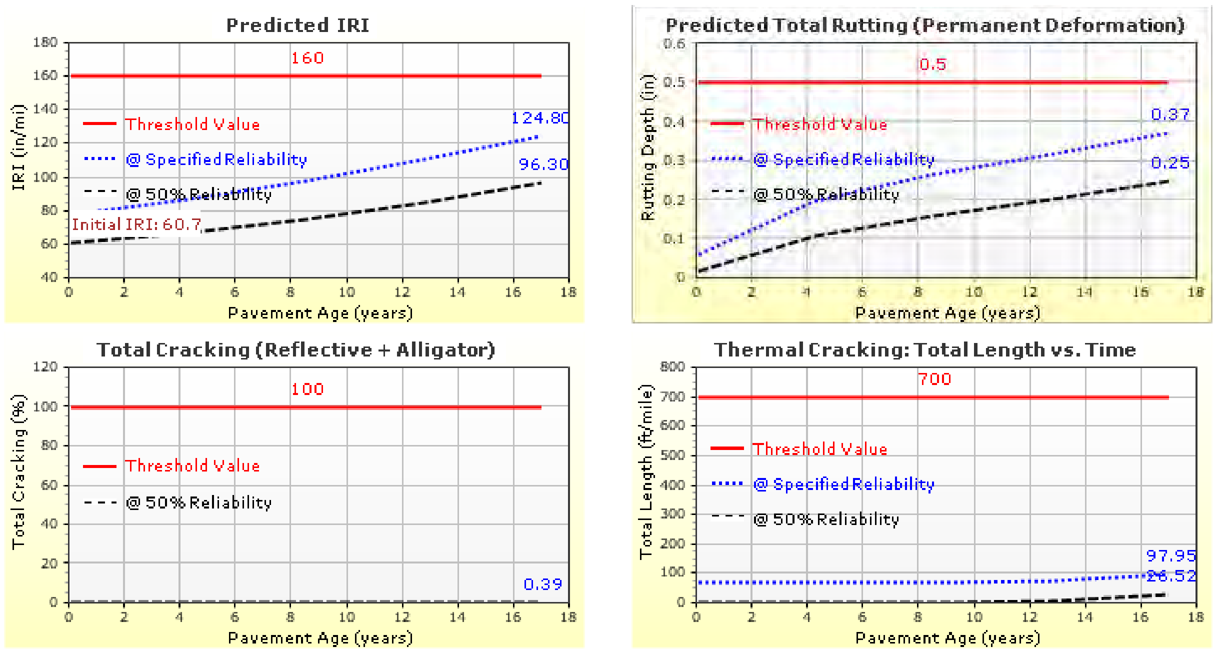
Layer Type	Material Type	Thickness (in)
AC Overlay (placed at 33 years)	HMA ½ in. mix (SX 100) with PG 64-28	2
AC Existing	HMA ¾ in. mix (S 100) with PG 64-22	7
Granular Base	A-1-a	12
Subgrade	A-2-4	Semi-infinite

27.1.2.3.4 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	124.77	85.00	98.97	Pass
Permanent deformation - total pavement (in.)	0.5	0.37	85.00	98.22	Pass

Total Cracking (Reflective + Alligator) (percent)	10.00	0.39	50.00		Pass
AC thermal fracture (ft/mile)	700.00	97.95	85.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	15.00	1.04	85.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.37	85.00	98.35	Pass

27.1.2.3.5 Distress Charts



27.1.2.4 Summary of Asphalt Pavement Design and Life Cycle Rehabilitation based on DARWin-ME Predictions

Pavement life cycle activities over a 50-year analysis period include the following as determined using the DARWin-ME threshold criteria:

Year	Activity	Description
0	New construction	Place 9 in. AC over 12 in. crushed stone base material
16	AC overlay 1	Mill 2 in. and replace 2 in. AC OL (Patching of 0.014% lane area is required in the travel lane).
33	AC overlay 2	Mill 2 in. and replace 2 in. AC OL (Patching of 0.09% lane area is required in the travel lane).
Salvage at 50	0 years	

27.2 PORTLAND CEMENT CONCRETE PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

The site conditions, Design period and analysis period are exactly the same as that used for the AC design.

27.2.1 CDOT-Based Maintenance and Rehabilitation (M&R)

The CDOT M&R strategy is to perform concrete pavement restoration at 27 years. This includes 0.5% cracked slabs replacement in the travel lane and diamond grinding of the surface to restore IRI and remove faulting.

27.2.1.1 New Construction

27.2.1.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	1000
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	7,075,810

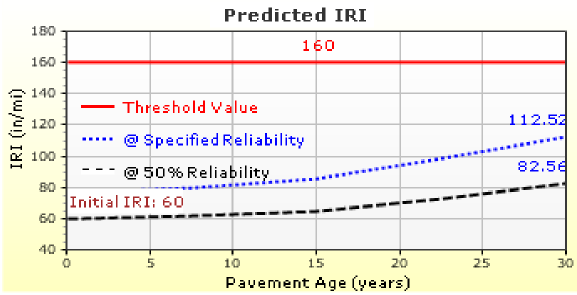
27.2.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

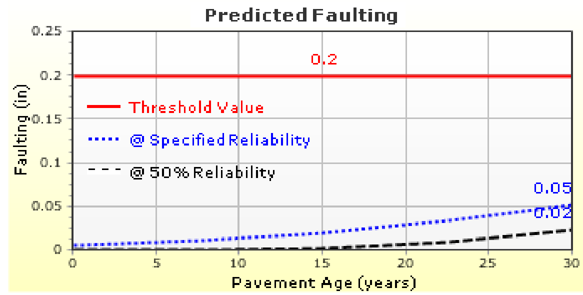
Layer Type	Material Type	Thickness (in)	Dowel Dia. (in)
JPCP-PCC	PCC	7.5	1.0
Granular Base	A-1-a	4	
Subgrade	A-2-4	Semi-infinite	

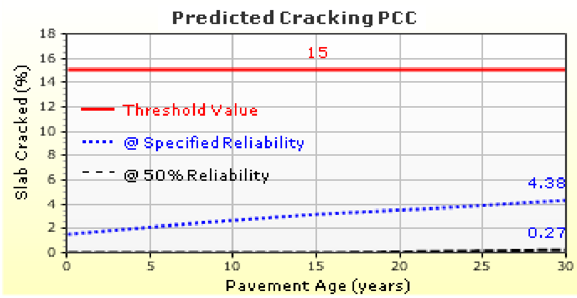
27.2.1.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	112.52	85.00	99.63	Pass
Mean joint faulting (in.)	0.20	0.05	85.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	4.38	85.00	99.99	Pass

27.2.1.1.4 Distress Charts







27.2.1.2 Summary of CDOT Concrete Pavement Design and Life Cycle Rehabilitation

Pavement life cycle activities over a 50-year analysis period include the following as determined using the Colorado DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 7.5 in. PCC (with 1.0 in diameter dowel) over 4 in. crushed stone material
27	PCC Rehabilitation 1	¼ in. Diamond grinding and full depth repair (0.5% slabs repaired in the travel lane as per CDOT M&R strategy)
50	End of analysis period	

27.2.2 DARWin-ME-Based Maintenance and Rehabilitation (M&R)

27.2.2.1 New Construction

27.2.2.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	1000
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	7,075,810

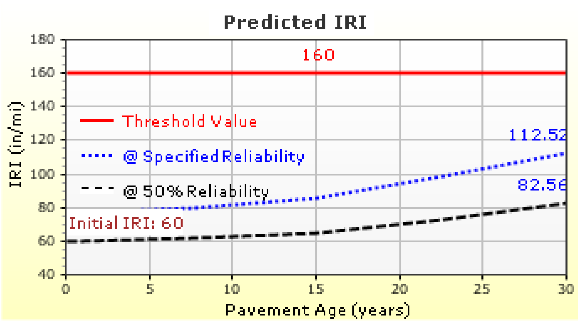
27.2.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

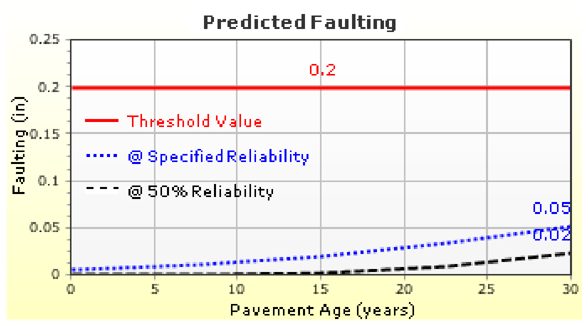
Layer Type	Material Type	Thickness (in)	Dowel Dia. (in)
JPCP-PCC	PCC	7.5	1.0
Granular Base	A-1-a	4	
Subgrade	A-2-4	Semi-infinite	

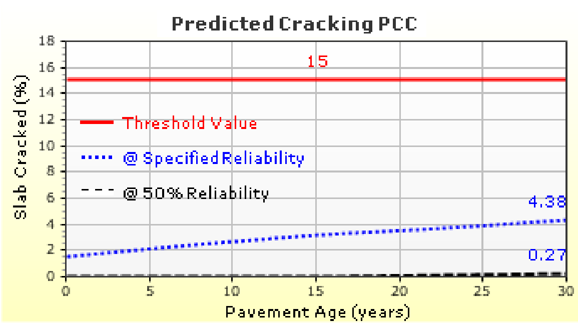
27.2.2.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	112.52	85.00	99.63	Pass
Mean joint faulting (in.)	0.20	0.05	85.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	4.38	85.00	99.99	Pass

27.2.2.1.4 Distress Charts







This design passes the DARWin-ME threshold criteria over 30 years. At 30 years, there is 4.38% fatigue cracking, 0.05 in faulting and 112.52 in/mile IRI at 85% reliability. Thus, diamond grinding and full depth repair are the most logical M&R treatment at 30 years.

27.2.2.2 First Rehabilitation –Diamond Grinding & Full Depth Repair

At 30 years, all cracked slabs will be replaced. Past fatigue cracking damage will be considered in future cracking projections. A maximum JPCP restoration life of 25 years was assumed since DARWin-ME does not consider all durability related distresses that develop over time. The first restoration project was then run for 20 years design period.

27.2.2.2.1 Traffic Inputs

Design period (from year 30 to 50)	20
Initial two-way AADTT	1900
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	8,025,820

27.2.2.2.2 Pavement Structure That Meets Performance & Reliability Requirements

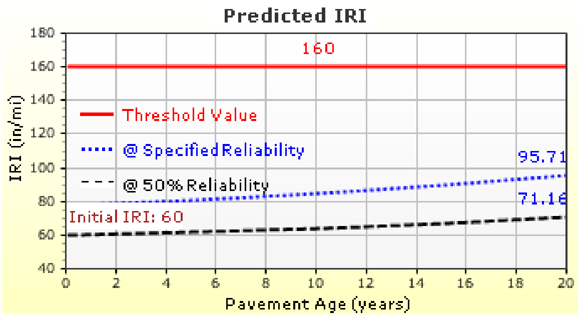
Layer Type	Material Type	Thickness (in)
JPCP-PCC	PCC	7.25*
Granular Base	A-1-a	4
Subgrade	A-2-4	Semi-infinite

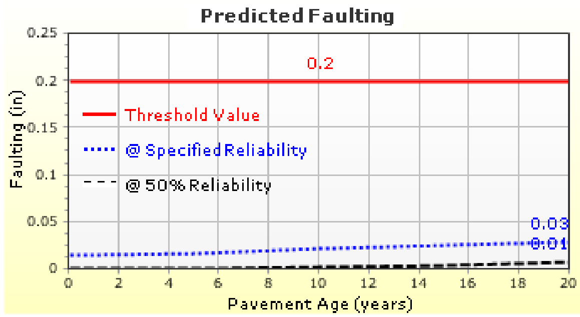
*Note: 0.25 inch slab thickness was removed by diamond grinding.

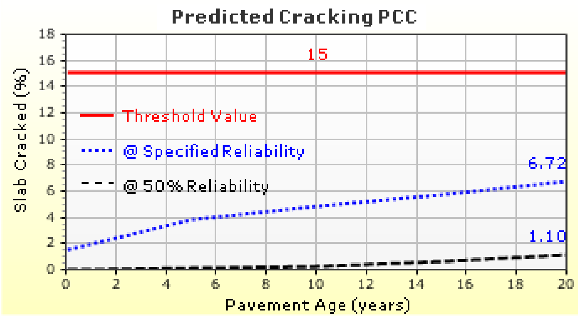
27.2.2.2.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	95.71	85.00	99.99	Pass
Mean joint faulting (in.)	0.20	0.03	85.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	6.72	85.00	99.48	Pass

27.2.2.2.4 Distress Charts







The pavement passes all of the criteria at 50 years. The restoration of the pavement actually will last 25 years (assuming texture depth does not wear down beyond critical level) or 5 years longer than the 50-year analysis period and some salvage value can be considered in the LCCA.

27.2.2.3 Summary of Concrete Pavement Design and Life Cycle Rehabilitation based on DARWin-ME Predictions

Pavement life cycle activities over a 50-year analysis period include the following as determined using the DARWin-ME based thresholds:

Year	Activity	Description
0	New construction	Place 7.5 in. PCC (with 1.0 in diameter dowel) over 4 in. crushed stone material
30	PCC Rehabilitation 1	¼ in. Diamond grinding & Full depth repair (0.27% slabs repaired in the travel lane)
Salvage at 50	5 years	

28 Detailed Information for Cell 8

28.1 ASPHALT CONCRETE PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

28.1.1 FDOT-Based Maintenance and Rehabilitation (M&R)

28.1.1.1 New Construction

28.1.1.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	1000
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period (design lane)	7,075,810

28.1.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

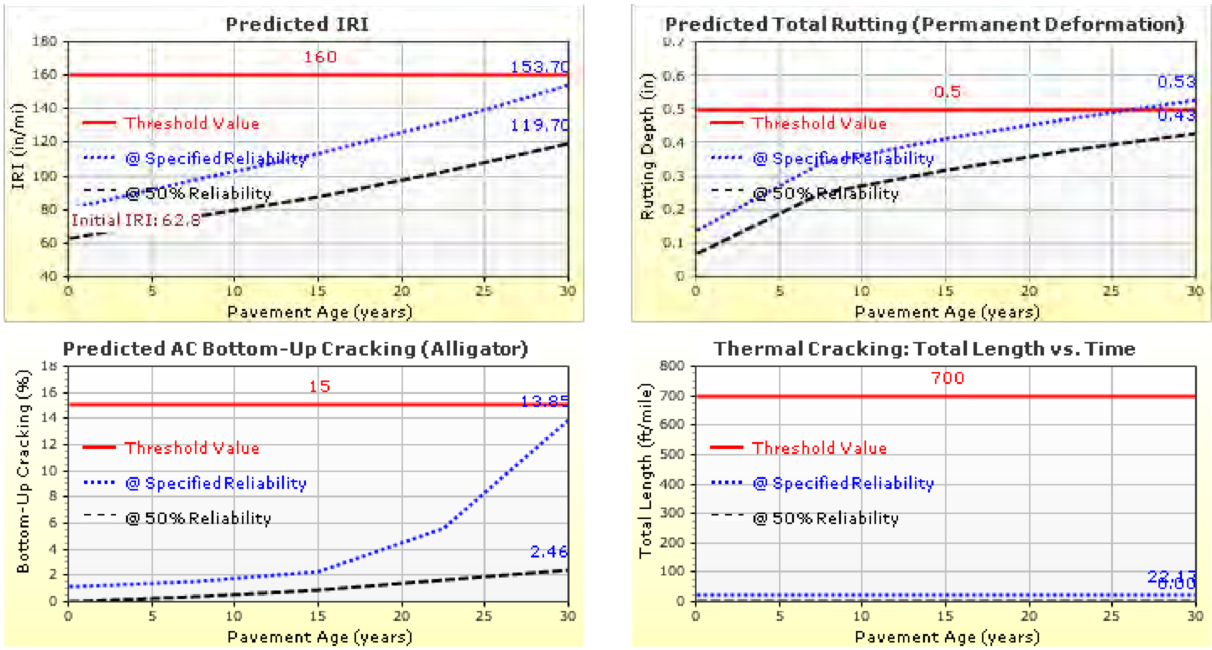
Layer Type	Material Type	Thickness (in)
AC Surface	HMA ½ in. mix with AC-30 (PG 67-22)	2.5 (including friction course FC12.5 = 0.5 in)
AC Binder	HMA ¾ in. mix with PG 64-22	3.5
Granular Base	Limerock Base	6
Subbase	Stabilized Embankment	12
Subgrade	A-2-4	Semi-infinite

28.1.1.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.0	153.74	85.00	89.01	Pass
Permanent deformation - total pavement (in.)	0.5	0.53	85.00	76.29*	Fail
AC bottom-up fatigue cracking (percent)	15.00	13.85	85.00	87.30	Pass
AC thermal fracture (ft/mile)	700.0	22.17	85.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.38	85.00	99.32	Pass

Note: * Predicted permanent deformation at specified reliability is within 0.5 in. threshold until the placement of first rehabilitation overlay at 14 years.

28.1.1.1.4 Distress Charts



28.1.1.2 FDOT Rehabilitation – Mill & Overlay

The Florida first rehabilitation is recommended at 14 years. The FDOT expected life of the AC overlay is 14 years. This becomes the Design Period for the next overlay. The Florida second rehabilitation was applied at 28 years with design period of 12 years and third overlay was placed at 40 years with design period of 10 years.

28.1.1.3 Summary of Asphalt Pavement Design and Life Cycle Rehabilitation using FDOT M&R

Pavement life cycle activities over a 50-year analysis period include the following as determined using the Florida DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 6 in. AC over 6 in. limerock base material
14	AC overlay 1	Mill 2.5 in. and replace 2.5 in. AC OL (Patching of 0.891% lane area is required in the travel lane)
28	AC overlay 2	Mill 2.5 in. and replace 2.5 in. AC OL (Patching of 1.21% lane area is required in the travel lane)
40	AC overlay 3	Mill 2.5 in. and replace 2.5 in. AC OL (Patching of 1.58% lane area is required in the travel lane)
50	End of analysis period	

28.1.2 DARWin-ME-Based Maintenance and Rehabilitation (M&R)

28.1.2.1 New Construction

28.1.2.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	1000
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	7,075,810

28.1.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

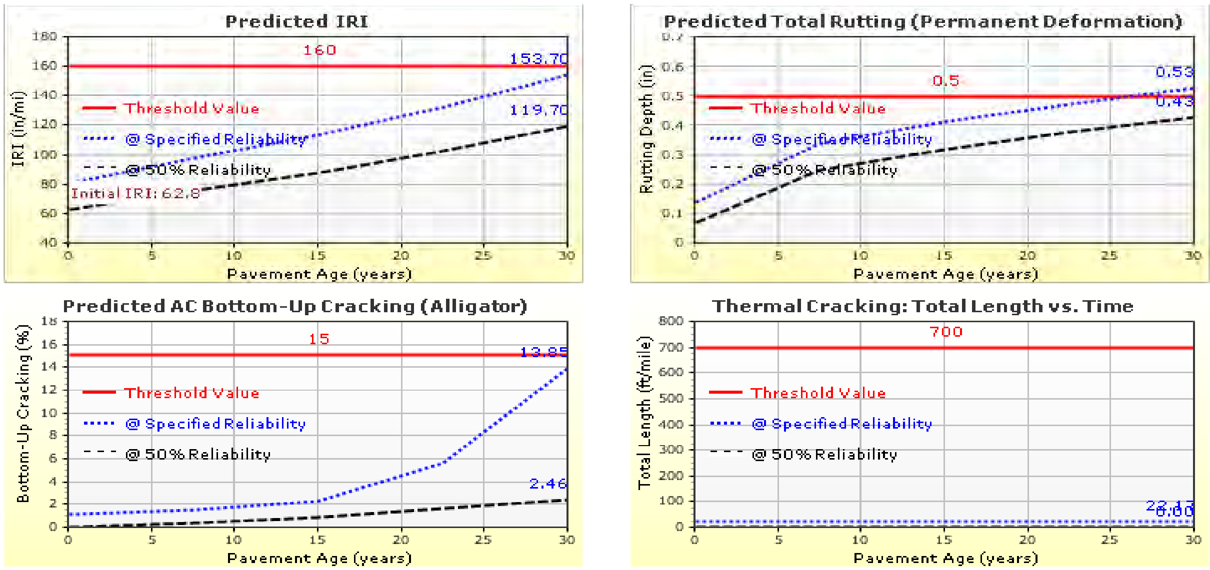
Layer Type	Material Type	Thickness (in)
AC Surface	HMA ½ in. mix with AC-30 (PG 67-22)	2.5 (including friction course FC12.5 = 0.5 in)
AC Binder	HMA ¾ in. mix with PG 64-22	3.5
Granular Base	Limerock Base	6
Subbase	Stabilized Embankment	12
Subgrade	A-2-4	Semi-infinite

28.1.2.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.0	153.74	85.00	89.01	Pass
Permanent deformation - total pavement (in.)	0.5	0.53	85.00	76.29*	Fail
AC bottom-up fatigue cracking (percent)	15.00	13.85	85.00	87.30	Pass
AC thermal fracture (ft/mile)	700.0	22.17	85.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.38	85.00	99.32	Pass

Note: * Predicted permanent deformation at specified reliability is within 0.5 in. threshold until the placement of first rehabilitation overlay at 20 years.

28.1.2.1.4 Distress Charts



28.1.2.2 First Rehabilitation – Mill & Overlay

The DARWin-ME based thresholds were used to establish future rehabilitation activities. A reasonable maximum service life of 20 years for new AC and 17 years for AC overlay was assumed for this climate since DARWin-ME does not consider all durability related distresses that develop over time. The first overlay project was then run for 17 years design period instead of typical FDOT design life and the second overlay was run for 13 years. The mill and overlay then starts out rutting at 0 and IRI at 60 in/mile. Fatigue damage was low but is also determined and considered in the next overlay cracking prediction.

28.1.2.2.1 Rehabilitation Information

Rehabilitation strategy	Mill top 2.5 in. of AC surface course and place an AC overlay of 2.5 in. thick. Patching of 1.41% lane area is required in the travel lane.
Year of rehabilitation	20
Design period	13

28.1.2.2.2 Traffic Inputs

Design period (from year 20 to 37)	17
Initial two-way AADTT	1600
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	5,543,620

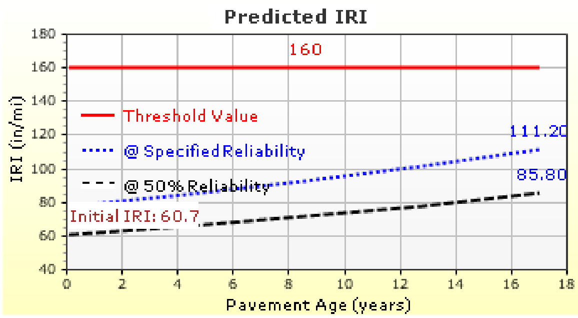
28.1.2.2.3 Pavement Structure

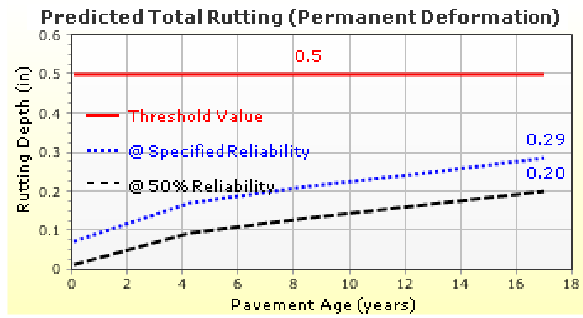
Layer Type	Material Type	Thickness (in)
AC Overlay (placed at 20 years)	HMA ½ in. mix with AC-30 (PG 67-22)	2.5 (including friction courseFC12.5 = 0.5 in)
AC Existing	HMA ¾ in. mix with PG 64-22	3.5
Granular Base	Limerock Base	6
Subbase	Stabilized Embankment	12
Subgrade	A-2-4	Semi-infinite

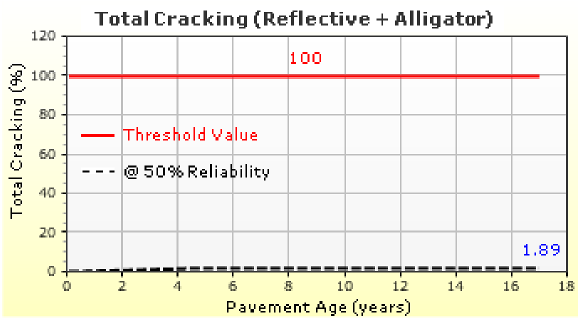
28.1.2.2.4 Distress Prediction & Reliability Summary

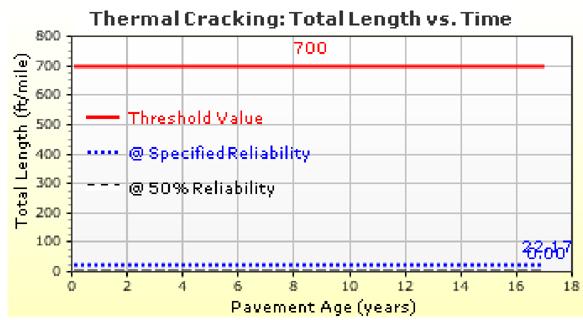
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	111.21	85.00	99.88	Pass
Permanent deformation - total pavement (in.)	0.5	0.29	85.00	99.98	Pass
Total Cracking (Reflective + Alligator) (percent)	10.00	1.89	50.00		Pass
AC thermal fracture (ft/mile)	700.00	22.17	85.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	15.00	1.17	85.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.28	85.00	100.00	Pass

28.1.2.2.5 Distress Charts









28.1.2.3 Second Rehabilitation – Mill & Overlay

The second rehabilitation was placed at 37 years with a design life of 13 years. Note that second rehabilitation has slightly greater than 3% linear traffic growth rate.

28.1.2.3.1 Rehabilitation Information

Rehabilitation strategy	Mill top 2.5 in. of AC surface course and place an AC overlay of 2.5 in. thick. Patching of 1.89% lane area is required in the travel lane.
Year of rehabilitation	37
Design period	13

28.1.2.3.2 Traffic Inputs

Design period (from year 37 to 50)	13
Initial two-way AADTT	2416
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	6,091,510

28.1.2.3.3 Pavement Structure

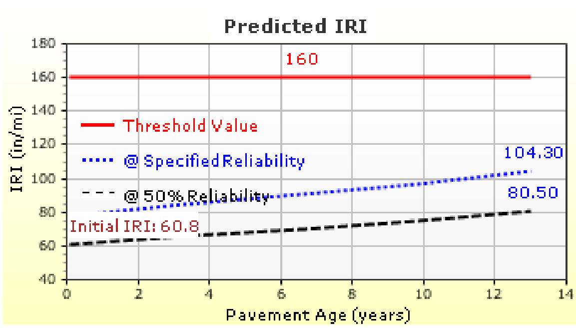
Layer Type	**Material Type**	**Thickness (in)**
AC Overlay	HMA ½ in. mix with AC-30	2.5

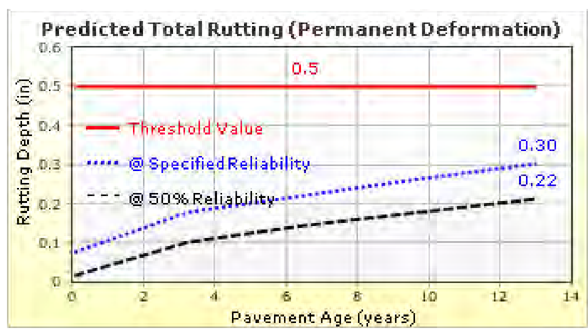
(placed at 37 years)	(PG 67-22)	(including friction course FC12.5 = 0.5 in)
AC Existing	HMA ¾ in. mix with PG 64-22	3.5
Granular Base	Limerock Base	6
Subbase	Stabilized Embankment	12
Subgrade	A-2-4	Semi-infinite

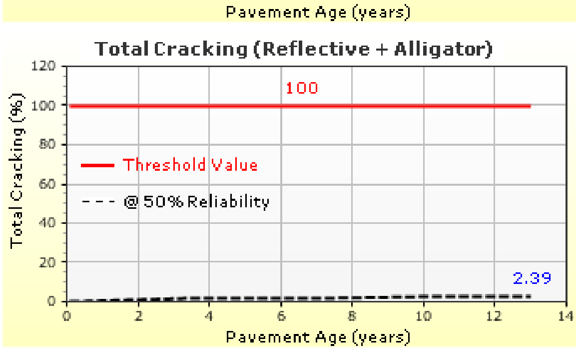
28.1.2.3.4 Distress Prediction & Reliability Summary

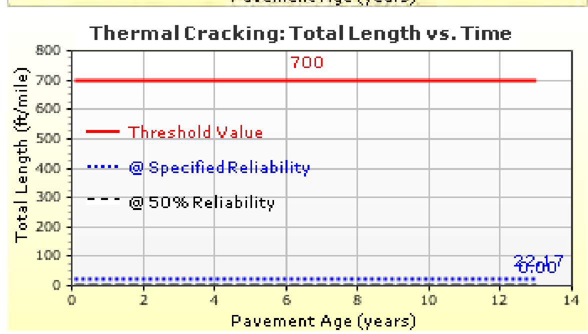
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	104.28	85.00	99.97	Pass
Permanent deformation - total pavement (in.)	0.5	0.30	85.00	99.96	Pass
Total Cracking (Reflective + Alligator) (percent)	10.00	2.39	50.00		Pass
AC thermal fracture (ft/mile)	700.00	22.17	85.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	15.00	1.17	85.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.29	85.00	99.99	Pass

28.1.2.3.5 Distress Charts









28.1.2.4 Summary of Asphalt Pavement Design and Life Cycle Rehabilitation based on DARWin-ME Predictions

Pavement life cycle activities over a 50-year analysis period include the following as determined using the DARWin-ME threshold criteria:

Year	Activity	Description
0	New construction	Place 6 in. AC over 6 in. limerock base material
20	AC overlay 1	Mill 2.5 in. and replace 2.5 in. AC OL (Patching of 1.41% lane area is required in the travel lane).
37	AC overlay 2	Mill 2.5 in. and replace 2.5 in. AC OL (Patching of 1.89% lane area is required in the travel lane).
Salvage at 50	4 years	

28.2 PORTLAND CEMENT CONCRETE PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

The site conditions, Design period and analysis period are exactly the same as that used for the AC design.

28.2.1 FDOT-Based Maintenance and Rehabilitation (M&R)

The FDOT M&R strategy is to perform concrete pavement restoration at 20 years and 35 years. This includes 3% and 5% respectively, cracked slabs replacement in the travel lane and diamond grinding of the surface to restore IRI and remove faulting.

28.2.1.1 New Construction

28.2.1.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	1000
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	7,075,810

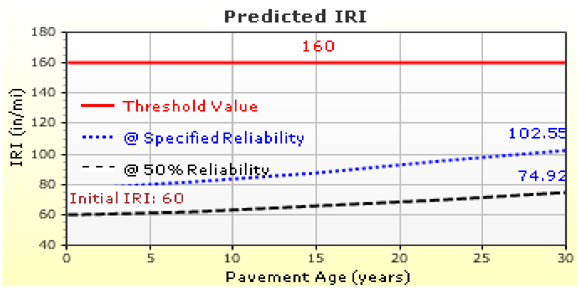
28.2.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

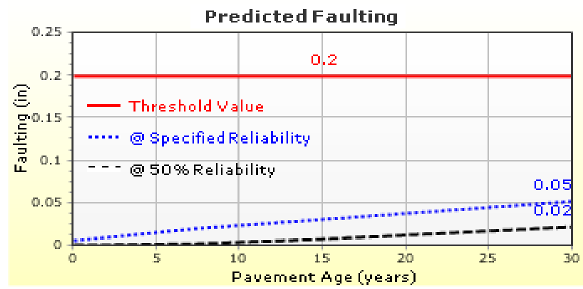
Layer Type	Material Type	Thickness (in)	Dowel Dia. (in)
JPCP-PCC	PCC	9	1.25
Granular Base	Limerock Base	6	
Subbase	Stabilized Embankment	12	
Subgrade	A-2-4	Semi-infinite	

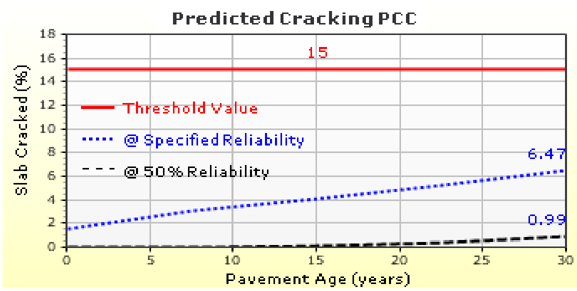
28.2.1.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	102.55	85.00	99.93	Pass
Mean joint faulting (in.)	0.20	0.05	85.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	6.47	85.00	99.60	Pass

28.2.1.1.4 Distress Charts







28.2.1.2 Summary of FDOT Concrete Pavement Design and Life Cycle Rehabilitation

Pavement life cycle activities over a 50-year analysis period include the following as determined using the Florida DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 9 in. PCC (with 1.25 in diameter dowel) over 6 in. limerock base material
20	PCC Rehabilitation 1	¼ in. Diamond grinding and full depth repair (3% slabs repaired in the travel lane as per FDOT M&R strategy)
35	PCC Rehabilitation 2	¼ in. Diamond grinding and full depth repair (5% slabs repaired in the travel lane as per FDOT M&R strategy)
50	End of analysis period	

28.2.2 DARWin-ME-Based Maintenance and Rehabilitation (M&R)

28.2.2.1 New Construction

28.2.2.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	1000
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	7,075,810

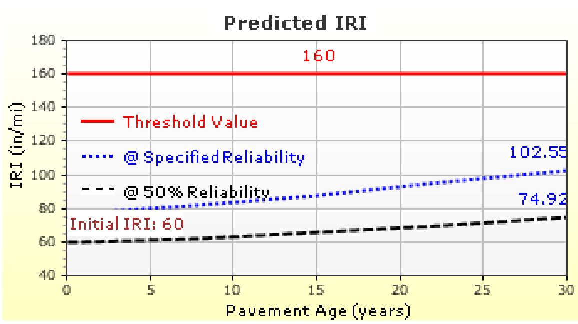
28.2.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

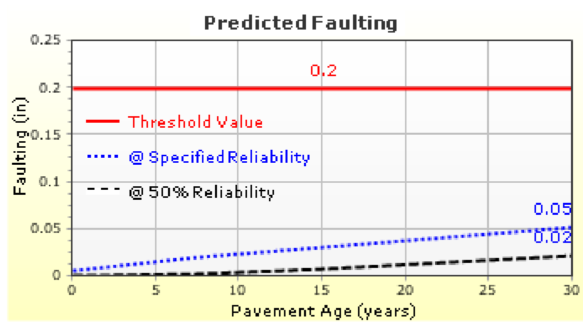
Layer Type	Material Type	Thickness (in)	Dowel Dia. (in)
JPCP-PCC	PCC	9	1.25
Granular Base	Limerock Base	6	
Subbase	Stabilized Embankment	12	
Subgrade	A-2-4	Semi-infinite	

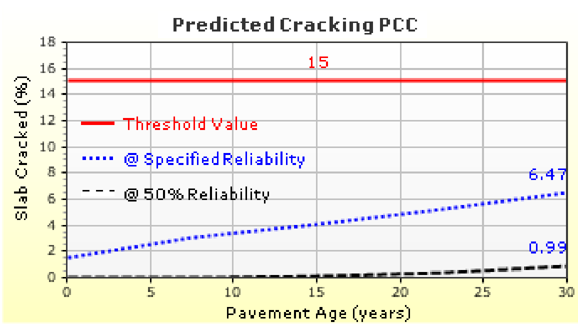
28.2.2.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	102.55	85.00	99.93	Pass
Mean joint faulting (in.)	0.20	0.05	85.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	6.47	85.00	99.60	Pass

28.2.2.1.4 Distress Charts







This design passes the DARWin-ME threshold criteria over 30 years. At 30 years, there is 6.47% fatigue cracking, 0.05 in faulting and 102.55 in/mile IRI at 85% reliability. Thus, diamond grinding and full depth repair are the most logical M&R treatment at 30 years.

28.2.2.2 First Rehabilitation –Diamond Grinding & Full Depth Repair

At 30 years, all cracked slabs will be replaced. Past fatigue cracking damage will be considered in future cracking projections. A maximum JPCP restoration life of 25 years was assumed since DARWin-ME does not consider all durability related distresses that develop over time. The first restoration project was then run for 20 years design period.

28.2.2.2.1 Traffic Inputs

Design period (from year 30 to 50)	20
Initial two-way AADTT	1900
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	90.0
Number of trucks over design period	8,025,820

28.2.2.2.2 Pavement Structure That Meets Performance & Reliability Requirements

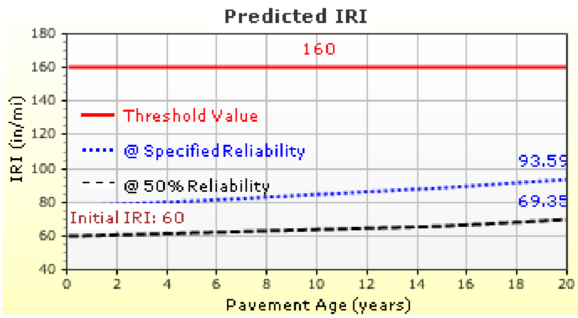
Layer Type	**Material Type**	**Thickness (in)**
JPCP-PCC	PCC	8.75*
Granular Base	Limerock Base	6
Subbase	Stabilized Embankment	12
Subgrade	A-2-4	Semi-infinite

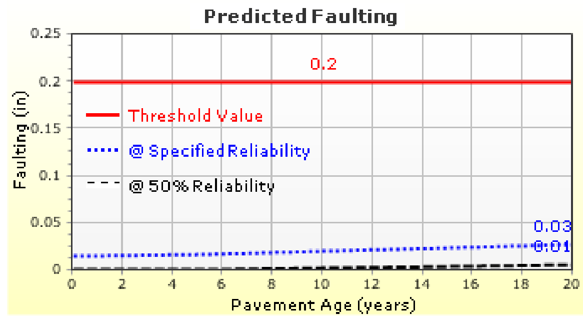
*Note: 0.25 inch slab thickness was removed by diamond grinding.

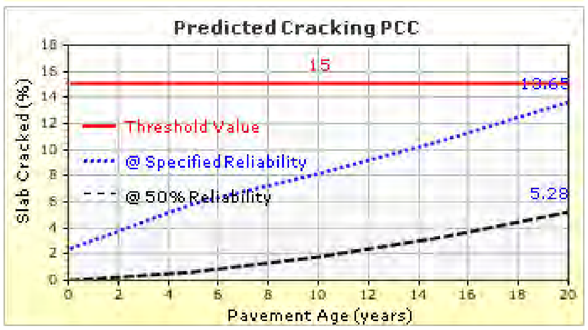
28.2.2.2.3 Distress Prediction & Reliability Summary

Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in./mile)	160.00	93.59	85.00	99.99	Pass
Mean joint faulting (in.)	0.20	0.03	85.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	13.65	85.00	88.56	Pass

28.2.2.2.4 Distress Charts







The pavement passes all of the criteria at 50 years. The restoration of the pavement actually will last 23 years or 3 years longer than the 50-year analysis period and some salvage value can be considered in the LCCA.

28.2.2.3 Summary of Concrete Pavement Design and Life Cycle Rehabilitation based on DARWin-ME Predictions

Pavement life cycle activities over a 50-year analysis period include the following as determined using the DARWin-ME based thresholds:

Year	Activity	Description
0	New construction	Place 9 in. PCC (with 1.25 in diameter dowel) over 6 in. limerock base material
30	PCC Rehabilitation 1	¼ in. Diamond grinding & Full depth repair (0.99% slabs repaired in the travel lane)
Salvage at 50	3 years	

29 Detailed Information for Cell 9a

29.1 ASPHALT CONCRETE PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

29.1.1 MoDOT-Based Maintenance and Rehabilitation (M&R)

29.1.1.1 New Construction

29.1.1.1.1 Traffic Inputs

Design period	20
Initial two-way AADTT	8,000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period (design lane)	30,038,200

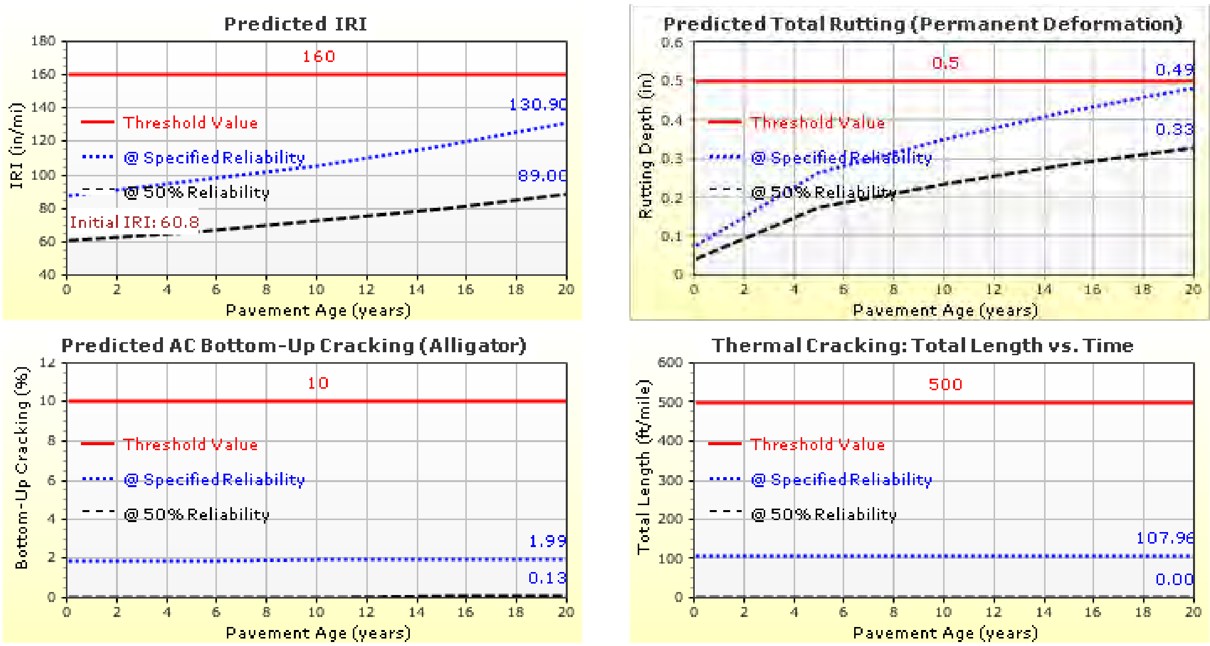
29.1.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	Material Type	Thickness (in)
AC Surface	HMA with PG 76-22	2
AC Binder	HMA with PG 76-22	3
AC Base	HMA with PG 64-22	8.5
Granular Base	A-1-a	24
Subgrade	A-7-6	Semi-infinite

29.1.1.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.0	130.89	95.00	99.73	Pass
Permanent deformation - total pavement (in.)	0.5	0.49	95.00	96.42	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.99	95.00	100.00	Pass
AC thermal fracture (ft/mile)	500.0	107.96	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.44	95.00	99.04	Pass

29.1.1.1.4 Distress Charts



29.1.1.2 MoDOT Rehabilitation – Mill & Overlay

The Missouri first rehabilitation is recommended at 20 years with overlay design period of 10 years.

29.1.1.3 Summary of Asphalt Pavement Design and Life Cycle Rehabilitation using MoDOT M&R

Pavement life cycle activities over a 30-year analysis period include the following as determined using the Missouri DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 13.5 in. AC over 24 in. crushed stone base material
20	AC overlay 1	Mill 2 in. and replace 2 in. AC OL (Patching of 0.13% lane area is required in the travel lane)
30	End of analysis period	

29.1.2 DARWin-ME-Based Maintenance and Rehabilitation (M&R)

29.1.2.1 New Construction

29.1.2.1.1 Traffic Inputs

Design period	20
Initial two-way AADTT	8,000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	30,038,200

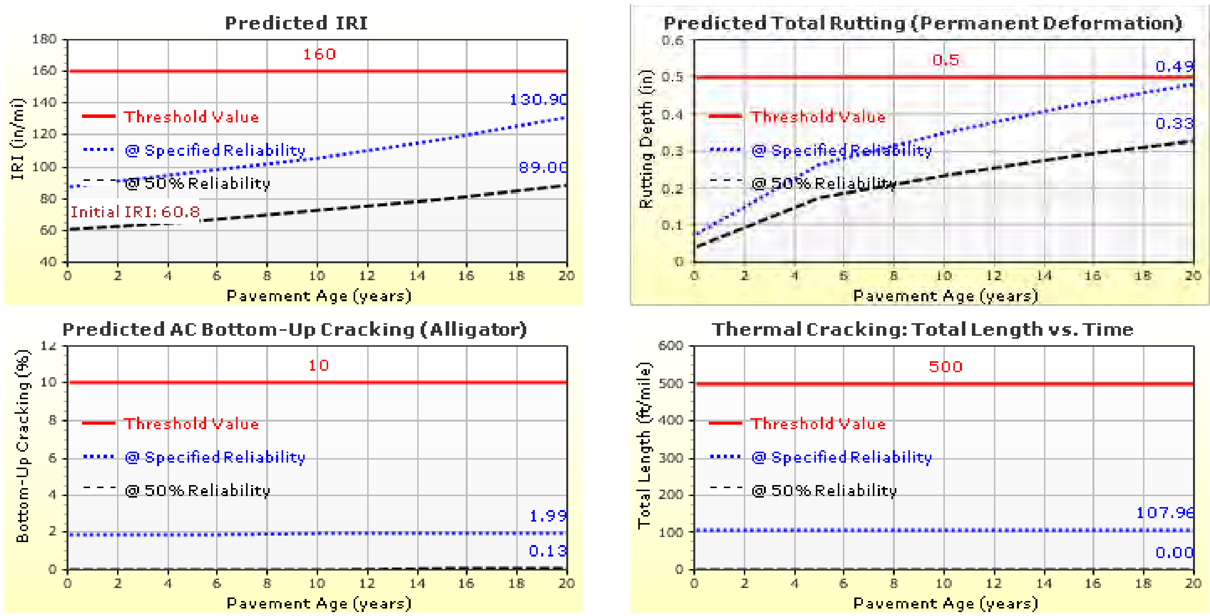
29.1.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	**Material Type**	**Thickness (in)**
AC Surface	HMA with PG 76-22	2
AC Binder	HMA with PG 76-22	3
AC Base	HMA with PG 64-22	8.5
Granular Base	A-1-a	24
Subgrade	A-7-6	Semi-infinite

29.1.2.1.3 Distress Prediction & Reliability Summary

Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in./mile)	160.0	130.89	95.00	99.73	Pass
Permanent deformation - total pavement (in.)	0.5	0.49	95.00	96.42	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.99	95.00	100.00	Pass
AC thermal fracture (ft/mile)	500.0	107.96	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.44	95.00	99.04	Pass

29.1.2.1.4 Distress Charts



29.1.2.2 First Rehabilitation – Mill & Overlay

The DARWin-ME based thresholds were used to establish future rehabilitation activities. A reasonable maximum service life of 20 years for new AC and 17 years for AC overlay was assumed for this climate since DARWin-ME does not consider all durability related distresses that develop over time. The first overlay project was then run for 10 years design period. The mill and overlay then starts out rutting at 0 and IRI at 60 in/mile. Fatigue damage was low but is also determined and considered in the next overlay cracking prediction.

29.1.2.2.1 Rehabilitation Information

Rehabilitation strategy	Mill top 2 in. of AC surface course and place an AC overlay of 2 in. thick. Patching of 0.13% lane area is required in the travel lane.
Year of rehabilitation	20
Design period	10

29.1.2.2.2 Traffic Inputs

Design period (from year 20 to 30)	10
Initial two-way AADTT	12,800
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	21,225,400

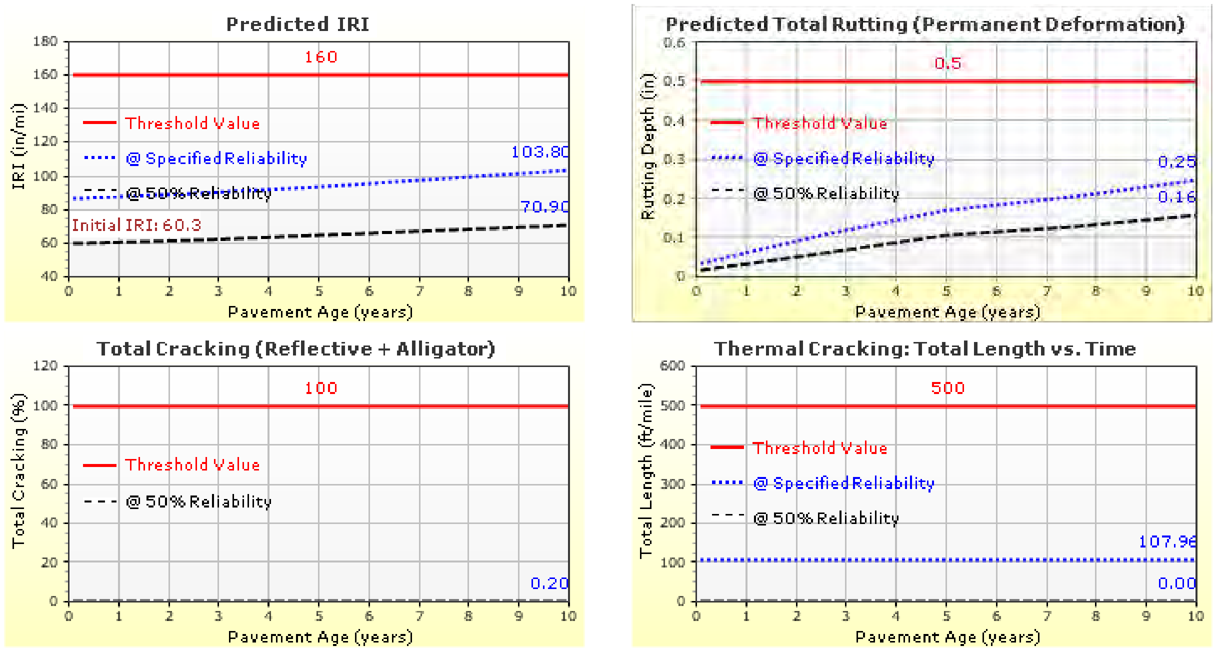
29.1.2.2.3 Pavement Structure

Layer Type	Material Type	Thickness (in)
AC Overlay (placed at 20 years)	HMA with PG 76-22	2
AC Binder	HMA with PG 76-22	3
AC Base	HMA with PG 64-22	8.5
Granular Base	A-1-a	24
Subgrade	A-7-6	Semi-infinite

29.1.2.2.4 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	103.82	95.00	100.00	Pass
Permanent deformation - total pavement (in.)	0.5	0.25	95.00	100.00	Pass
Total Cracking (Reflective + Alligator) (percent)	5.00	0.20	95.00		Pass
AC thermal fracture (ft/mile)	500.00	107.96	95.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.86	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.25	95.00	100.00	Pass

29.1.2.2.5 Distress Charts



The pavement passes all of the criteria at 30 years. The overlay actually will last 17 years or 7 years longer than the 30-year analysis period and some salvage value can be considered in the LCCA.

29.1.2.3 Summary of Asphalt Pavement Design and Life Cycle Rehabilitation based on DARWin-ME Predictions

Pavement life cycle activities over a 30-year analysis period include the following as determined using the DARWin-ME threshold criteria:

Year	Activity	Description
0	New construction	Place 13.5 in. AC over 24 in. crushed stone base material
20	AC overlay 1	Mill 2 in. and replace 2 in. AC OL (Patching of 0.13% lane area is required in the travel lane).
Salvage at 30	7 years (maximum 17 years overlay life)	

29.2 PORTLAND CEMENT CONCRETE PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

The site conditions, design period and analysis period are exactly the same as that used for the AC design.

29.2.1 MoDOT-Based Maintenance and Rehabilitation (M&R)

The MoDOT M&R strategy is to perform concrete pavement restoration at 20 years. This includes 1.5% cracked slabs replacement in the travel lane and diamond grinding of the surface to restore IRI and remove faulting.

29.2.1.1 New Construction

29.2.1.1.1 Traffic Inputs

Design period	20
Initial two-way AADTT	8,000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	30,038,200

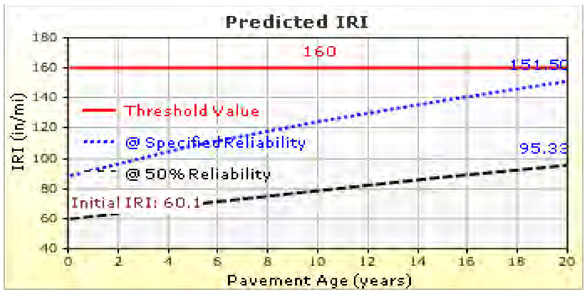
29.2.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

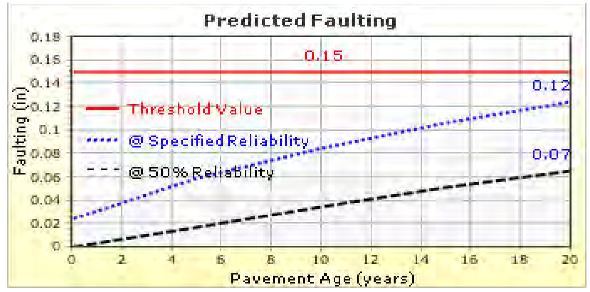
Layer Type	**Material Type**	**Thickness (in)**	**Dowel Dia. (in)**
JPCP-PCC	PCC	10.5	1.5
Granular Base	A-1-a	6	
Subgrade	A-7-6	Semi-infinite	

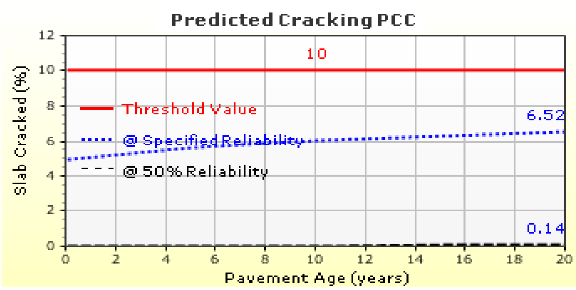
29.2.1.1.3 Distress Prediction & Reliability Summary

Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in./mile)	160.00	151.50	95.00	97.09	Pass
Mean joint faulting (in.)	0.15	0.12	95.00	99.07	Pass
JPCP transverse cracking (percent slabs)	10.00	6.52	95.00	99.45	Pass

29.2.1.1.4 Distress Charts







29.2.1.2 Summary of MoDOT Concrete Pavement Design and Life Cycle Rehabilitation

Pavement life cycle activities over a 30-year analysis period include the following as determined using the Missouri DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 10.5 in. PCC (with 1.5 in diameter dowel) over 6 in. crushed stone material
20	PCC Rehabilitation 1	¼ in. Diamond grinding and full depth repair (1.5% slabs repaired in the travel lane as per MoDOT M&R strategy)
30	End of analysis period	

29.2.2 DARWin-ME-Based Maintenance and Rehabilitation (M&R)

29.2.2.1 New Construction

29.2.2.1.1 Traffic Inputs

Design period	20
Initial two-way AADTT	8,000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	30,038,200

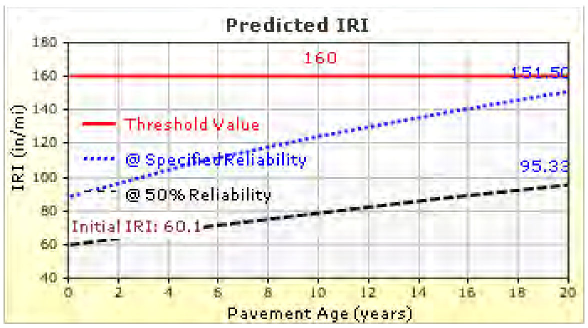
29.2.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

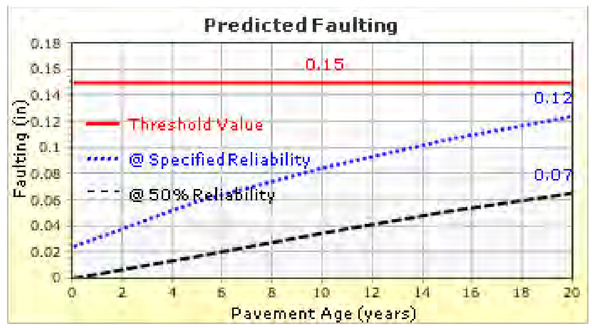
Layer Type	Material Type	Thickness (in)	Dowel Dia. (in)
JPCP-PCC	PCC	10.5	1.5
Granular Base	A-1-a	6	
Subgrade	A-7-6	Semi-infinite	

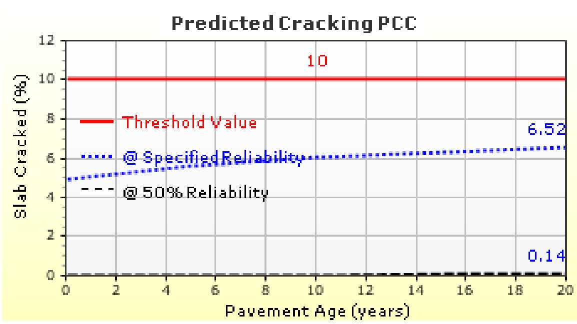
29.2.2.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	151.50	95.00	97.09	Pass
Mean joint faulting (in.)	0.15	0.12	95.00	99.07	Pass
JPCP transverse cracking (percent slabs)	10.00	6.52	95.00	99.45	Pass

29.2.2.1.4 Distress Charts







This design passes the DARWin-ME threshold criteria over 20 years. At 20 years, there is 6.52% fatigue cracking, 0.12 in faulting and 151.50 in/mile IRI at 95% reliability. Thus, diamond grinding and full depth repair are the most logical M&R treatment at 20 years.

29.2.2.2 First Rehabilitation –Diamond Grinding & Full Depth Repair

At 20 years, all cracked slabs will be replaced. Past fatigue cracking damage will be considered in future cracking projections. A maximum JPCP restoration life of 25 years was assumed since DARWin-ME does not consider all durability related distresses that develop over time. The first restoration project was then run for 10 years design period.

29.2.2.2.1 Traffic Inputs

Design period (from year 20 to 30)	10
Initial two-way AADTT	12,800
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	21,225,400

29.2.2.2.2 Pavement Structure That Meets Performance & Reliability Requirements

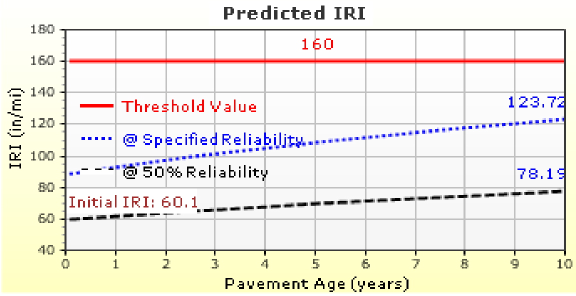
Layer Type	**Material Type**	**Thickness (in)**
JPCP-PCC	PCC	10.25*
Granular Base	A-1-a	6
Subgrade	A-7-6	Semi-infinite

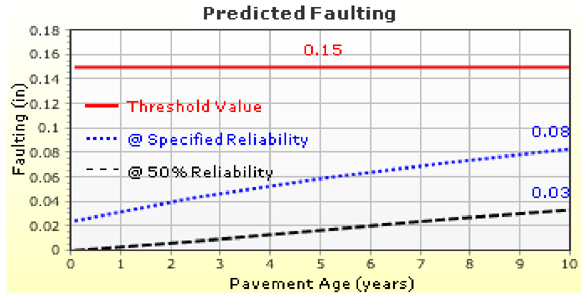
*Note: 0.25 inch slab thickness was removed by diamond grinding.

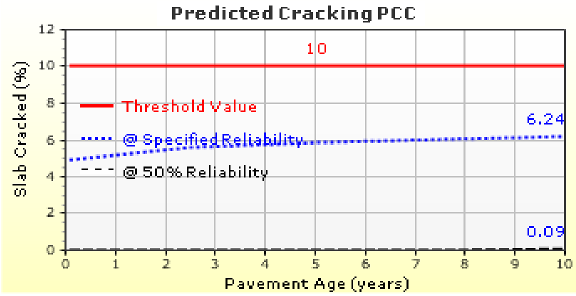
29.2.2.2.3 Distress Prediction & Reliability Summary

Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in./mile)	160.00	123.72	95.00	99.84	Pass
Mean joint faulting (in.)	0.15	0.08	95.00	99.99	Pass
JPCP transverse cracking (percent slabs)	10.00	6.24	95.00	99.60	Pass

29.2.2.2.4 Distress Charts







The pavement passes all of the criteria at 30 years. The restoration of the pavement actually will last 25 years or 15 years longer than the 30-year analysis period and some salvage value can be considered in the LCCA.

29.2.3 Summary of Concrete Pavement Design and Life Cycle Rehabilitation based on DARWin-ME Predictions

Pavement life cycle activities over a 30-year analysis period include the following as determined using the DARWin-ME based thresholds:

Year	Activity	Description
0	New construction	Place 10.5 in. PCC (with 1.5 in diameter dowel) over 6 in. crushed stone material
20	PCC Rehabilitation 1	¼ in. Diamond grinding & Full depth repair (0.14% slabs repaired in the travel lane)
Salvage at 30	15 years (maximum 25 years restoration life)	

30 Detailed Information for Cell 9b

30.1 ASPHALT CONCRETE PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

30.1.1 MoDOT-Based Maintenance and Rehabilitation (M&R)

30.1.1.1 New Construction

30.1.1.1.1 Traffic Inputs

Design period	20
Initial two-way AADTT	8,000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period (design lane)	30,038,200

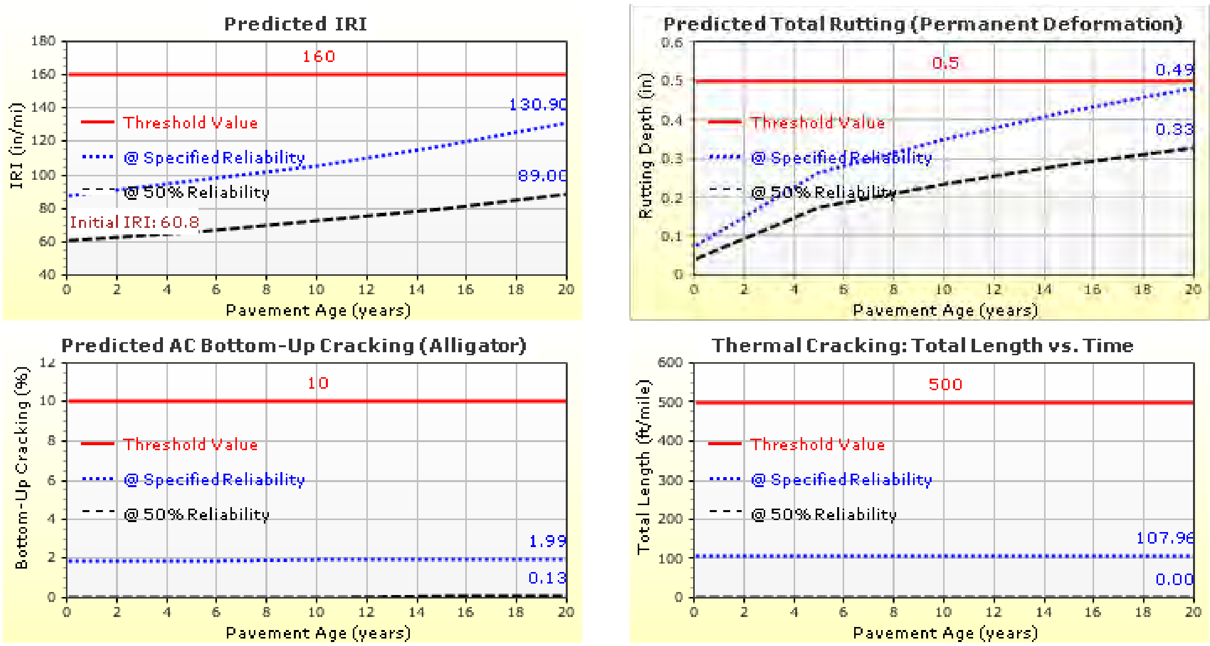
30.1.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	Material Type	Thickness (in)
AC Surface	HMA with PG 76-22	2
AC Binder	HMA with PG 76-22	3
AC Base	HMA with PG 64-22	8.5
Granular Base	A-1-a	24
Subgrade	A-7-6	Semi-infinite

30.1.1.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.0	130.89	95.00	99.73	Pass
Permanent deformation - total pavement (in.)	0.5	0.49	95.00	96.42	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.99	95.00	100.00	Pass
AC thermal fracture (ft/mile)	500.0	107.96	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.44	95.00	99.04	Pass

30.1.1.1.4 Distress Charts



30.1.1.2 MoDOT Rehabilitation – Mill & Overlay

The Missouri first rehabilitation is recommended at 20 years. The MoDOT expected life of the AC overlay is 15 years. This becomes the Design Period for the next overlay. The Missouri second rehabilitation was applied at 35 years with design period of 15 years.

30.1.1.3 9b.AC.A3Summary of Asphalt Pavement Design and Life Cycle Rehabilitation using MoDOT M&R

Pavement life cycle activities over a 50-year analysis period include the following as determined using the Missouri DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 13.5 in. AC over 24 in. crushed stone base material
20	AC overlay 1	Mill 2 in. and replace 2 in. AC OL (Patching of 0.13% lane area is required in the travel lane)
35	AC overlay 2	Mill 2 in. and replace 2 in. AC OL (Patching of 0.26% lane area is required in the travel lane)
50	End of analysis period	

30.1.2 DARWin-ME-Based Maintenance and Rehabilitation (M&R)

30.1.2.1 New Construction

30.1.2.1.1 Traffic Inputs

Design period	20
Initial two-way AADTT	8,000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	30,038,200

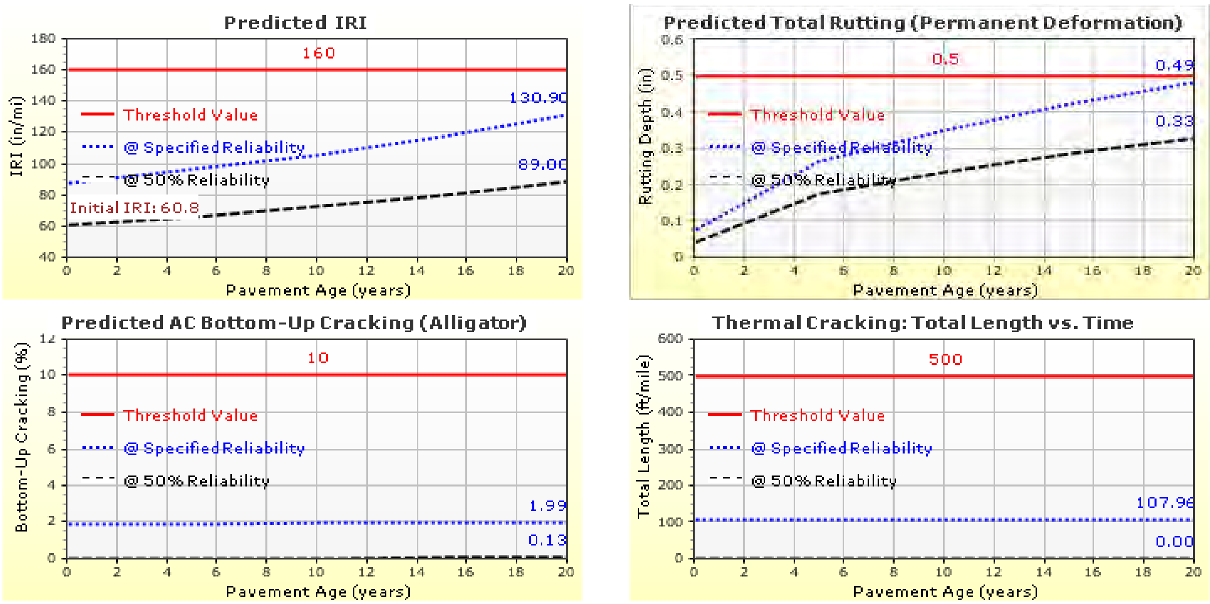
30.1.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	Material Type	Thickness (in)
AC Surface	HMA with PG 76-22	2
AC Binder	HMA with PG 76-22	3
AC Base	HMA with PG 64-22	8.5
Granular Base	A-1-a	24
Subgrade	A-7-6	Semi-infinite

30.1.2.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.0	130.89	95.00	99.73	Pass
Permanent deformation - total pavement (in.)	0.5	0.49	95.00	96.42	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.99	95.00	100.00	Pass
AC thermal fracture (ft/mile)	500.0	107.96	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.44	95.00	99.04	Pass

30.1.2.1.4 Distress Charts



30.1.2.2 First Rehabilitation – Mill & Overlay

The DARWin-ME based thresholds were used to establish future rehabilitation activities. A reasonable maximum service life of 20 years for new AC and 17 years for AC overlay was assumed for this climate since DARWin-ME does not consider all durability related distresses that develop over time. The first overlay project was then run for 17 years design period instead of typical MoDOT design life. The mill and overlay then starts out rutting at 0 and IRI at 60 in/mile. Fatigue damage was low but is also determined and considered in the next overlay cracking prediction.

30.1.2.2.1 Rehabilitation Information

Rehabilitation strategy	Mill top 2 in. of AC surface course and place an AC overlay of 2 in. thick. Patching of 0.13% lane area is required in the travel lane.
Year of rehabilitation	20
Design period	17

30.1.2.2.2 Traffic Inputs

Design period (from year 20 to 37)	17
Initial two-way AADTT	12,800
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	39,421,300

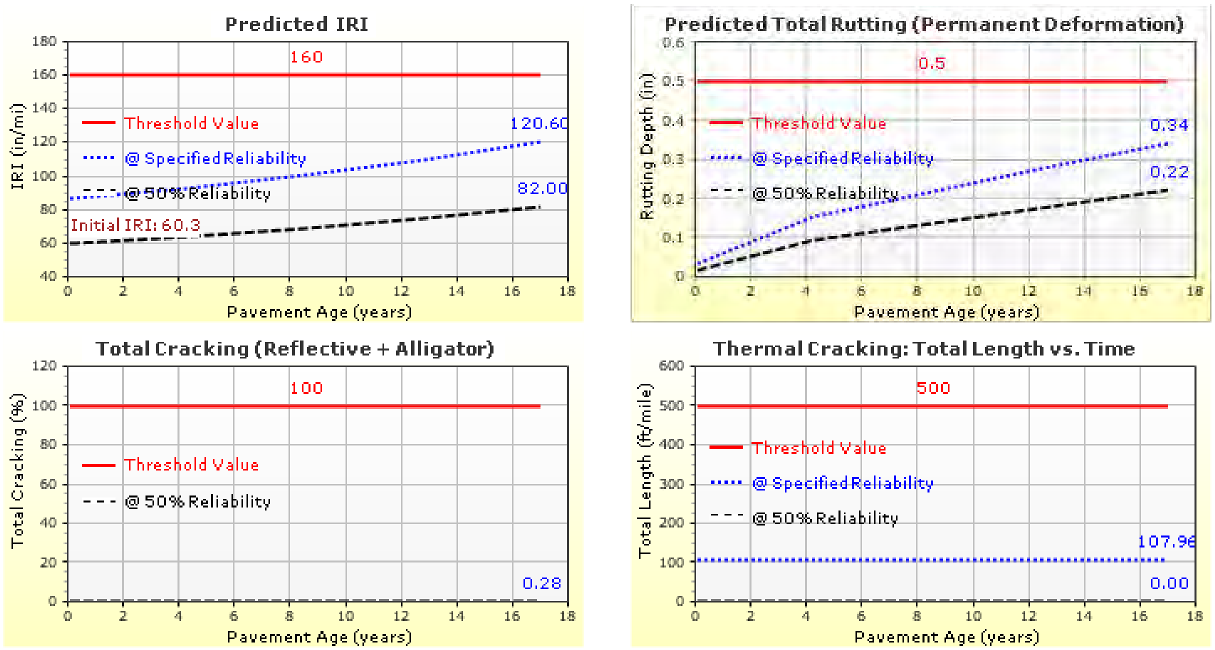
30.1.2.2.3 Pavement Structure

Layer Type	Material Type	Thickness (in)
AC Overlay (placed at 20 years)	HMA with PG 76-22	2
AC Binder	HMA with PG 76-22	3
AC Base	HMA with PG 64-22	8.5
Granular Base	A-1-a	24
Subgrade	A-7-6	Semi-infinite

30.1.2.2.4 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	120.56	95.00	99.96	Pass
Permanent deformation - total pavement (in.)	0.5	0.34	95.00	99.99	Pass
Total Cracking (Reflective + Alligator) (percent)	5.00	0.28	95.00		Pass
AC thermal fracture (ft/mile)	500.00	107.96	95.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.86	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.34	95.00	99.99	Pass

30.1.2.2.5 Distress Charts



30.1.2.3 Second Rehabilitation – Mill & Overlay

The second rehabilitation was placed at 37 years with a design life of 13 years.

30.1.2.3.1 Rehabilitation Information

Rehabilitation strategy	Mill top 2 in. of AC surface course and place an AC overlay of 2 in. thick. Patching of 0.28% lane area is required in the travel lane.
Year of rehabilitation	37
Design period	13

30.1.2.3.2 Traffic Inputs

Design period (from year 37 to 50)	13
Initial two-way AADTT	16,880
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	37,831,000

30.1.2.3.3 Pavement Structure

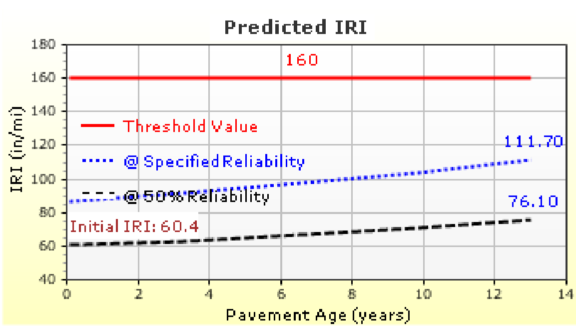
Layer Type	**Material Type**	**Thickness (in)**
AC Overlay (placed at 37 years)	HMA with PG 76-22	2

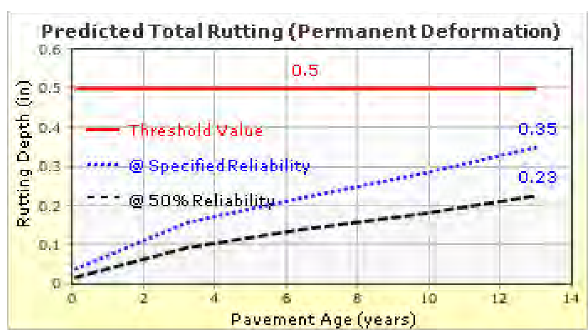
AC Binder	HMA with PG 76-22	3
AC Base	HMA with PG 64-22	8.5
Granular Base	A-1-a	24
Subgrade	A-7-6	Semi-infinite

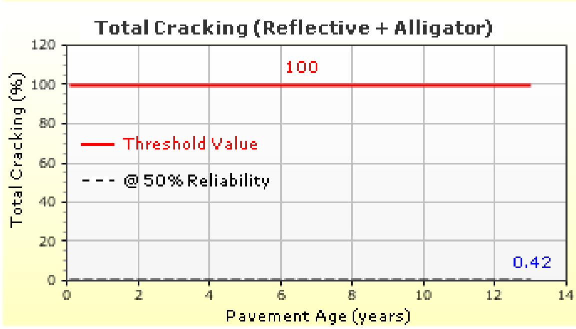
30.1.2.3.4 Distress Prediction & Reliability Summary

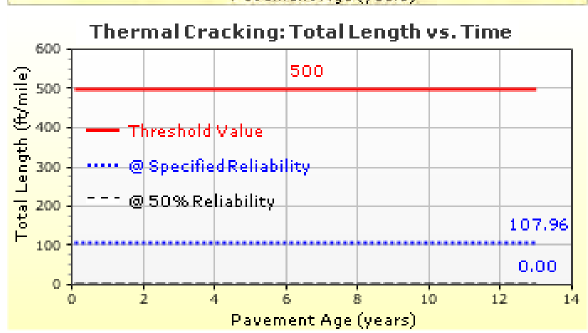
Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in./mile)	160.00	111.73	95.00	99.99	Pass
Permanent deformation - total pavement (in.)	0.5	0.35	95.00	99.99	Pass
Total Cracking (Reflective + Alligator) (percent)	5.00	0.42	95.00		Pass
AC thermal fracture (ft/mile)	500.00	107.96	95.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.86	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.35	95.00	99.99	Pass

30.1.2.3.5 Distress Charts









The pavement passes all of the criteria at 50 years. The overlay actually will last 17 years or 4 years longer than the 50-year analysis period and some salvage value can be considered in the LCCA.

30.1.2.4 Summary of Asphalt Pavement Design and Life Cycle Rehabilitation based on DARWin-ME Predictions

Pavement life cycle activities over a 50-year analysis period include the following as determined using the DARWin-ME threshold criteria:

Year	Activity	Description
0	New construction	Place 13.5 in. AC over 24 in. crushed stone base material
20	AC overlay 1	Mill 2 in. and replace 2 in. AC OL (Patching of 0.13% lane area is required in the travel lane).
37	AC overlay 2	Mill 2 in. and replace 2 in. AC OL (Patching of 0.28% lane area is required in the travel lane).
Salvage at 50	4 years (maximum 17 years overlay life)	

30.2 PORTLAND CEMENT CONCRETE PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

The site conditions, design period and analysis period are exactly the same as that used for the AC design.

30.2.1 MoDOT-Based Maintenance and Rehabilitation (M&R)

The MoDOT M&R strategy is to perform concrete pavement restoration at 20 years. This includes 1.5% cracked slabs replacement in the travel lane and diamond grinding of the surface to restore IRI and remove faulting.

30.2.1.1 New Construction

30.2.1.1.1 Traffic Inputs

Design period	20
Initial two-way AADTT	8,000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	30,038,200

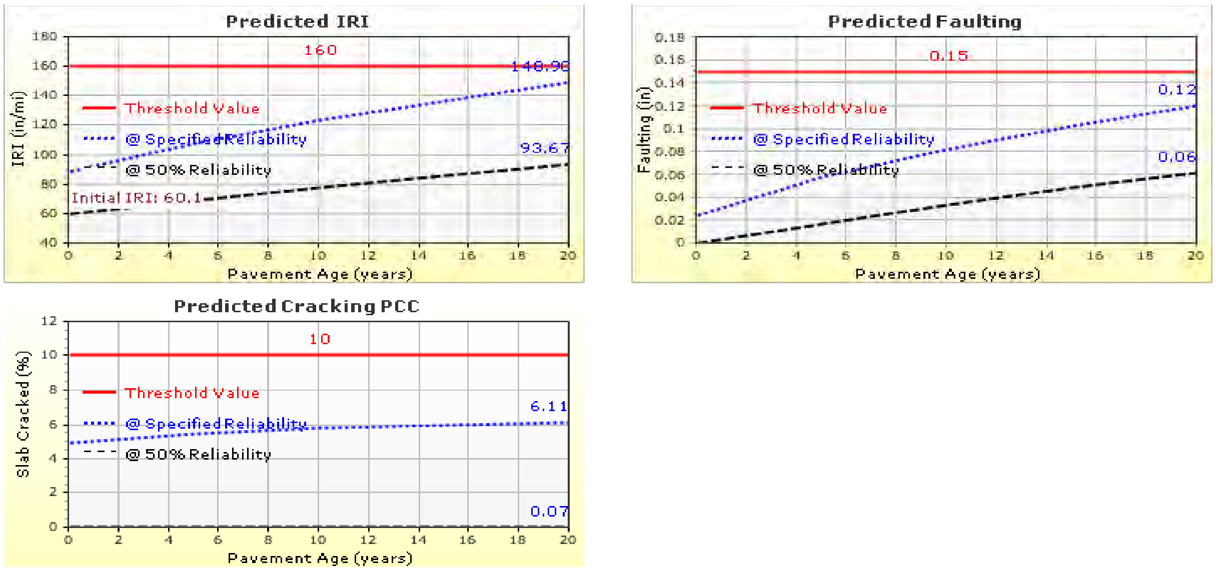
30.2.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	Material Type	Thickness (in)	Dowel Dia. (in)
JPCP-PCC	PCC	11	1.5
Granular Base	A-1-a	6	
Subgrade	A-7-6	Semi-infinite	

30.2.1.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	148.90	95.00	97.59	Pass
Mean joint faulting (in.)	0.15	0.12	95.00	99.31	Pass
JPCP transverse cracking (percent slabs)	10.00	6.11	95.00	99.66	Pass

30.2.1.1.4 Distress Charts



30.2.1.2 Summary of MoDOT Concrete Pavement Design and Life Cycle Rehabilitation

Pavement life cycle activities over a 50-year analysis period include the following as determined using the Missouri DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 11 in. PCC (with 1.5 in diameter dowel) over 6 in. crushed stone material
20	PCC Rehabilitation 1	¼ in. Diamond grinding and full depth repair (1.5% slabs repaired in the travel lane as per MoDOT M&R strategy)
35	PCC Rehabilitation 2	¼ in. Diamond grinding and full depth repair (1.5% slabs repaired in the travel lane as per MoDOT M&R strategy)
50	End of analysis period	

30.2.2 DARWin-ME-Based Maintenance and Rehabilitation (M&R)

30.2.2.1 New Construction

30.2.2.1.1 Traffic Inputs

Design period	20
Initial two-way AADTT	8,000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	30,038,200

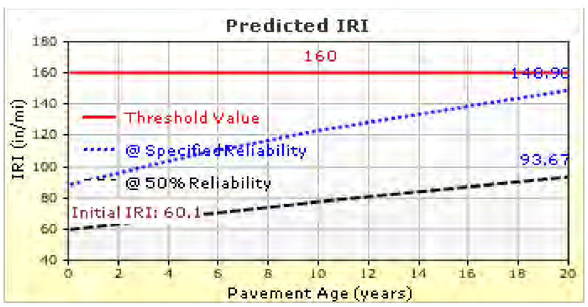
30.2.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

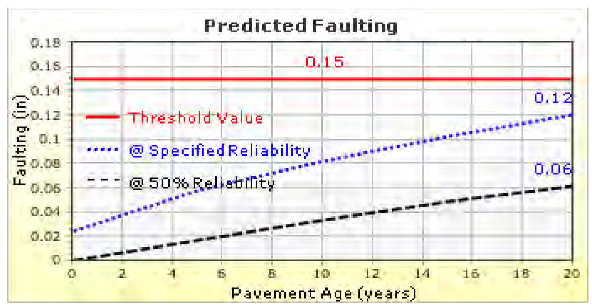
Layer Type	Material Type	Thickness (in)	Dowel Dia. (in)
JPCP-PCC	PCC	11	1.5
Granular Base	A-1-a	6	
Subgrade	A-7-6	Semi-infinite	

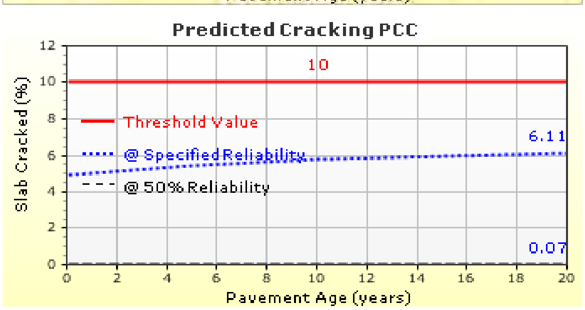
30.2.2.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	148.90	95.00	97.59	Pass
Mean joint faulting (in.)	0.15	0.12	95.00	99.31	Pass
JPCP transverse cracking (percent slabs)	10.00	6.11	95.00	99.66	Pass

30.2.2.1.4 Distress Charts







This design passes the DARWin-ME threshold criteria over 20 years. At 20 years, there is 6.11% fatigue cracking, 0.12 in faulting and 148.90 in/mile IRI at 95% reliability. Thus, diamond grinding and full depth repair are the most logical M&R treatment at 20 years.

30.2.2.2 First Rehabilitation –Diamond Grinding & Full Depth Repair

At 20 years, all cracked slabs will be replaced. Past fatigue cracking damage will be considered in future cracking projections. A maximum JPCP restoration life of 25 years was assumed since DARWin-ME does not consider all durability related distresses that develop over time. The first restoration project was then run for 20 years design period instead of typical MoDOT design life.

30.2.2.2.1 Traffic Inputs

Design period (from year 20 to 40)	20
Initial two-way AADTT	12,800
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	48,061,100

30.2.2.2.2 Pavement Structure That Meets Performance & Reliability Requirements

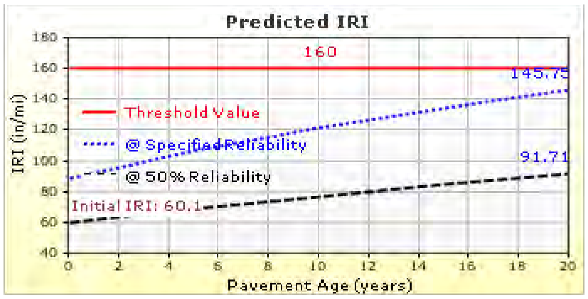
Layer Type	Material Type	Thickness (in)
JPCP-PCC	PCC	10.75*
Granular Base	A-1-a	6
Subgrade	A-7-6	Semi-infinite

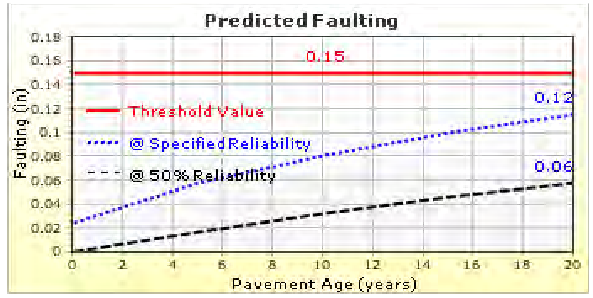
*Note: 0.25 inch slab thickness was removed by diamond grinding.

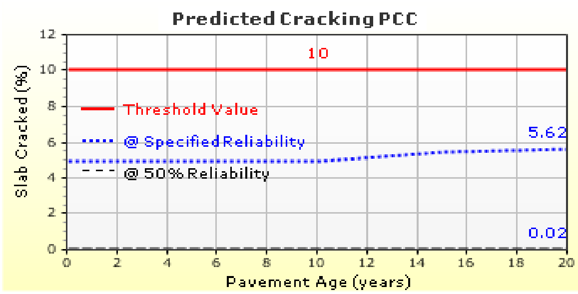
30.2.2.2.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	145.75	95.00	98.12	Pass
Mean joint faulting (in.)	0.15	0.12	95.00	99.57	Pass
JPCP transverse cracking (percent slabs)	10.00	5.62	95.00	99.83	Pass

30.2.2.2.4 Distress Charts







30.2.2.3 Second Rehabilitation –Diamond Grinding & Full Depth Repair

The second rehabilitation (restoration) was placed at 40 years with a design life of 10 years.

30.2.2.3.1 Traffic Inputs

Design period (from year 40 to 50)	10
Initial two-way AADTT	17,600
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	29,184,900

30.2.2.3.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	Material Type	Thickness (in)
JPCP-PCC	PCC	10.5*
Granular Base	A-1-a	6
Subgrade	A-7-6	Semi-infinite

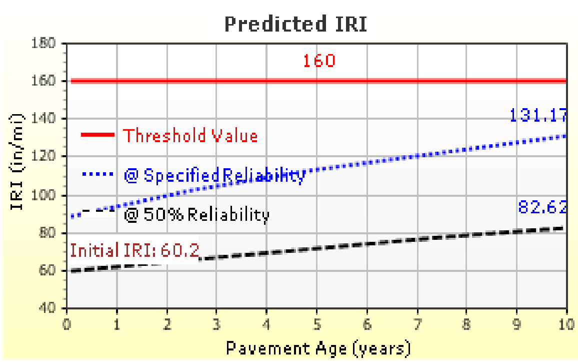
*Note: 0.25 inch slab thickness was removed by diamond grinding.

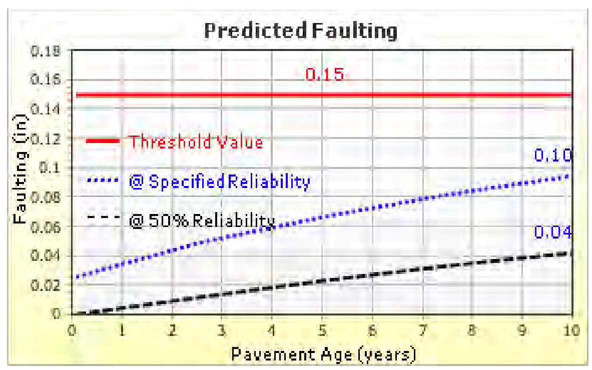
30.2.2.3.3 Distress Prediction & Reliability Summary

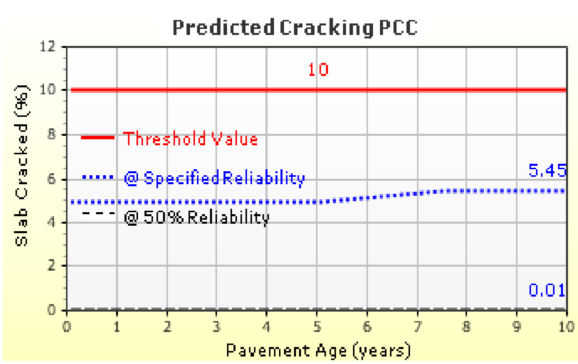
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	131.17	95.00	99.56	Pass

Mean joint faulting (in.)	0.15	0.10	95.00	99.96	Pass
JPCP transverse cracking (percent slabs)	10.00	5.45	95.00	99.87	Pass

30.2.2.3.4 Distress Charts







The pavement passes all of the criteria at 50 years. The restoration of the pavement actually will last 20 years or 10 years longer than the 50-year analysis period and some salvage value can be considered in the LCCA.

30.2.2.4 Summary of Concrete Pavement Design and Life Cycle Rehabilitation based on DARWin-ME Predictions

Pavement life cycle activities over a 50-year analysis period include the following as determined using the DARWin-ME based thresholds:

Year	Activity	Description
0	New construction	Place 11 in. PCC (with 1.5 in diameter dowel) over 6 in. crushed stone material
20	PCC Rehabilitation 1	¼ in. Diamond grinding & Full depth repair (0.07% slabs repaired in the travel lane)
40	PCC Rehabilitation 2	¼ in. Diamond grinding & Full depth repair (0.02% slabs repaired in the travel lane)
Salvage at 50	10 years	

31 Detailed Information for Cell 10a

31.1 ASPHALT PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

31.1.1 MODOT-Based Maintenance and Rehabilitation (M&R)

31.1.1.1 New Construction

31.1.1.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	8,000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	50,316,800

31.1.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	Material Type	Thickness (in)
AC Surface	HMA ½ in. mix with PG 76-22	2
AC Binder	HMA ¾ in. mix with PG 76-22	3
AC Base	HMA 1 in. mix with PG 64-22	8.5
Granular Base/Subbase	A-1-a (rock base material)	24
Subgrade	A-7-6	Semi-infinite

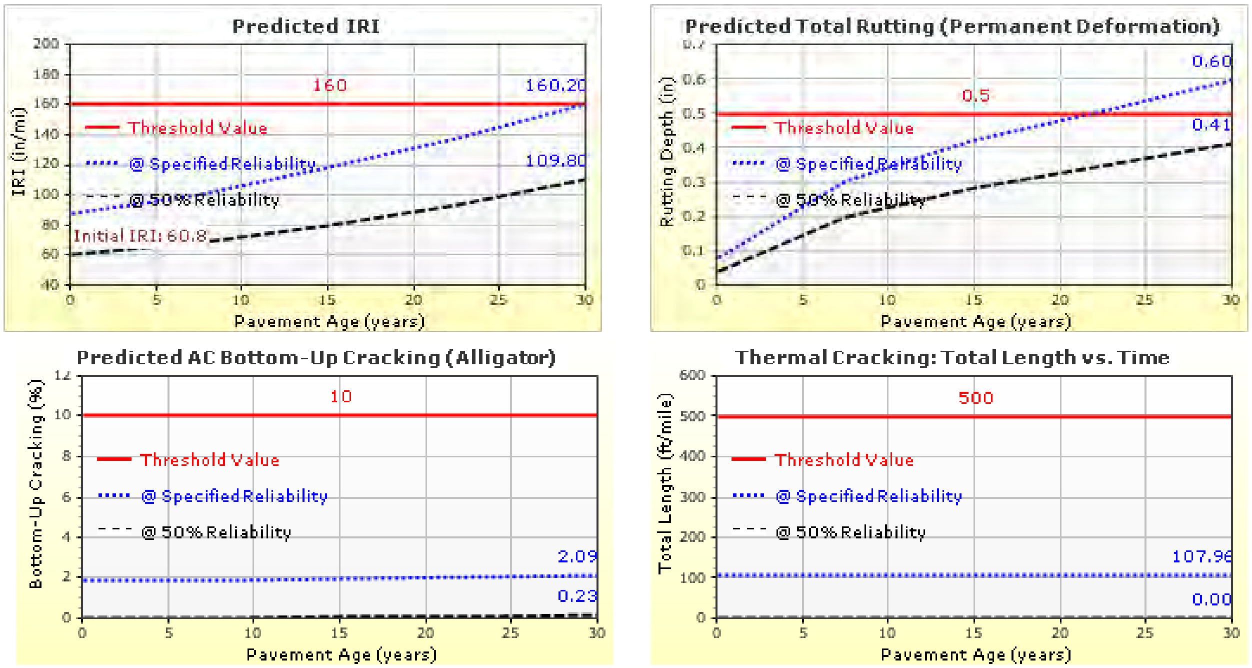
31.1.1.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied ?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.0	160.15	95.00	94.95*	Fail
Permanent deformation - total pavement (in.)	0.50	0.60	95.00	78.02**	Fail
AC bottom-up fatigue cracking (percent)	10.00	2.09	95.00	100.00	Pass
AC thermal fracture (ft/mile)	500.0	107.96	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.50	0.55	95.00	88.61	Fail

Note: * Predicted IRI at specified reliability is within 160 in/mile threshold until the placement of first rehabilitation overlay at 20 years.

** Predicted permanent deformation at specified reliability is within 0.5 in. threshold until the placement of first rehabilitation overlay at 20 years.

31.1.1.1.4 Distress Charts



31.1.1.2 First Rehabilitation – Mill & Overlay

The Missouri first rehabilitation was used to establish future rehabilitation activities. These values were checked using the MEPDG and found to be acceptable.

31.1.1.2.1 Rehabilitation Information

Rehabilitation strategy	Mill top 2 in. of AC surface course and place an AC overlay of 2 in. thick.
Year of rehabilitation	20
Design period	15

31.1.1.2.2 Traffic Inputs

Design period	15
Initial two-way AADTT	12,800
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	33,942,000

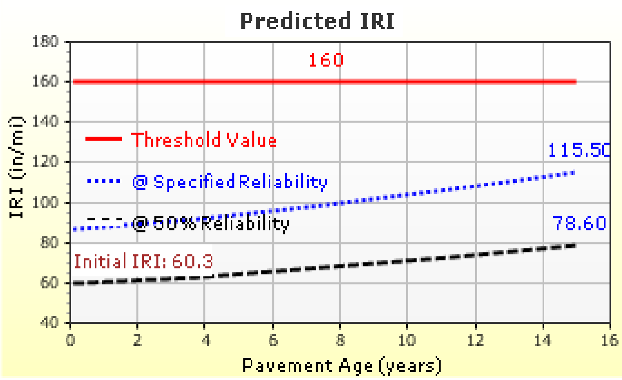
31.1.1.2.3 Pavement Structure

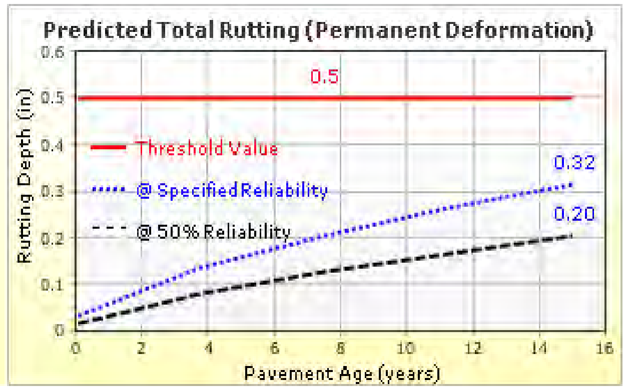
Layer Type	Material Type	Thickness (in)
AC Overlay (placed at year 20)	HMA ½ in. mix with PG 76-22	2
AC Binder	HMA ¾ in. mix with PG 76-22	3
AC Base	HMA 1 in. mix with PG 64-22	8
Granular Base/Subbase	A-1-a (rock base material)	24
Subgrade	A-7-6	Semi-infinite

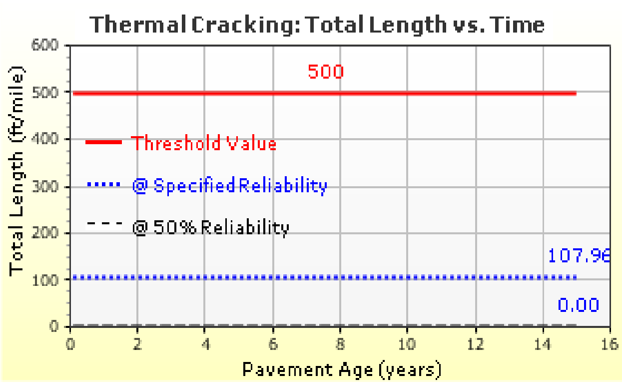
31.1.1.2.4 Distress Prediction & Reliability Summary

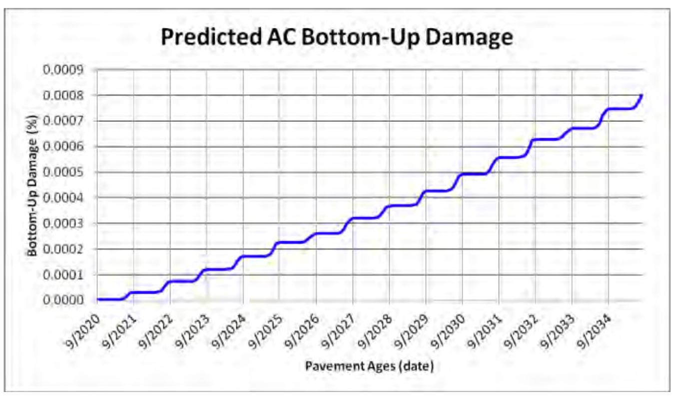
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	115.48	95.00	99.99	Pass
Permanent deformation - total pavement (in.)	0.50	0.32	95.00	100.00	Pass
AC thermal fracture (ft/mile)	500.00	107.96	95.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.86	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.50	0.32	95.00	100.00	Pass

31.1.1.2.5 Distress Charts









Note: This graph is provided to show that fatigue damage at bottom of AC layer is low indicating only minor fatigue cracking will develop over the overlay design period. Therefore, no structural improvement is needed.

31.1.1.3 Second Rehabilitation – Mill & Overlay

The Missouri second rehabilitation was used to establish future rehabilitation activities. These values were checked using the MEPDG and found to be acceptable.

31.1.1.3.1 Rehabilitation Information

Rehabilitation strategy	Mill top 2 in. of AC surface course and place an AC overlay of 2 in. thick.
Year of rehabilitation	35

Design period	15

31.1.1.3.2 Traffic Inputs

Design period	15
Initial two-way AADTT	18,560
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	49,215,800

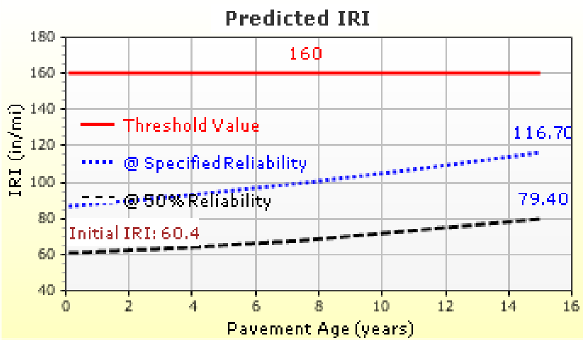
31.1.1.4 Pavement Structure

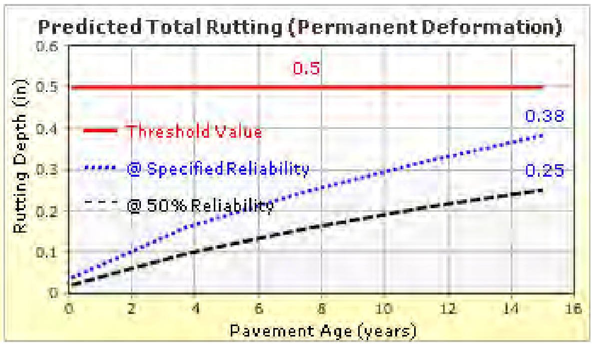
Layer Type	Material Type	Thickness (in)
AC Overlay (placed at year 35)	HMA ½ in. mix with PG 76-22	2
AC Binder	HMA ¾ in. mix with PG 76-22	3
AC Base	HMA 1 in. mix with PG 64-22	8
Granular Base/Subbase	A-1-a (rock base material)	24
Subgrade	A-7-6	Semi-infinite

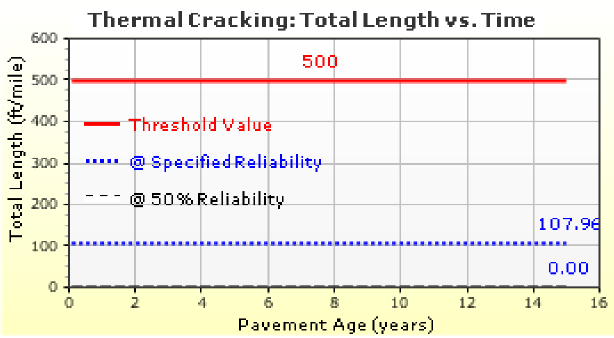
31.1.1.4.1 Distress Prediction Summary

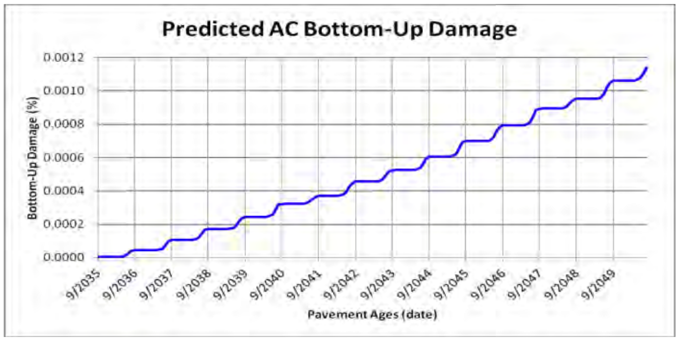
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	116.75	95.00	99.98	Pass
Permanent deformation - total pavement (in.)	0.50	0.38	95.00	99.90	Pass
AC thermal fracture (ft/mile)	500.00	107.96	95.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.86	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.50	0.38	95.00	99.90	Pass

31.1.1.4.2 Distress Charts









Note: This graph provided to show that fatigue damage at bottom of AC layer is low indicating only minor fatigue cracking will develop over the design period.

31.1.1.5 Summary of Asphalt Pavement Design and Life Cycle Rehabilitation using MODOT M&R

Pavement life cycle activities over a 50 year analysis period include the following as determined using the Missouri DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 13.5 in. AC over 24 in. rock base material
20	AC overlay 1	Mill 2 in. and replace 2 in. AC OL
35	AC overlay 2	Mill 2 in. and replace 2 in. AC OL
50	End of analysis period	

31.1.2 MEPDG-Based Maintenance and Rehabilitation (M&R)

31.1.2.1 New Construction

31.1.2.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	8,000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	50,316,800

31.1.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

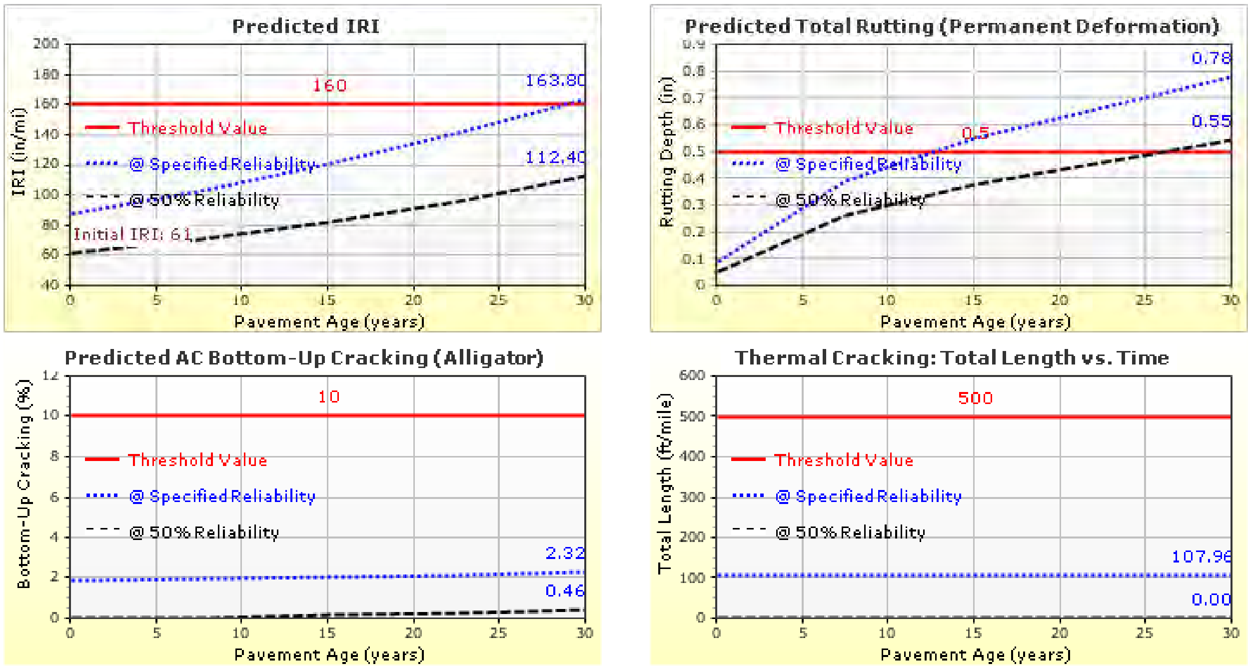
Layer Type	**Material Type**	**Thickness (in)**
AC Surface	HMA ½ in. mix with PG 76-22	2
AC Binder	HMA ¾ in. mix with PG 76-22	3
AC Base	HMA 1 in. mix with PG 64-22	7
Granular Base/Subbase	A-1-a (rock base material)	24
Subgrade	A-7-6	Semi-infinite

31.1.2.1.3 Distress Prediction & Reliability Summary

Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied ?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in./mile)	160.0	163.75	95.00	93.63	Fail
Permanent deformation - total pavement (in.)	0.50	0.78	95.00	36.50*	Fail
AC bottom-up fatigue cracking (percent)	10.00	2.32	95.00	100.00	Pass
AC thermal fracture (ft/mile)	500.0	107.96	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.50	0.73	95.00	49.54	Fail

Note: Based on MEPDG predictions, the total pavement rutting is expected to reach the specified threshold in 12 years at 95% reliability. IRI reaches its threshold at 28 years.

31.1.2.1.4 Distress Charts



31.1.2.2 First Rehabilitation – Mill & Overlay

The M-E based thresholds were used to establish future rehabilitation activities. Based on MEPDG predictions, the total pavement rutting is expected to reach the specified threshold in 12 years, indicating the need for rehabilitation in year 12. This overlay then starts out rutting at 0 and IRI at 60 in/mile. Fatigue damage was low but is also determined and considered in the next overlay cracking prediction.

31.1.2.2.1 Rehabilitation Information

Rehabilitation strategy	Mill top 2 in. of AC surface course and place an AC overlay of 2 in. thick.
Year of rehabilitation	12
Design period	30

31.1.2.2.2 Traffic Inputs

Design period	30
Initial two-way AADTT	10,880

Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	68,430,900

31.1.2.2.3 Pavement Structure

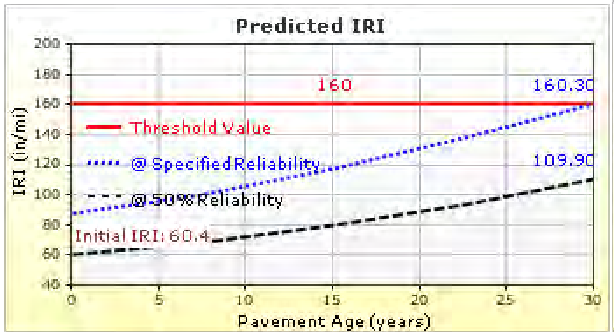
Layer Type	Material Type	Thickness (in)
AC Overlay (placed at year 20)	HMA ½ in. mix with PG 76-22	2
AC Binder	HMA ¾ in. mix with PG 76-22	3
AC Base	HMA 1 in. mix with PG 64-22	7
Granular Base/Subbase	A-1-a (rock base material)	24
Subgrade	A-7-6	Semi-infinite

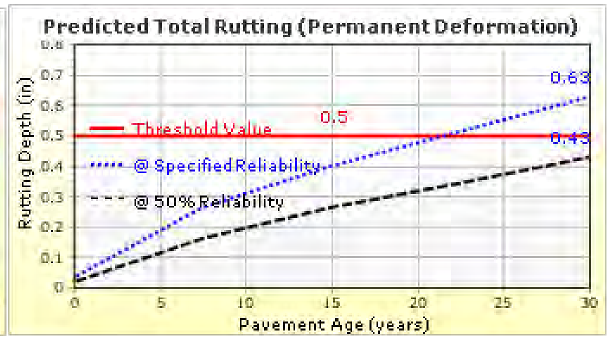
31.1.2.2.4 Distress Prediction & Reliability Summary

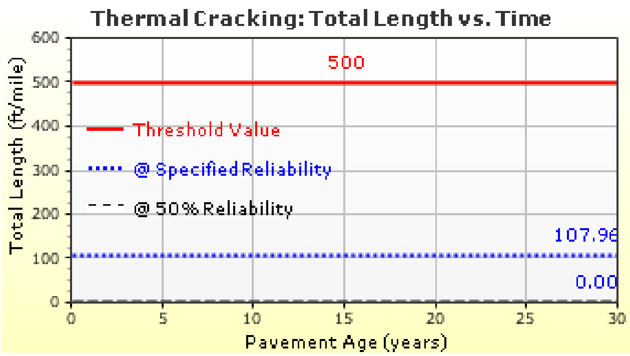
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	160.30	95.00	94.90	Fail
Permanent deformation - total pavement (in.)	0.50	0.63	95.00	71.14	Fail
AC thermal fracture (ft/mile)	500.00	107.96	95.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.86	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.50	0.63	95.00	71.14	Fail

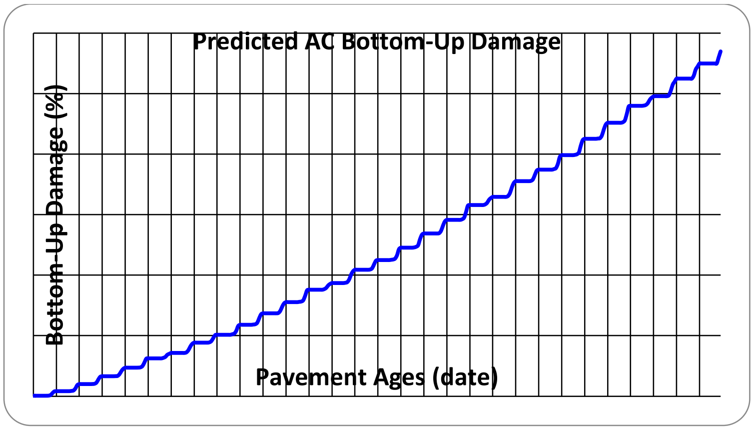
Note: Based on MEPDG predictions, the total rutting of the AC overlay is expected to reach the specified threshold in 21 years at 95% reliability.

31.1.2.2.5 Distress Charts









Note: This graph provided to show that fatigue damage at bottom of AC layer is low indicating only minor fatigue cracking will develop over the analysis period.

31.1.2.3 Second Rehabilitation – Mill & Overlay

The M-E based thresholds were used to establish future rehabilitation activities. Based on MEPDG predictions, the total pavement rutting is expected to reach the specified threshold in 21 years, indicating the need for another rehabilitation in year 33.

31.1.2.3.1 Rehabilitation Information

Rehabilitation strategy	Mill top 2 in. of AC surface course and place an AC overlay of 2 in. thick.
Year of rehabilitation	33
Design period	17

31.1.2.3.2 Traffic Inputs

Design period	17
Initial two-way AADTT	15,920
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	49,030,200

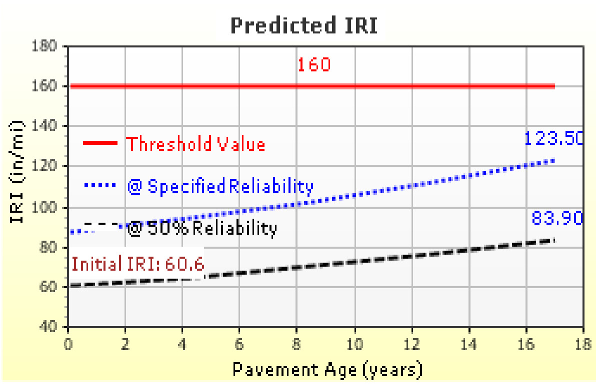
31.1.2.3.3 Pavement Structure

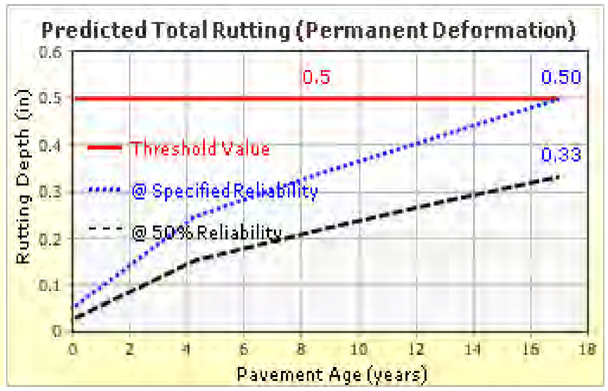
Layer Type	**Material Type**	**Thickness (in)**
AC Overlay (placed at year 35)	HMA ½ in. mix with PG 76-22	3
AC Binder	HMA ¾ in. mix with PG 76-22	3
AC Base	HMA 1 in. mix with PG 64-22	7
Granular Base/Subbase	A-1-a (rock base material)	24
Subgrade	A-7-6	Semi-infinite

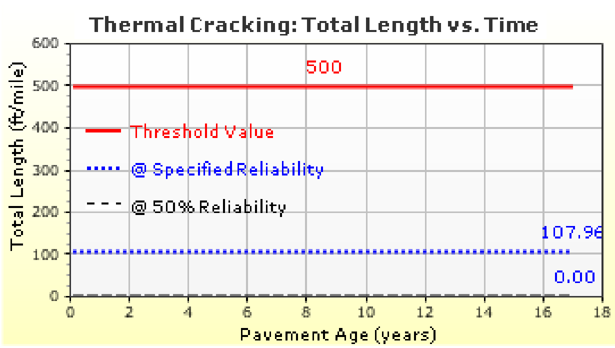
31.1.2.3.4 Distress Prediction Summary

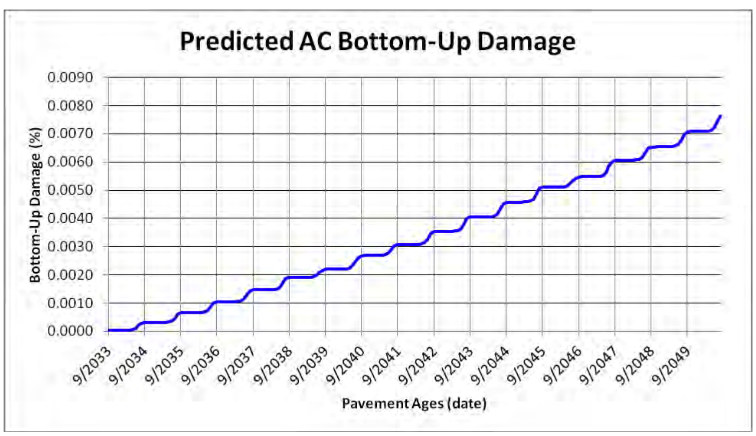
Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in./mile)	160.00	123.50	95.00	99.92	Pass
Permanent deformation - total pavement (in.)	0.50	0.50	95.00	95.10	Pass
AC thermal fracture (ft/mile)	500.00	107.96	95.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.86	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.50	0.50	95.00	95.09	Pass

31.1.2.3.5 Distress Charts









Note: This graph provided to show that fatigue damage at bottom of AC layer is low indicating only minor fatigue cracking will develop over the analysis period.

31.1.2.4 Summary of Asphalt Pavement Design and Life Cycle Rehabilitation for MEPDG

Pavement life cycle activities over a 50 year analysis period include the following as determined using the MEPDG threshold criteria:

Year	Activity	Description
0	New construction	Place 12 in. AC over 24 in. rock base material
12	AC overlay 1	Mill 2 in. and replace 2 in. AC OL
33	AC overlay 2	Mill 2 in. and replace 3 in. AC OL
Salvage	None	

The predicted total rutting for the second overlay is expected to reach the specified threshold in year 50, indicating the need for another overlay/reconstruction.

31.2 CONCRETE PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

The site conditions, design period and analysis period are exactly the same as that used for the AC design.

31.2.1 MODOT-Based Maintenance and Rehabilitation (M&R)

31.2.1.1 10a. PCC.A1 New Construction

31.2.1.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	8,000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	50,316,800

31.2.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

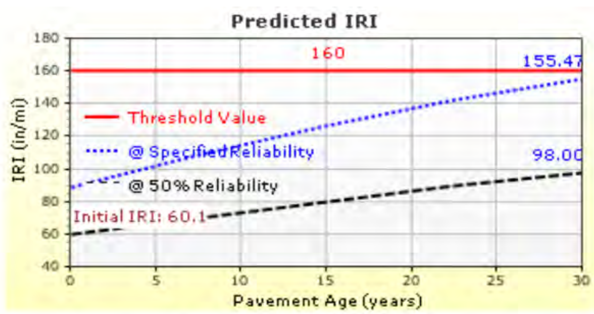
Layer Type	Material Type	Thickness (in)	Dowel Dia. (in)

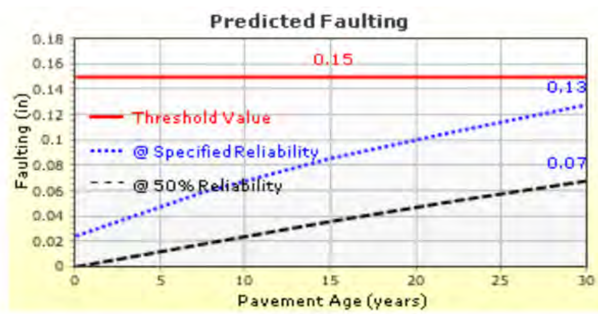
JPCP-PCC	PCC	11.0	1.63
Granular Base/Subbase	A-1-a	6	
Subgrade	A-7-6	Semi-infinite	

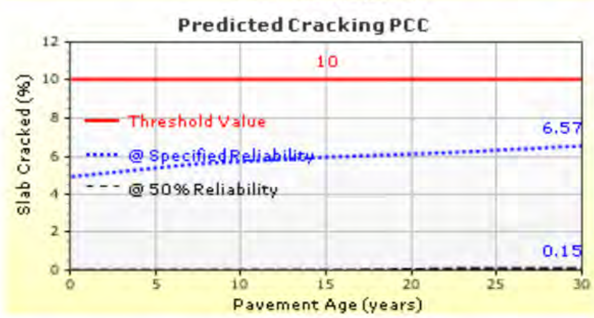
31.2.1.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied ?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	155.47	95.00	96.20	155.47
Mean joint faulting (in.)	0.15	0.13	95.00	98.78	0.13
JPCP transverse cracking (percent slabs)	10.00	6.57	95.00	99.42	6.57

31.2.1.1.4 Distress Charts







31.2.1.2 First Rehabilitation – Diamond Grinding and Full Depth Repair MODOT

31.2.1.2.1 Traffic Inputs

Design period	25
Initial two-way AADTT	14,000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0

Number of trucks over design period	69,543,600

31.2.1.2.2 Pavement Structure That Meets Performance & Reliability Requirements

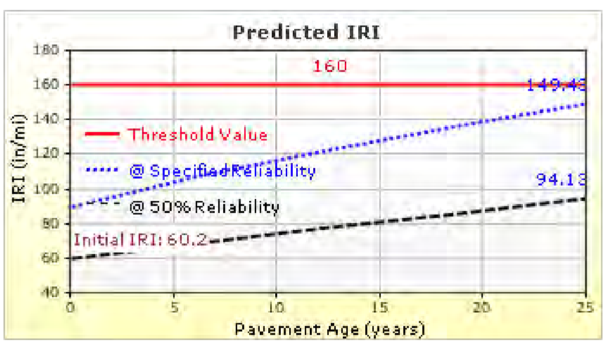
Layer Type	Material Type	Thickness (in)
JPCP-PCC	PCC	10.75*
Granular Base/Subbase	A-1-a	6
Subgrade	A-7-6	Semi-infinite

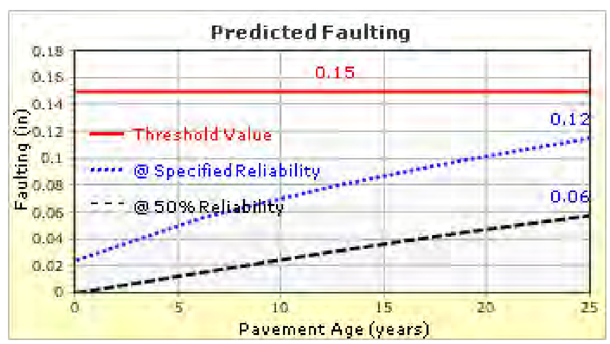
*Note: 0.25 inch slab was removed by diamond grinding.

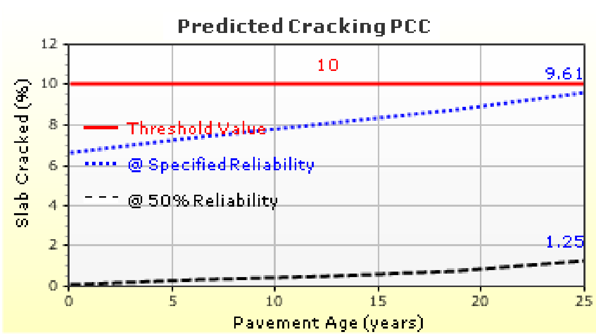
31.2.1.2.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied ?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	149.43	95.00	97.50	Pass
Mean joint faulting (in.)	0.15	0.12	95.00	99.58	Pass
JPCP transverse cracking (percent slabs)	10.00	9.61	95.00	95.74	Pass

31.2.1.2.4 Distress Charts







31.2.1.3 Summary of Concrete Pavement Design and Life Cycle Rehabilitation

Pavement life cycle activities over a 50 year analysis period include the following as determined using the Missouri DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 11.0 in. PCC (with 1⅝ in diameter dowel) over 6 in. crushed stone material
25	PCC Rehabilitation 1	Diamond grinding and full depth repair MODOT
50	End of analysis period	

31.2.2 MEPDG-Based Maintenance and Rehabilitation (M&R)

31.2.2.1 New Construction

31.2.2.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	8,000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	50,316,800

31.2.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

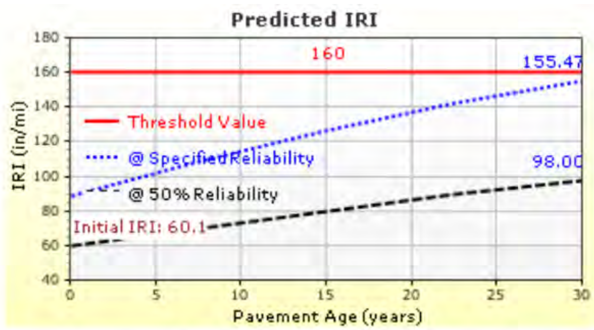
Layer Type	**Material Type**	**Thickness (in)**	**Dowel Dia. (in)**
JPCP-PCC	PCC	11.0	1.63
Granular Base/Subbase	A-1-a	6	
Subgrade	A-7-6	Semi-infinite	

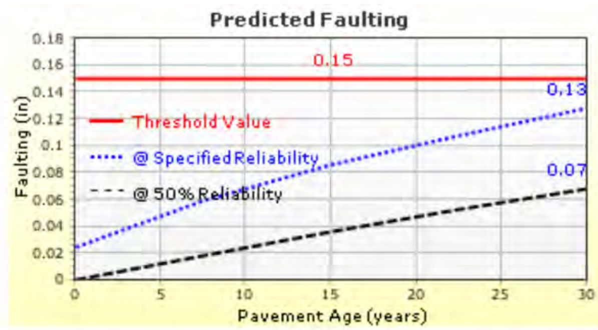
31.2.2.1.3 Distress Prediction & Reliability Summary

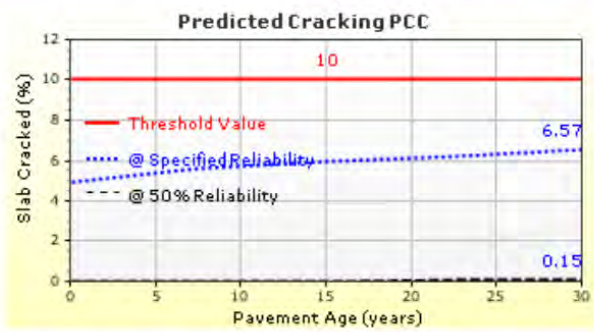
Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied ?**
	Target	**Predicted**	**Target**	**Achieved**	

Terminal IRI (in./mile)	160.00	155.47	95.00	96.20	155.47
Mean joint faulting (in.)	0.15	0.13	95.00	98.78	0.13
JPCP transverse cracking (percent slabs)	10.00	6.57	95.00	99.42	6.57

31.2.2.1.4 Distress Charts







This design passes the MEPDG threshold criteria over 30 years. At 30 years, there is 6% fatigue cracking, 0.13 in faulting and and IRI at 156 in/mile at 95% reliability. Thus, diamond grinding is the most logical M&R treatment at 30 years.

31.2.2.2 First Rehabilitation – Diamond Grinding and Full Depth Repair

At 30 years, all cracked slabs will be replaced and the surface will be diamond ground renewing the IRI and joint faulting. Past fatigue cracking damage will be considered in future cracking projections.

31.2.2.2.1 Traffic Inputs

Design period	20
Initial two-way AADTT	15,200
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0

Number of trucks over design period	57,072,500

31.2.2.2.2 Pavement Structure That Meets Performance & Reliability Requirements

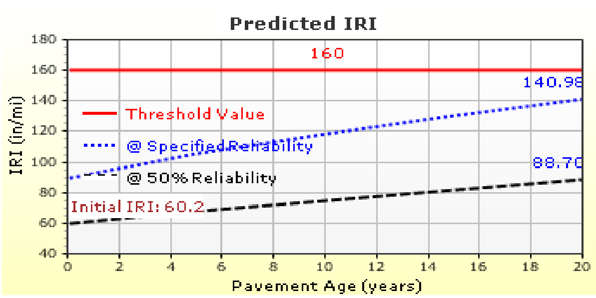
Layer Type	Material Type	Thickness (in)
JPCP-PCC	PCC	10.75*
Granular Base/Subbase	A-1-a	6
Subgrade	A-7-6	Semi-infinite

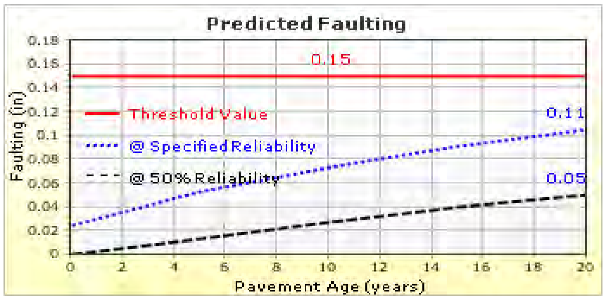
*Note: 0.25 inch slab was removed by diamond grinding.

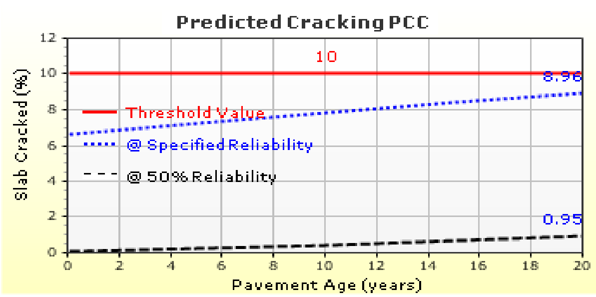
31.2.2.2.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied ?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	140.98	95.00	98.76	Pass
Mean joint faulting (in.)	0.15	0.11	95.00	99.85	Pass
JPCP transverse cracking (percent slabs)	10.00	8.96	95.00	96.84	Pass

31.2.2.3 Distress Charts







The pavement passes all of the criteria at 50 years. The restoration of the pavement actually will last 27 years or 7 years longer than the 50 year analysis period and some salvage value can be considered in the LCCA.

31.2.2.4 Summary of Concrete Pavement Design and Life Cycle Rehabilitation MEPDG Threshold Criteria

Pavement life cycle activities over a 50 year analysis period include the following as determined using the MEPDG based thresholds:

Year	Activity	Description
0	New construction	Place 11.0 in. PCC (with 1⅝ in diameter dowel) over 6 in. crushed stone material
30	PCC Rehabilitation 1	Diamond grinding and full depth repair MEPDG
Salvage	7 years	

32 Detailed Information for Cell 10b

32.1 ASPHALT CONCRETE PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

32.1.1 MoDOT-Based Maintenance and Rehabilitation (M&R)

32.1.1.1 New Construction

32.1.1.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	8,000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period (design lane)	50,316,800

32.1.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	Material Type	Thickness (in)
AC Surface	HMA with PG 76-22	2
AC Binder	HMA with PG 76-22	3
AC Base	HMA with PG 64-22	8.5
Granular Base	A-1-a	24
Subgrade	A-7-6	Semi-infinite

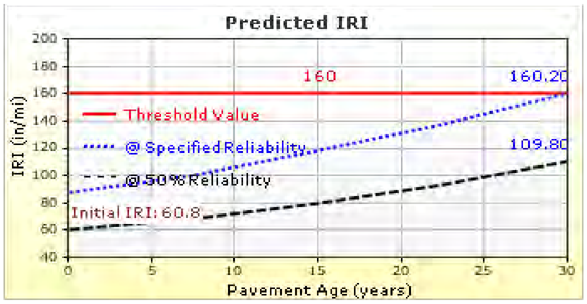
32.1.1.1.3 Distress Prediction & Reliability Summary

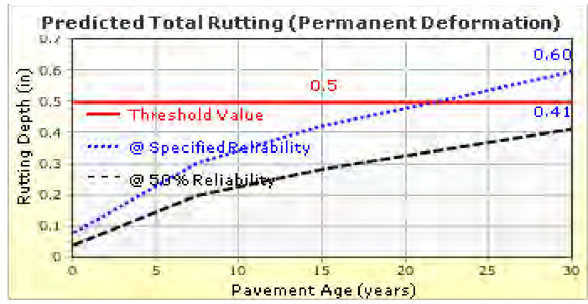
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.0	160.15	95.00	94.95*	Fail
Permanent deformation - total pavement (in.)	0.5	0.60	95.00	78.02**	Fail
AC bottom-up fatigue cracking (percent)	10.00	2.09	95.00	100.00	Pass
AC thermal fracture (ft/mile)	500.0	107.96	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.55	95.00	88.61	Pass

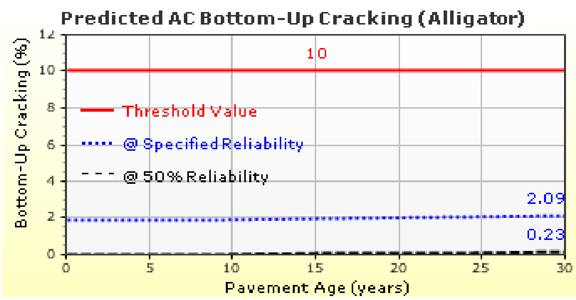
Note: * Predicted IRI at specified reliability is within 160 in/mile threshold until the placement of first rehabilitation overlay at 20 years.

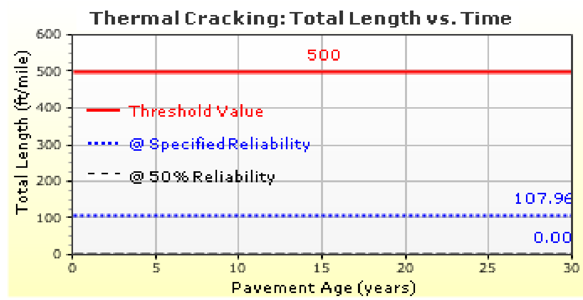
** Predicted permanent deformation at specified reliability is within 0.5 in. threshold until the placement of first rehabilitation overlay at 20 years.

32.1.1.1.4 Distress Charts









32.1.1.2 MoDOT Rehabilitation – Mill & Overlay

The Missouri first rehabilitation is recommended at 20 years. The MoDOT expected life of the AC overlay is 15 years. This becomes the Design Period for the next overlay. The Missouri second rehabilitation was applied at 35 years with design period of 15 years. After 50 years in service, a major rehabilitation is recommended that includes milling half of the existing asphalt materials and replacing with new materials.

32.1.1.3 Summary of Asphalt Pavement Design and Life Cycle Rehabilitation using MoDOT M&R

Pavement life cycle activities over a 75-year analysis period include the following as determined using the Missouri DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 13.5 in. AC over 24 in. crushed stone base material
20	AC overlay 1	Mill 2 in. and replace 2 in. AC OL (Patching of 0.13% lane area is required in the travel lane)
35	AC overlay 2	Mill 2 in. and replace 2 in. AC OL (Patching of 0.26% lane area is required in the travel lane)
50	AC overlay 3	Mill 7 in existing asphalt materials and replace with 7 in. AC Overlay over existing asphalt
65	AC overlay 4	Mill 2 in. and replace 2 in. AC OL (Patching of 0.55% lane area is required in the travel lane)
75	End of analysis period	

32.1.2 DARWin-ME-Based Maintenance and Rehabilitation (M&R)

32.1.2.1 New Construction

32.1.2.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	8,000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	50,316,800

32.1.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	Material Type	Thickness (in)
AC Surface	HMA with PG 76-22	2
AC Binder	HMA with PG 76-22	3
AC Base	HMA with PG 64-22	8.5
Granular Base	A-1-a	24
Subgrade	A-7-6	Semi-infinite

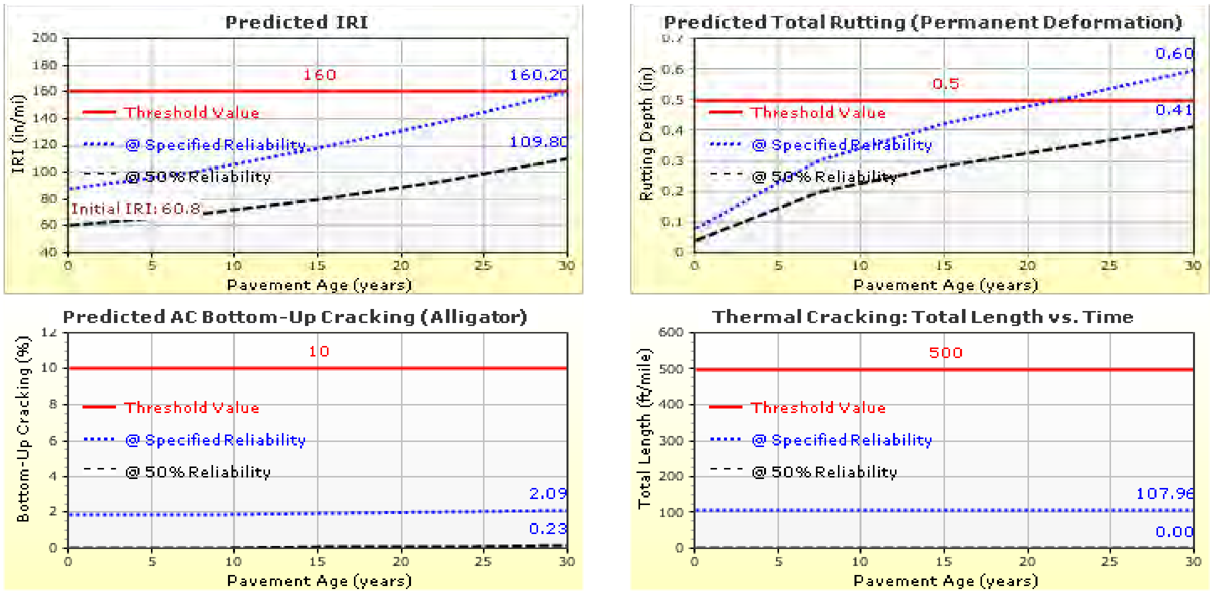
32.1.2.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.0	160.15	95.00	94.95*	Fail
Permanent deformation - total pavement (in.)	0.5	0.60	95.00	78.02**	Fail
AC bottom-up fatigue cracking (percent)	10.00	2.09	95.00	100.00	Pass
AC thermal fracture (ft/mile)	500.0	107.96	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.55	95.00	88.61	Pass

Note: * Predicted IRI at specified reliability is within 160 in/mile threshold until the placement of first rehabilitation overlay at 20 years.

** Predicted permanent deformation at specified reliability is within 0.5 in. threshold until the placement of first rehabilitation overlay at 20 years.

32.1.2.1.4 Distress Charts



32.1.2.2 First Rehabilitation – Mill & Overlay

The DARWin-ME based thresholds were used to establish future rehabilitation activities. A reasonable maximum service life of 20 years for new AC and 17 years for AC overlay was assumed for this climate since DARWin-ME does not consider all durability related distresses that develop over time. The first overlay project was then run for 17 years design period instead of typical MoDOT design life. The mill and overlay then starts out rutting at 0 and IRI at 60 in/mile. Fatigue damage was low but is also determined and considered in the next overlay cracking prediction.

32.1.2.2.1 Rehabilitation Information

Rehabilitation strategy	Mill top 2 in. of AC surface course and place an AC overlay of 2 in. thick. Patching of 0.13% lane area is required in the travel lane.
Year of rehabilitation	20
Design period	17

32.1.2.2.2 Traffic Inputs

Design period (from year 20 to 37)	17
Initial two-way AADTT	12,800
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	39,421,300

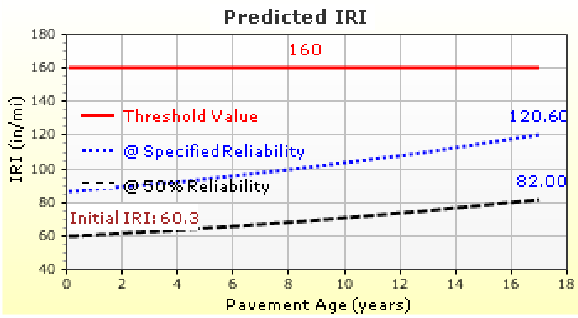
32.1.2.2.3 Pavement Structure

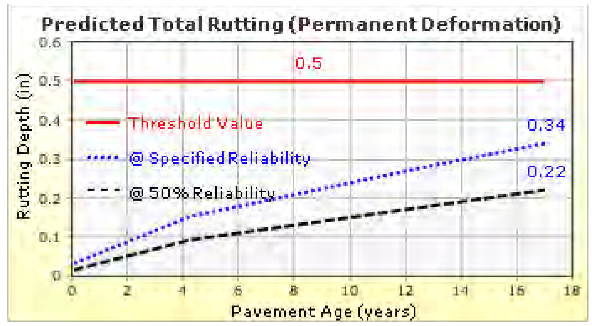
Layer Type	Material Type	Thickness (in)
AC Overlay (placed at 20 years)	HMA with PG 76-22	2
AC Binder	HMA with PG 76-22	3
AC Base	HMA with PG 64-22	8.5
Granular Base	A-1-a	24
Subgrade	A-7-6	Semi-infinite

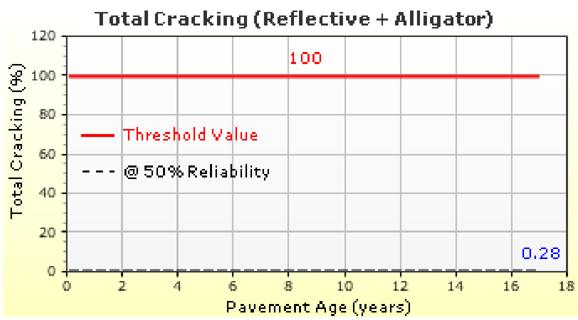
32.1.2.2.4 Distress Prediction & Reliability Summary

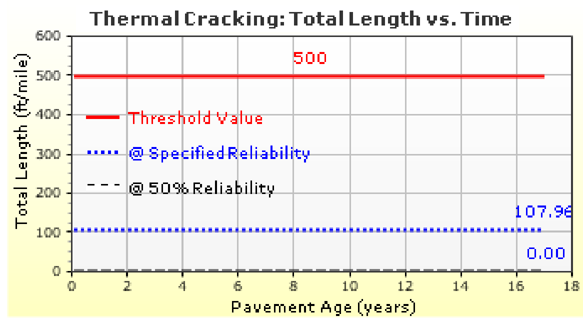
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	120.56	95.00	99.96	Pass
Permanent deformation - total pavement (in.)	0.5	0.34	95.00	99.99	Pass
Total Cracking (Reflective + Alligator) (percent)	5.00	0.28	95.00		Pass
AC thermal fracture (ft/mile)	500.00	107.96	95.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.86	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.34	95.00	99.99	Pass

32.1.2.2.5 Distress Charts









32.1.2.3 Second Rehabilitation – Mill & Overlay

The second rehabilitation was placed at 37 years with a design life of 13 years.

32.1.2.3.1 Rehabilitation Information

Rehabilitation strategy	Mill top 2 in. of AC surface course and place an AC overlay of 2 in. thick. Patching of 0.28% lane area is required in the travel lane.
Year of rehabilitation	37
Design period	13

32.1.2.3.2 Traffic Inputs

Design period (from year 37 to 50)	13
Initial two-way AADTT	16,880
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	37,831,000

32.1.2.3.3 Pavement Structure

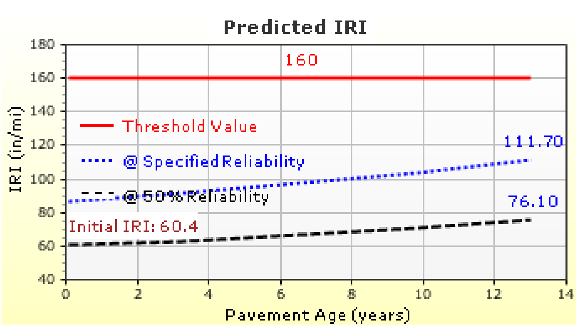
Layer Type	Material Type	Thickness (in)
AC Overlay (placed at 37 years)	HMA with PG 76-22	2

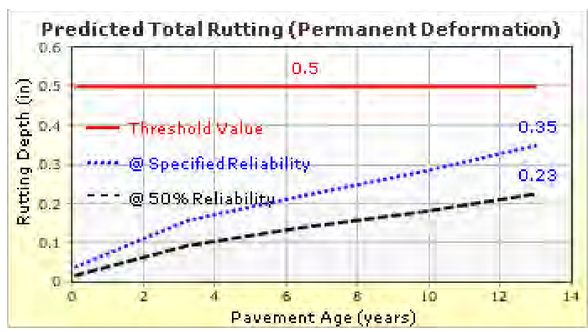
AC Binder	HMA with PG 76-22	3
AC Base	HMA with PG 64-22	8.5
Granular Base	A-1-a	24
Subgrade	A-7-6	Semi-infinite

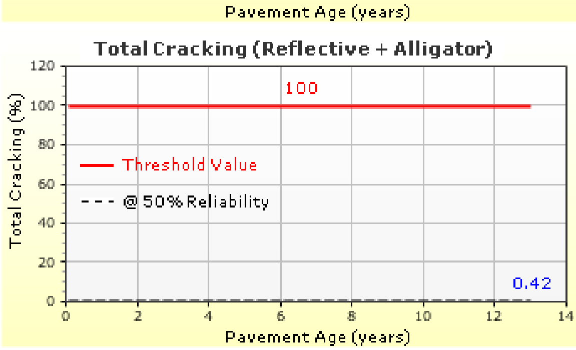
32.1.2.3.4 Distress Prediction & Reliability Summary

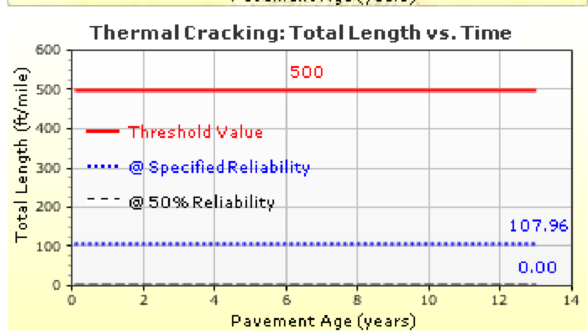
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	111.73	95.00	99.99	Pass
Permanent deformation - total pavement (in.)	0.5	0.35	95.00	99.99	Pass
Total Cracking (Reflective + Alligator) (percent)	5.00	0.42	95.00		Pass
AC thermal fracture (ft/mile)	500.00	107.96	95.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.86	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.35	95.00	99.99	Pass

32.1.2.3.5 Distress Charts









32.1.2.4 Third Rehabilitation – Mill & Overlay

The third rehabilitation was placed at 50 years instead of reconstruction. This major rehabilitation includes milling half of the existing asphalt materials (7 in.) and replacing with AC Overlay (7 in.) over existing asphalt. The third rehabilitation was then run for 15 years to see where it fails.

32.1.2.4.1 Rehabilitation Information

Rehabilitation strategy	Mill 7 in existing asphalt materials and replace with 7 in. AC Overlay over existing asphalt
Year of rehabilitation	50
Design period	15

32.1.2.4.2 Traffic Inputs

Design period	15
Initial two-way AADTT	20,000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	53,034,300

32.1.2.4.3 Pavement Structure

Layer Type	Material Type	Thickness (in)
AC Surface (placed at 50 years)	HMA with PG 76-22	3
AC Binder (placed at 50 years)	HMA with PG 76-22	4
AC Base	HMA with PG 64-22	6.5
Granular Base	A-1-a	24
Subgrade	A-7-6	Semi-infinite

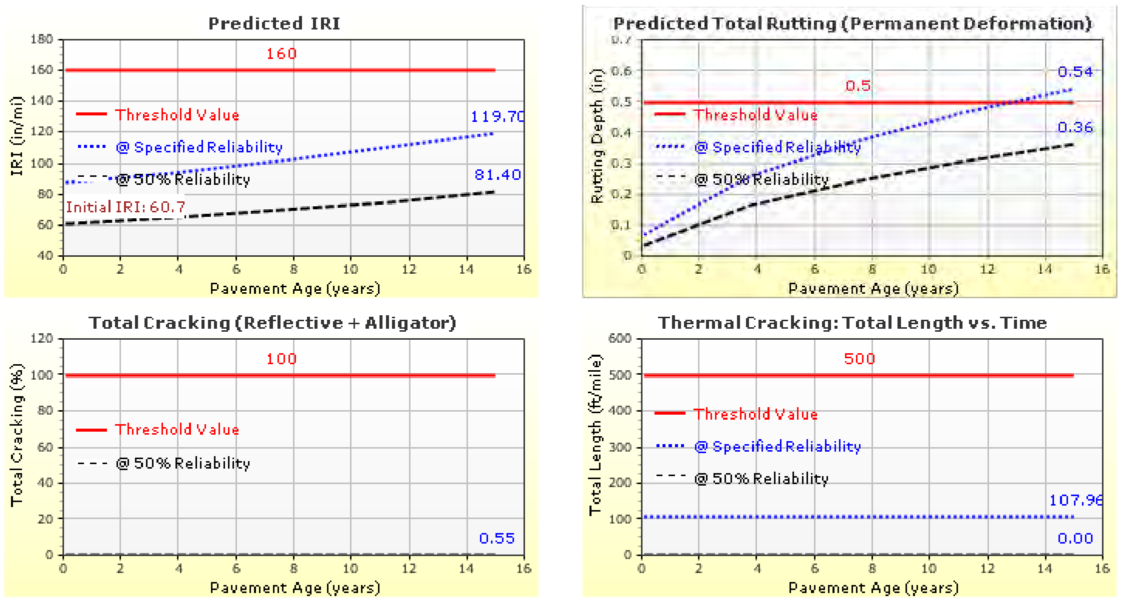
32.1.2.4.4 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	119.75	95.00	99.96	Pass
Permanent deformation - total pavement (in.)	0.5	0.54	95.00	89.57*	Fail

Total Cracking (Reflective + Alligator) (percent)	5.00	0.55	95.00		Pass
AC thermal fracture (ft/mile)	500.00	107.96	95.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.87	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.54	95.00	89.59*	Fail

Note: *Predicted permanent deformation at specified reliability is within 0.5 in. threshold until the placement of fourth rehabilitation overlay at 13 years.

32.1.2.4.5 Distress Charts



32.1.2.5 Fourth Rehabilitation – Mill & Overlay

The fourth rehabilitation was placed at 63 years with a design life of 12 years.

32.1.2.5.1 Rehabilitation Information

Rehabilitation strategy	Mill top 3 in. of AC surface course and place an AC overlay of 3 in. thick. Patching of 0.52% lane area is required in the travel lane.
Year of rehabilitation	63
Design period	12

32.1.2.5.2 Traffic Inputs

Design period (from year 63 to 75)	12
Initial two-way AADTT	23,120

Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	47,222,100

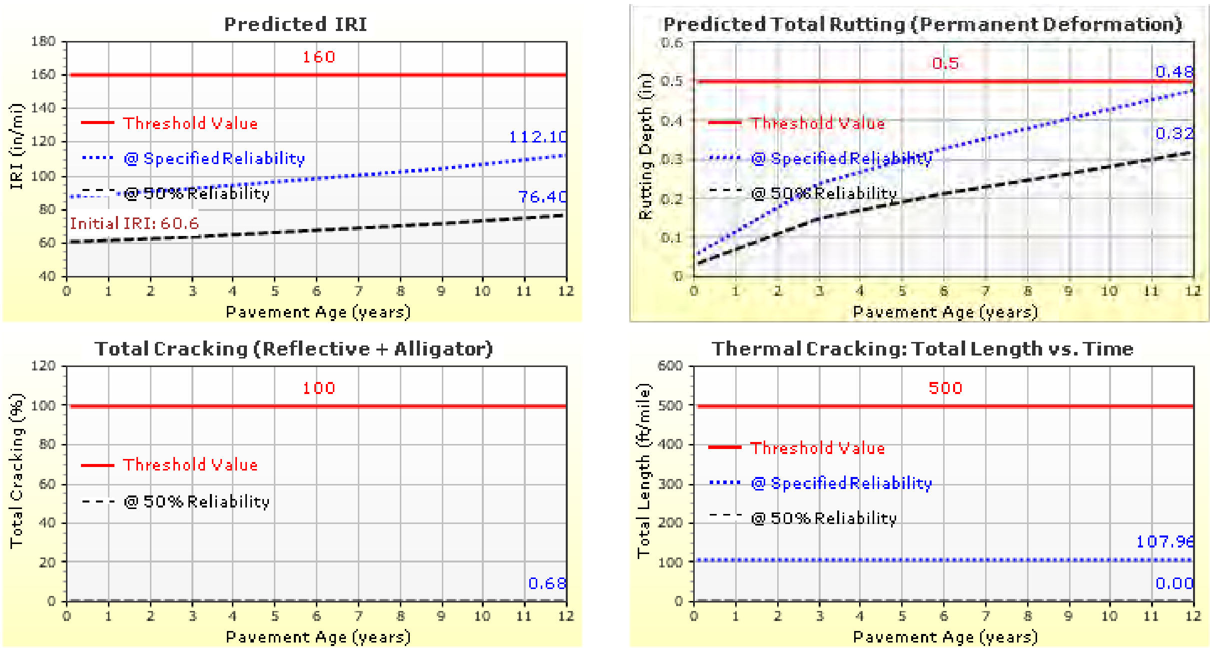
32.1.2.5.3 Pavement Structure

Layer Type	Material Type	Thickness (in)
AC Overlay (placed at 63 years)	HMA with PG 76-22	3
AC Binder	HMA with PG 76-22	4
AC Base	HMA with PG 64-22	6.5
Granular Base	A-1-a	24
Subgrade	A-7-6	Semi-infinite

32.1.2.5.4 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	112.14	95.00	99.99	Pass
Permanent deformation - total pavement (in.)	0.5	0.48	95.00	96.85	Pass
Total Cracking (Reflective + Alligator) (percent)	5.00	0.68	95.00		Pass
AC thermal fracture (ft/mile)	500.00	107.96	95.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.86	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.48	95.00	96.85	Pass

32.1.2.5.5 Distress Charts



32.1.2.6 Summary of Asphalt Pavement Design and Life Cycle Rehabilitation based on DARWin-ME Predictions

Pavement life cycle activities over a 75-year analysis period include the following as determined using the DARWin-ME threshold criteria:

Year	Activity	Description
0	New construction	Place 13.5 in. AC over 24 in. crushed stone base material
20	AC overlay 1	Mill 2 in. and replace 2 in. AC OL (Patching of 0.13% lane area is required in the travel lane).
37	AC overlay 2	Mill 2 in. and replace 2 in. AC OL (Patching of 0.28% lane area is required in the travel lane).
50	AC overlay 3	Mill 7 in existing asphalt materials and replace with 7 in. AC Overlay over existing asphalt
63	AC overlay 4	Mill 2 in. and replace 2 in. AC OL (Patching of 0.52% lane area is required in the travel lane)
Salvage at 75	End of Analysis (no salvage)	

32.2 PORTLAND CEMENT CONCRETE PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

The site conditions, design period and analysis period are exactly the same as that used for the AC design.

32.2.1 MoDOT-Based Maintenance and Rehabilitation (M&R)

The MoDOT M&R strategy is to perform concrete pavement restoration at 25 years. This includes 1.5% cracked slabs replacement in the travel lane and diamond grinding of the surface to restore IRI and remove faulting.

32.2.1.1 New Construction

32.2.1.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	8,000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	50,316,800

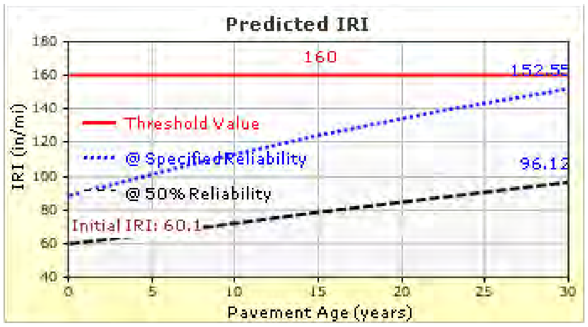
32.2.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

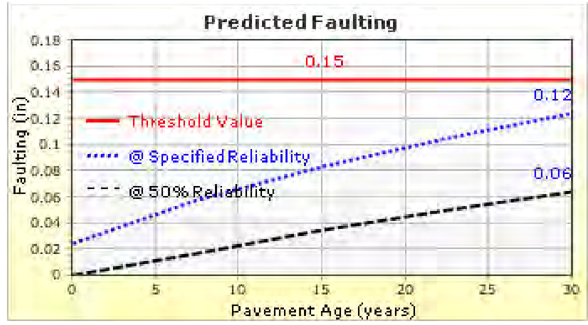
Layer Type	Material Type	Thickness (in)	Dowel Dia. (in)
JPCP-PCC	PCC	11.5	1.625
Granular Base	A-1-a	6	
Subgrade	A-7-6	Semi-infinite	

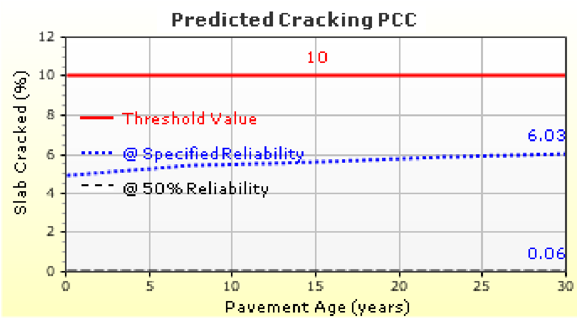
32.2.1.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	152.55	95.00	96.87	Pass
Mean joint faulting (in.)	0.15	0.12	95.00	99.10	Pass
JPCP transverse cracking (percent slabs)	10.00	6.03	95.00	99.69	Pass

32.2.1.1.4 Distress Charts







32.2.1.2 Summary of MoDOT Concrete Pavement Design and Life Cycle Rehabilitation

Pavement life cycle activities over a 75-year analysis period include the following as determined using the Missouri DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 11.5 in. PCC (with 1.625 in diameter dowel) over 6 in. crushed stone material
25	PCC Rehabilitation 1	¼ in. Diamond grinding and full depth repair (1.5% slab replacement is required in the travel lane as per MoDOT M&R strategy)
50	PCC Rehabilitation 2	¼ inch diamond grinding and full depth repair (10% slab replacement is required in the travel lane)*
65	PCC Rehabilitation 3	¼ inch diamond grinding and full depth repair (15% slab replacement is required in the travel lane)*
75	End of analysis period	

*Note that a higher amount of slab replacement is specified for the 50 and 65 year rehabilitations. This estimate is based on expected long term environmental impacts including PCC material durability factors and subgrade movements that would require the removal and replacement of cracked or deteriorated slabs (non-fatigue cracks).

32.2.2 DARWin-ME-Based Maintenance and Rehabilitation (M&R)

32.2.2.1 New Construction

32.2.2.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	8,000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	50,316,800

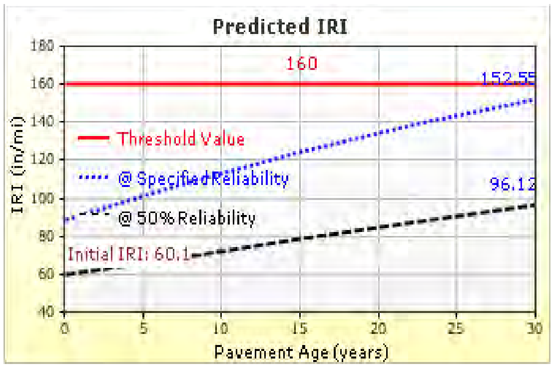
32.2.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

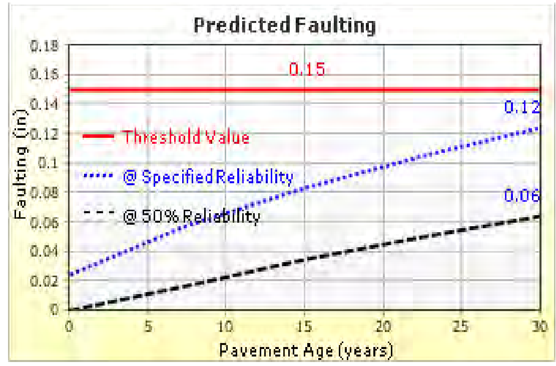
Layer Type	Material Type	Thickness (in)	Dowel Dia. (in)
JPCP-PCC	PCC	11.5	1.625
Granular Base	A-1-a	6	
Subgrade	A-7-6	Semi-infinite	

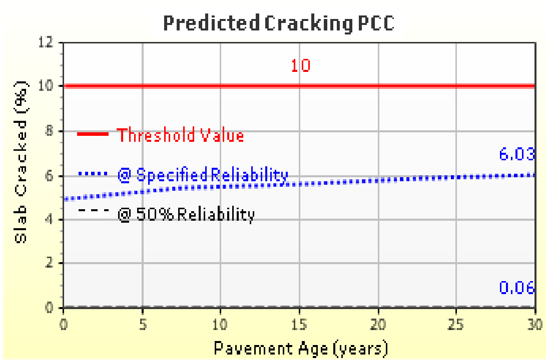
32.2.2.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	152.55	95.00	96.87	Pass
Mean joint faulting (in.)	0.15	0.12	95.00	99.10	Pass
JPCP transverse cracking (percent slabs)	10.00	6.03	95.00	99.69	Pass

32.2.2.1.4 Distress Charts







This design passes the DARWin-ME threshold criteria over 30 years. At 30 years, there is 6.03% fatigue cracking, 0.12 in faulting and 152.55 in/mile IRI at 95% reliability. Thus, diamond grinding and full depth repair are the most logical M&R treatment at 30 years.

32.2.2.2 First Rehabilitation –Diamond Grinding & Full Depth Repair

At 30 years, all cracked slabs will be replaced. Past fatigue cracking damage will be considered in future cracking projections. A maximum JPCP restoration life of 25 years was assumed since DARWin-ME does not consider all durability related distresses that develop over time. The first restoration project was then run for 25 years design period.

32.2.2.2.1 Traffic Inputs

Design period (from year 30 to 55)	25
Initial two-way AADTT	15,200
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	75,504,500

32.2.2.2.2 Pavement Structure That Meets Performance & Reliability Requirements

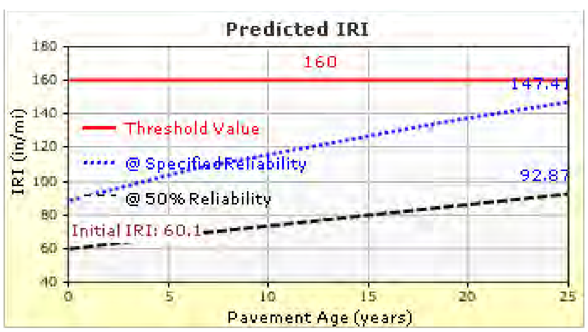
Layer Type	Material Type	Thickness (in)
JPCP-PCC	PCC	11.25*
Granular Base	A-1-a	6
Subgrade	A-7-6	Semi-infinite

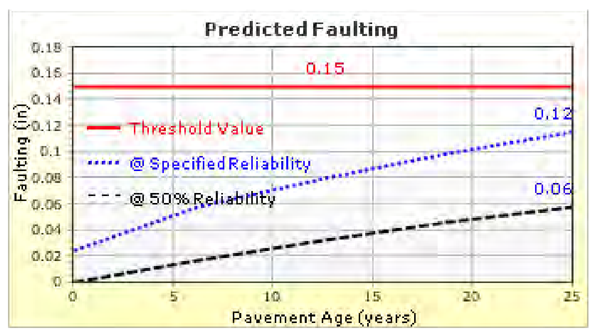
*Note: 0.25 inch slab thickness was removed by diamond grinding.

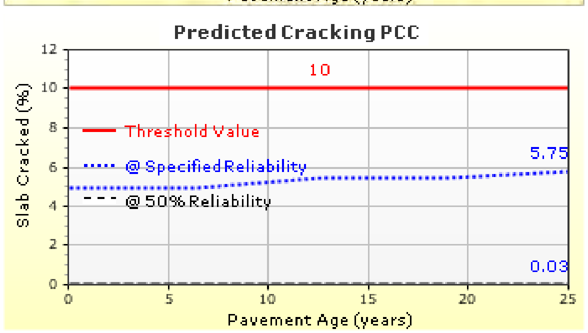
32.2.2.2.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	147.41	95.00	97.85	Pass
Mean joint faulting (in.)	0.15	0.12	95.00	99.57	Pass
JPCP transverse cracking (percent slabs)	10.00	5.75	95.00	99.79	Pass

32.2.2.2.4 Distress Charts







32.2.2.3 10b.PCC.B3 Second Rehabilitation –Diamond Grinding & Full Depth Repair

The second rehabilitation (restoration) was placed at 55 years with a design life of 10 years. A higher slab replacement of 12 % is assumed due to long term environmental effects including PCC durability, subgrade movement, etc.

32.2.2.3.1 Traffic Inputs

Design period (from year 55 to 65)	10
Initial two-way AADTT	21,200
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	

32.2.2.3.2 Pavement Structure That Meets Performance & Reliability Requirements

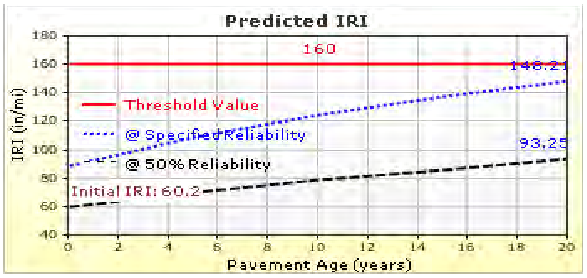
Layer Type	Material Type	Thickness (in)
JPCP-PCC	PCC	11*
Granular Base	A-1-a	6
Subgrade	A-7-6	Semi-infinite

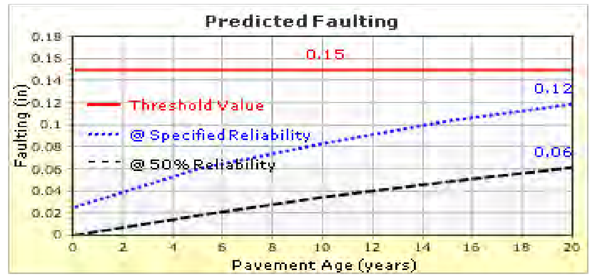
*Note: 0.25 inch slab thickness was removed by diamond grinding.

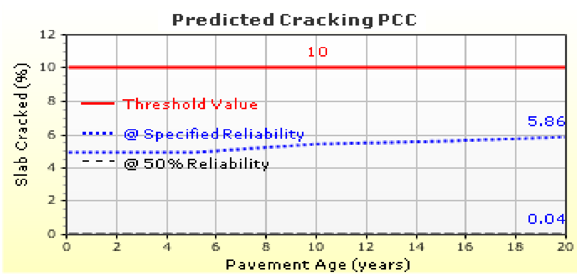
32.2.2.3.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	148.21	95.00	97.71	Pass
Mean joint faulting (in.)	0.15	0.12	95.00	99.37	Pass
JPCP transverse cracking (percent slabs)	10.00	5.86	95.00	99.76	Pass

32.2.2.3.4 Distress Charts







While the pavement passes all of the criteria at 75 years, given the long term environmental effects in this climatic zone, it is assumed that addition rehabilitation is needed at 65 years. This will consist of slab replacement of 17 percent and diamond grinding. At 75 years, given the age and deterioration of the pavement at this time no salvage value is included (other than the normal recycling of materials).

32.2.2.4 Summary of Concrete Pavement Design and Life Cycle Rehabilitation based on DARWin-ME Predictions

Pavement life cycle activities over a 75-year analysis period include the following as determined using the DARWin-ME based thresholds plus additional judgment on environmental related deterioration:

Year	Activity	Description
0	New construction	Place 11.5 in. PCC (with 1.625 in diameter dowel) over 6 in. crushed stone material
30	PCC Rehabilitation 1	¼ in. Diamond grinding & Full depth repair (6% slab replacement is required in the travel lane)
55	PCC Rehabilitation 2	¼ inch diamond grinding and full depth repair (12% slab replacement is required in the travel lane)*
65	PCC Rehabilitation 3	¼ inch diamond grinding and full depth repair (17% slab replacement is required in the travel lane)*
Salvage at 75	End of analysis period (no salvage)	

*Note that a higher amount of slab replacement is specified for the 55 and 65 year rehabilitations. This estimate is based on expected long term environmental impacts including PCC material durability factors and subgrade movements that would require the removal and replacement of cracked or deteriorated slabs (non-fatigue cracks).

33 Detailed Information for Cell 11a

33.1 ASPHALT CONCRETE PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

33.1.1 MoDOT-Based Maintenance and Rehabilitation (M&R)

33.1.1.1 New Construction

33.1.1.1.1 Traffic Inputs

Design period	50
Initial two-way AADTT	8,000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period (design lane)	101,393,000

33.1.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	Material Type	Thickness (in)
AC Surface	HMA with PG 76-22	2
AC Binder	HMA with PG 76-22	3
AC Base	HMA with PG 64-22	8.5
Granular Base	A-1-a	24
Subgrade	A-7-6	Semi-infinite

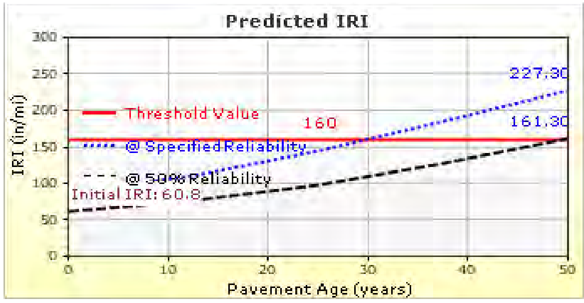
33.1.1.1.3 Distress Prediction & Reliability Summary

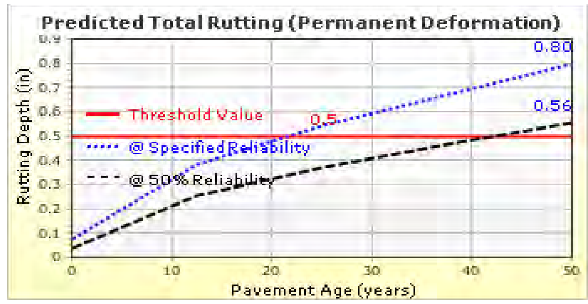
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.0	227.31	95.00	48.74*	Fail
Permanent deformation - total pavement (in.)	0.5	0.80	95.00	33.57**	Fail
AC bottom-up fatigue cracking (percent)	10.00	2.33	95.00	100.00	Pass
AC thermal fracture (ft/mile)	500.0	107.96	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.74	95.00	46.53	Pass

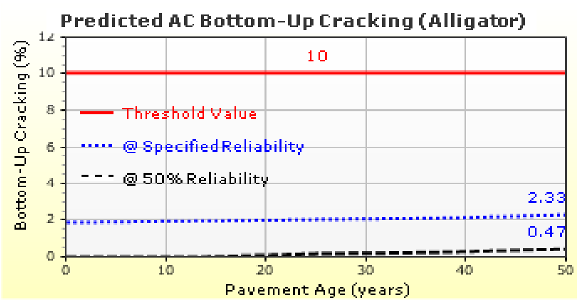
Note: * Predicted IRI at specified reliability is within 160 in/mile threshold until the placement of first rehabilitation overlay at 20 years.

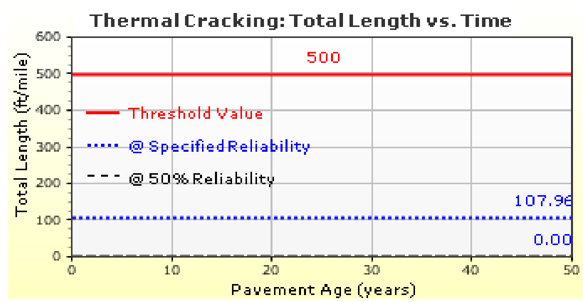
** Predicted permanent deformation at specified reliability is within 0.5 in. threshold until the placement of first rehabilitation overlay at 20 years.

33.1.1.1.4 Distress Charts









33.1.1.2 MoDOT Rehabilitation – Mill & Overlay

The Missouri first rehabilitation is recommended at 20 years. The MoDOT expected life of the AC overlay is 15 years. This becomes the Design Period for the next overlay. The Missouri second rehabilitation was applied at 35 years with design period of 15 years. After 50 years in service, a major rehabilitation is recommended that includes milling half of the existing asphalt materials and replacing with new materials.

33.1.1.3 Summary of Asphalt Pavement Design and Life Cycle Rehabilitation using MoDOT M&R

Pavement life cycle activities over a 75-year analysis period include the following as determined using the Missouri DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 13.5 in. AC over 24 in. crushed stone base material
20	AC overlay 1	Mill 2 in. and replace 2 in. AC OL (Patching of 0.13% lane area is required in the travel lane)
35	AC overlay 2	Mill 2 in. and replace 2 in. AC OL (Patching of 0.26% lane area is required in the travel lane)
50	AC overlay 3	Mill 7 in existing asphalt materials and replace with 7 in. AC Overlay over existing asphalt
65	AC overlay 4	Mill 2 in. and replace 2 in. AC OL (Patching of 0.55% lane area is required in the travel lane)
75	End of analysis period	

33.1.2 DARWin-ME-Based Maintenance and Rehabilitation (M&R)

33.1.2.1 New Construction

33.1.2.1.1 Traffic Inputs

Design period	50
Initial two-way AADTT	8,000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	101,393,000

33.1.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	Material Type	Thickness (in)
AC Surface	HMA with PG 76-22	2
AC Binder	HMA with PG 76-22	3
AC Base	HMA with PG 64-22	8.5
Granular Base	A-1-a	24
Subgrade	A-7-6	Semi-infinite

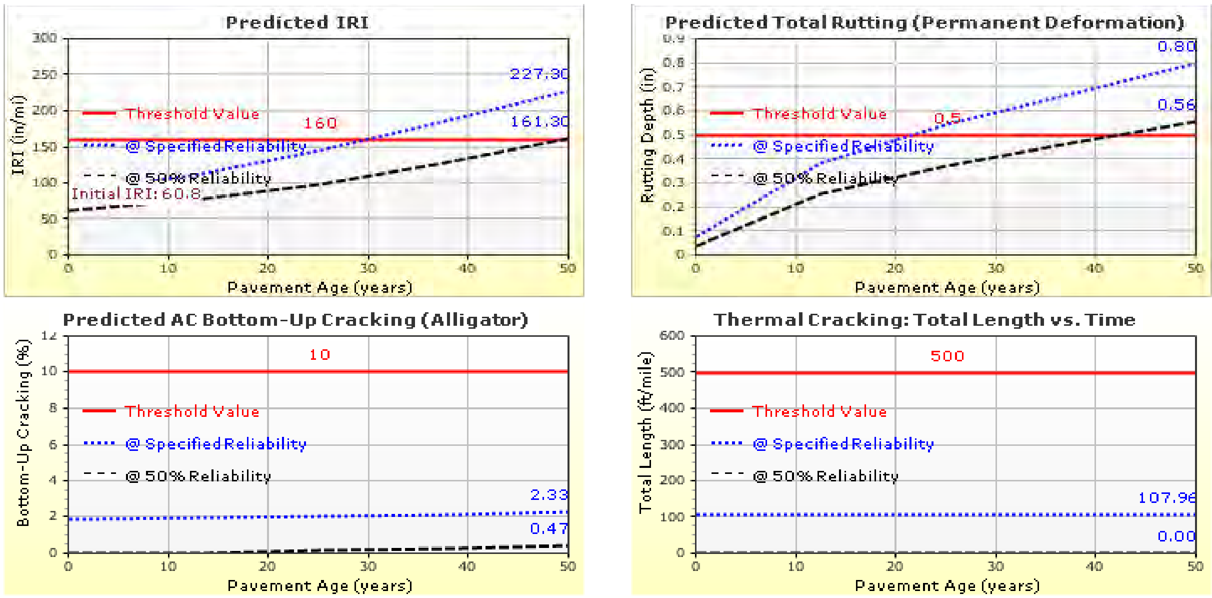
33.1.2.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.0	227.31	95.00	48.74*	Fail
Permanent deformation - total pavement (in.)	0.5	0.80	95.00	33.57**	Fail
AC bottom-up fatigue cracking (percent)	10.00	2.33	95.00	100.00	Pass
AC thermal fracture (ft/mile)	500.0	107.96	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.74	95.00	46.53	Pass

Note: * Predicted IRI at specified reliability is within 160 in/mile threshold until the placement of first rehabilitation overlay at 20 years.

** Predicted permanent deformation at specified reliability is within 0.5 in. threshold until the placement of first rehabilitation overlay at 20 years.

33.1.2.1.4 Distress Charts



33.1.2.2 First Rehabilitation – Mill & Overlay

The DARWin-ME based thresholds were used to establish future rehabilitation activities. A reasonable maximum service life of 20 years for new AC and 17 years for AC overlay was assumed for this climate since DARWin-ME does not consider all durability related distresses that develop over time. The first overlay project was then run for 17 years design period instead of typical MoDOT design life. The mill and overlay then starts out rutting at 0 and IRI at 60 in/mile. Fatigue damage was low but is also determined and considered in the next overlay cracking prediction.

33.1.2.2.1 Rehabilitation Information

Rehabilitation strategy	Mill top 2 in. of AC surface course and place an AC overlay of 2 in. thick. Patching of 0.13% lane area is required in the travel lane.
Year of rehabilitation	20
Design period	17

33.1.2.2.2 Traffic Inputs

Design period (from year 20 to 37)	17
Initial two-way AADTT	12,800
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	39,421,300

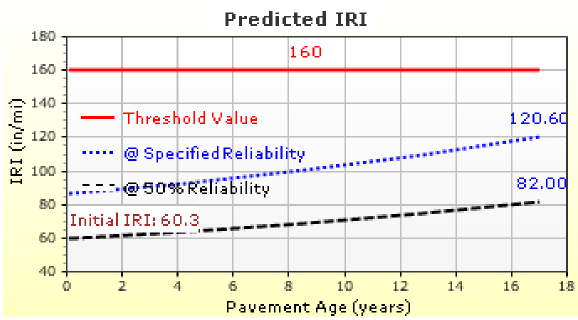
33.1.2.2.3 Pavement Structure

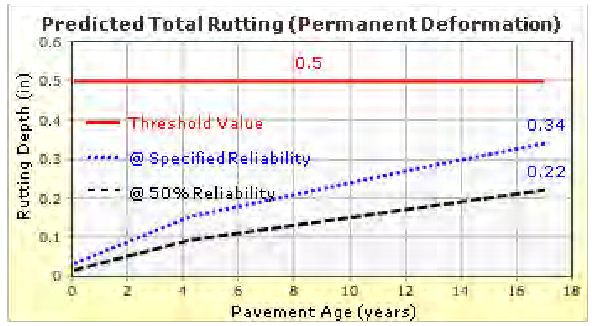
Layer Type	Material Type	Thickness (in)
AC Overlay (placed at 20 years)	HMA with PG 76-22	2
AC Binder	HMA with PG 76-22	3
AC Base	HMA with PG 64-22	8.5
Granular Base	A-1-a	24
Subgrade	A-7-6	Semi-infinite

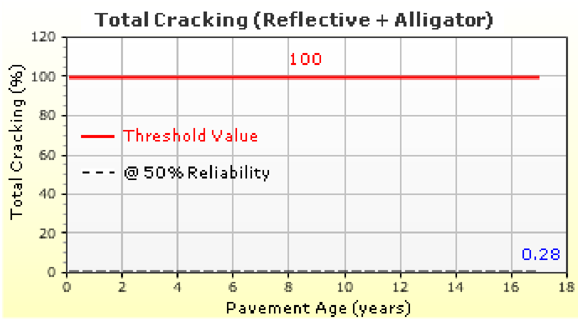
33.1.2.2.4 Distress Prediction & Reliability Summary

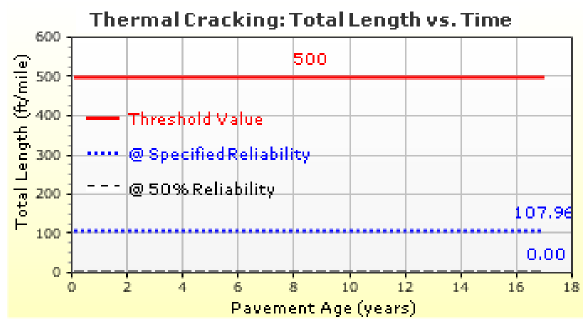
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	120.56	95.00	99.96	Pass
Permanent deformation - total pavement (in.)	0.5	0.34	95.00	99.99	Pass
Total Cracking (Reflective + Alligator) (percent)	5.00	0.28	95.00		Pass
AC thermal fracture (ft/mile)	500.00	107.96	95.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.86	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.34	95.00	99.99	Pass

33.1.2.2.5 Distress Charts









33.1.2.3 Second Rehabilitation – Mill & Overlay

The second rehabilitation was placed at 37 years with a design life of 13 years.

33.1.2.3.1 Rehabilitation Information

Rehabilitation strategy	Mill top 2 in. of AC surface course and place an AC overlay of 2 in. thick. Patching of 0.28% lane area is required in the travel lane.
Year of rehabilitation	37
Design period	13

33.1.2.3.2 Traffic Inputs

Design period (from year 37 to 50)	13
Initial two-way AADTT	16,880
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	37,831,000

33.1.2.3.3 Pavement Structure

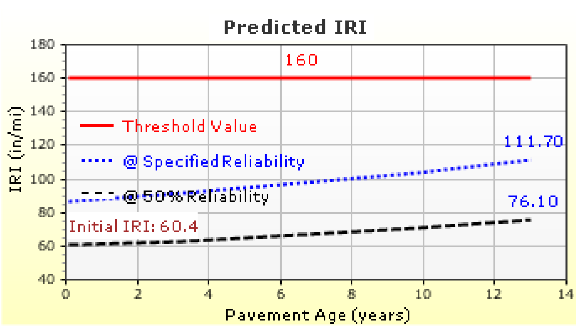
Layer Type	**Material Type**	**Thickness (in)**
AC Overlay (placed at 37 years)	HMA with PG 76-22	2

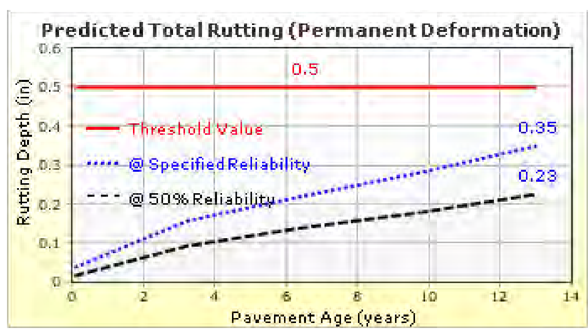
AC Binder	HMA with PG 76-22	3
AC Base	HMA with PG 64-22	8.5
Granular Base	A-1-a	24
Subgrade	A-7-6	Semi-infinite

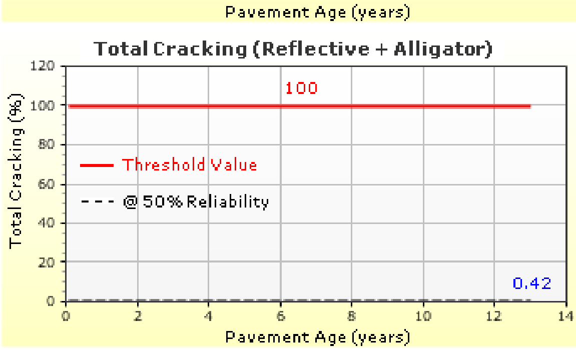
33.1.2.3.4 Distress Prediction & Reliability Summary

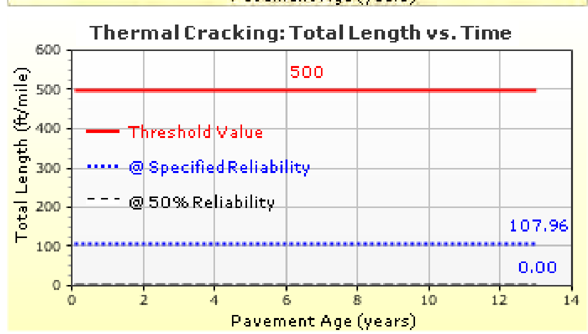
Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in./mile)	160.00	111.73	95.00	99.99	Pass
Permanent deformation - total pavement (in.)	0.5	0.35	95.00	99.99	Pass
Total Cracking (Reflective + Alligator) (percent)	5.00	0.42	95.00		Pass
AC thermal fracture (ft/mile)	500.00	107.96	95.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.86	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.35	95.00	99.99	Pass

33.1.2.3.5 Distress Charts









33.1.2.4 Third Rehabilitation – Mill & Overlay

The third rehabilitation was placed at 50 years instead of reconstruction. This major rehabilitation includes milling half of the existing asphalt materials (7 in.) and replacing with AC Overlay (7 in.) over existing asphalt. The third rehabilitation was then run for 15 years to see where it fails.

33.1.2.4.1 Rehabilitation Information

Rehabilitation strategy	Mill 7 in existing asphalt materials and replace with 7 in. AC Overlay over existing asphalt
Year of rehabilitation	50
Design period	15

33.1.2.4.2 Traffic Inputs

Design period	15
Initial two-way AADTT	20,000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	53,034,300

33.1.2.4.3 Pavement Structure

Layer Type	Material Type	Thickness (in)
AC Surface (placed at 50 years)	HMA with PG 76-22	3
AC Binder (placed at 50 years)	HMA with PG 76-22	4
AC Base	HMA with PG 64-22	6.5
Granular Base	A-1-a	24
Subgrade	A-7-6	Semi-infinite

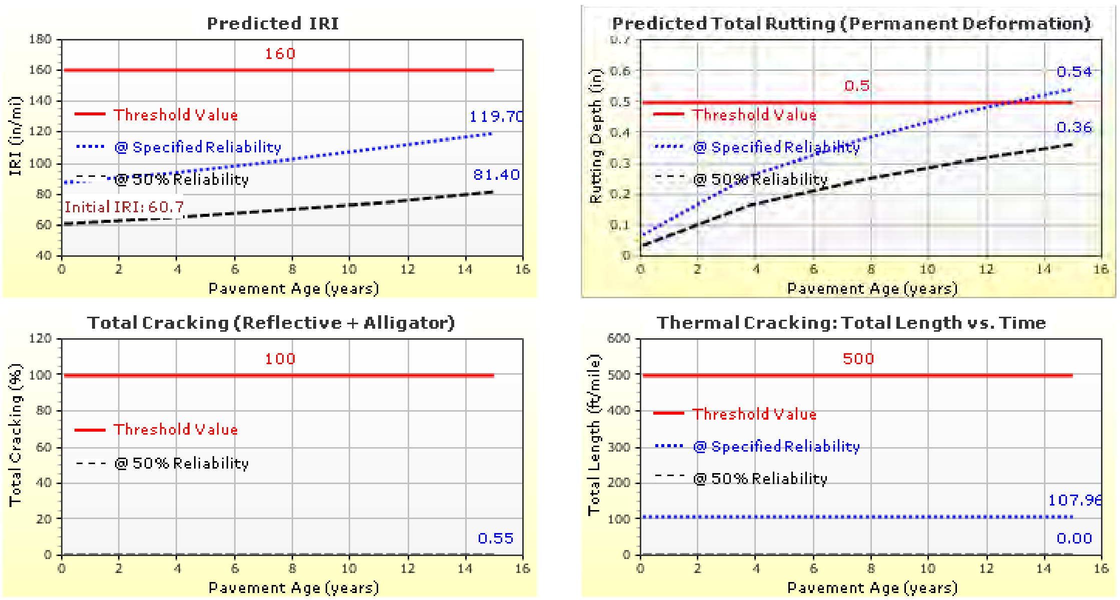
33.1.2.4.4 Distress Prediction & Reliability Summary

Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in./mile)	160.00	119.75	95.00	99.96	Pass
Permanent deformation - total pavement (in.)	0.5	0.54	95.00	89.57*	Fail

Total Cracking (Reflective + Alligator) (percent)	5.00	0.55	95.00		Pass
AC thermal fracture (ft/mile)	500.00	107.96	95.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.87	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.54	95.00	89.59*	Fail

Note: *Predicted permanent deformation at specified reliability is within 0.5 in. threshold until the placement of fourth rehabilitation overlay at 13 years.

33.1.2.4.5 Distress Charts



33.1.2.5 Fourth Rehabilitation – Mill & Overlay

The fourth rehabilitation was placed at 63 years with a design life of 12 years.

33.1.2.5.1 Rehabilitation Information

Rehabilitation strategy	Mill top 3 in. of AC surface course and place an AC overlay of 3 in. thick. Patching of 0.52% lane area is required in the travel lane.
Year of rehabilitation	63
Design period	12

33.1.2.5.2 Traffic Inputs

Design period (from year 63 to 75)	12
Initial two-way AADTT	23,120

Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	47,222,100

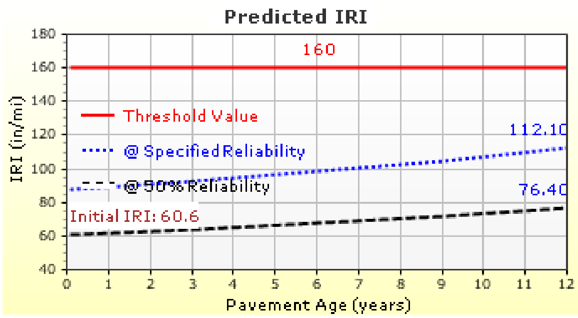
33.1.2.5.3 Pavement Structure

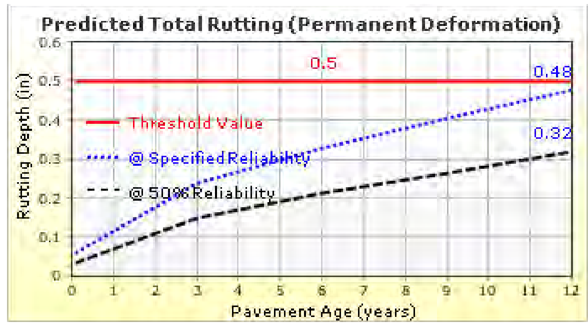
Layer Type	Material Type	Thickness (in)
AC Overlay (placed at 63 years)	HMA with PG 76-22	3
AC Binder	HMA with PG 76-22	4
AC Base	HMA with PG 64-22	6.5
Granular Base	A-1-a	24
Subgrade	A-7-6	Semi-infinite

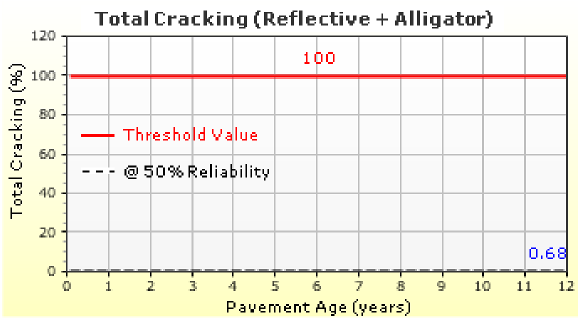
33.1.2.5.4 Distress Prediction & Reliability Summary

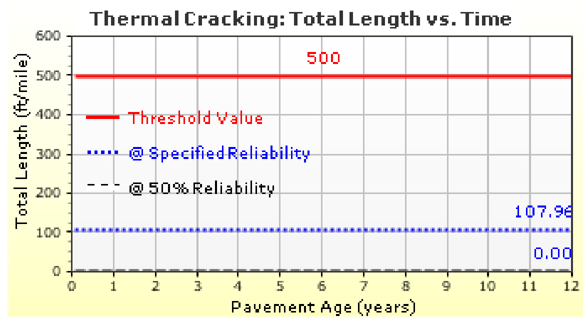
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	112.14	95.00	99.99	Pass
Permanent deformation - total pavement (in.)	0.5	0.48	95.00	96.85	Pass
Total Cracking (Reflective + Alligator) (percent)	5.00	0.68	95.00		Pass
AC thermal fracture (ft/mile)	500.00	107.96	95.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.86	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.48	95.00	96.85	Pass

33.1.2.5.5 Distress Charts









33.1.2.6 Summary of Asphalt Pavement Design and Life Cycle Rehabilitation based on DARWin-ME Predictions

Pavement life cycle activities over a 75-year analysis period include the following as determined using the DARWin-ME threshold criteria:

Year	Activity	Description
0	New construction	Place 13.5 in. AC over 24 in. crushed stone base material
20	AC overlay 1	Mill 2 in. and replace 2 in. AC OL (Patching of 0.13% lane area is required in the travel lane).
37	AC overlay 2	Mill 2 in. and replace 2 in. AC OL (Patching of 0.28% lane area is required in the travel lane).
50	AC overlay 3	Mill 7 in existing asphalt materials and replace with 7 in. AC Overlay over existing asphalt
63	AC overlay 4	Mill 2 in. and replace 2 in. AC OL (Patching of 0.52% lane area is required in the travel lane)
Salvage at 75	End of Analysis (no salvage)	

33.2 PORTLAND CEMENT CONCRETE PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

The site conditions, design period and analysis period are exactly the same as that used for the AC design.

33.2.1 MoDOT-Based Maintenance and Rehabilitation (M&R)

The MoDOT M&R strategy is to perform concrete pavement restoration at 25 years. This includes 1.5% cracked slabs replacement in the travel lane and diamond grinding of the surface to restore IRI and remove faulting.

33.2.1.1 New Construction

33.2.1.1.1 Traffic Inputs

Design period	50
Initial two-way AADTT	8,000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	101,393,000

33.2.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	**Material Type**	**Thickness (in)**	**Dowel Dia. (in)**
JPCP-PCC	PCC	11.5	1.625
Granular Base	A-1-a	6	
Subgrade	A-7-6	Semi-infinite	

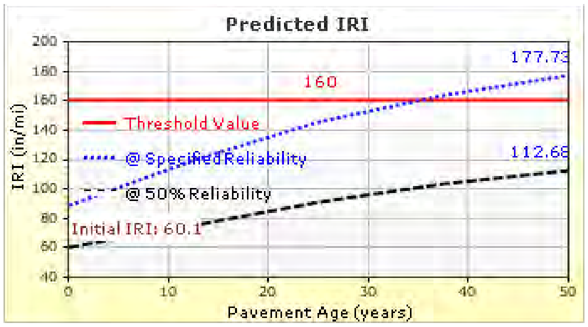
33.2.1.1.3 Distress Prediction & Reliability Summary

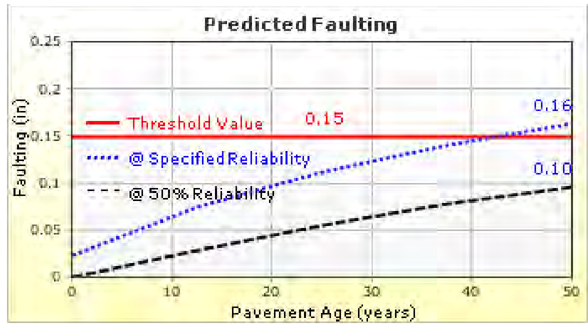
Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in./mile)	160.00	177.73	95.00	88.43*	Fail
Mean joint faulting (in.)	0.15	0.16	95.00	90.34**	Fail
JPCP transverse cracking (percent slabs)	10.00	6.57	95.00	99.42	Pass

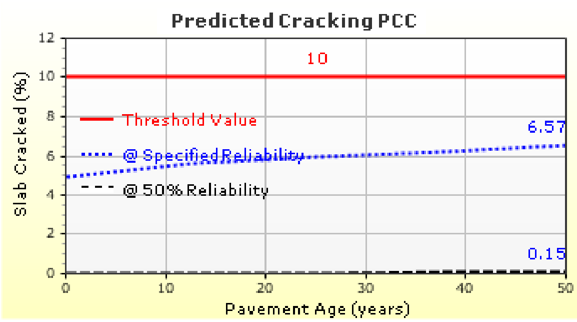
Note: * Predicted IRI at specified reliability is within 160 in/mile threshold until the placement of first restoration at 25 years.

** Predicted faulting at specified reliability is within 0.15 in. threshold until the placement of first restoration at 25 years.

33.2.1.1.4 Distress Charts







33.2.1.2 Summary of MoDOT Concrete Pavement Design and Life Cycle Rehabilitation

Pavement life cycle activities over a 75-year analysis period include the following as determined using the Missouri DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 11.5 in. PCC (with 1.625 in diameter dowel) over 6 in. crushed stone material
25	PCC Rehabilitation 1	¼ in. Diamond grinding and full depth repair (1.5% slab replacement is required in the travel lane as per MoDOT M&R strategy)
50	PCC Rehabilitation 2	¼ inch diamond grinding and full depth repair (10% slab replacement is required in the travel lane)*
65	PCC Rehabilitation 3	¼ inch diamond grinding and full depth repair (15% slab replacement is required in the travel lane)*
75	End of analysis period	

*Note that a higher amount of slab replacement is specified for the 50 and 65 year rehabilitations. This estimate is based on expected long term environmental impacts including PCC material durability factors and subgrade movements that would require the removal and replacement of cracked or deteriorated slabs (non-fatigue cracks).

33.2.2 DARWin-ME-Based Maintenance and Rehabilitation (M&R)

33.2.2.1 New Construction

33.2.2.1.1 Traffic Inputs

Design period	50
Initial two-way AADTT	8,000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	101,393,000

33.2.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	Material Type	Thickness (in)	Dowel Dia. (in)
JPCP-PCC	PCC	11.5	1.625
Granular Base	A-1-a	6	
Subgrade	A-7-6	Semi-infinite	

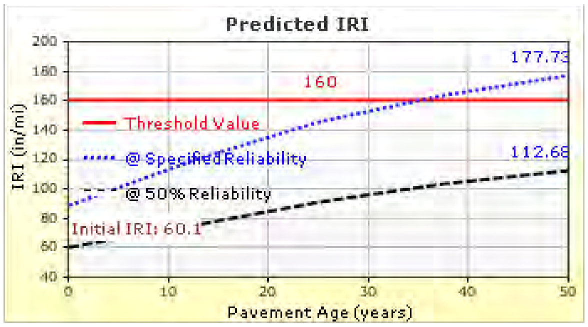
33.2.2.1.3 Distress Prediction & Reliability Summary

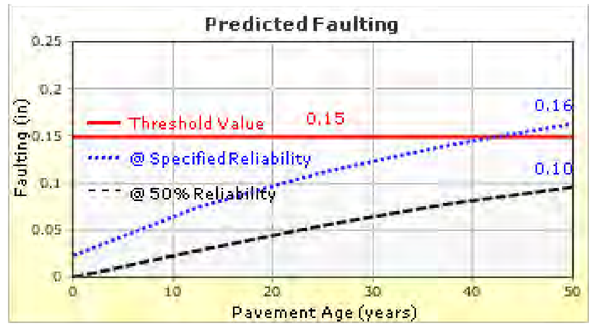
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	177.73	95.00	88.43*	Fail
Mean joint faulting (in.)	0.15	0.16	95.00	90.34**	Fail
JPCP transverse cracking (percent slabs)	10.00	6.57	95.00	99.42	Pass

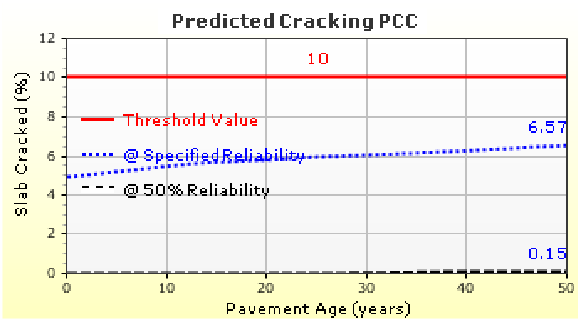
Note: * Predicted IRI at specified reliability is within 160 in/mile threshold until the placement of first restoration at 35 years.

** Predicted faulting at specified reliability is within 0.15 in. threshold until the placement of first restoration at 35 years.

33.2.2.1.4 Distress Charts







At 50 years, there is 6.57% fatigue cracking, 0.16 in faulting, and 177.73 in/mile IRI at 95% reliability. The faulting and IRI do not reach the threshold until 35 years. Thus, diamond grinding and full depth repair are the most logical M&R treatment at 35 years.

33.2.2.2 First Rehabilitation –Diamond Grinding & Full Depth Repair

At 35 years, all cracked slabs will be replaced. Past fatigue cracking damage will be considered in future cracking projections. A maximum JPCP restoration life of 20 years was assumed since DARWin-ME does not consider all durability related distresses that develop over time. The first restoration project was then run for 20 years design period.

33.2.2.2.1 Traffic Inputs

Design period (from year 35 to 55)	20
Initial two-way AADTT	16,400
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	61,578,200

33.2.2.2.2 Pavement Structure That Meets Performance & Reliability Requirements

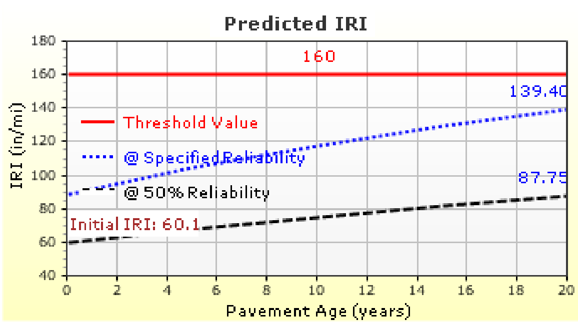
Layer Type	Material Type	Thickness (in)
JPCP-PCC	PCC	11.25*
Granular Base	A-1-a	6
Subgrade	A-7-6	Semi-infinite

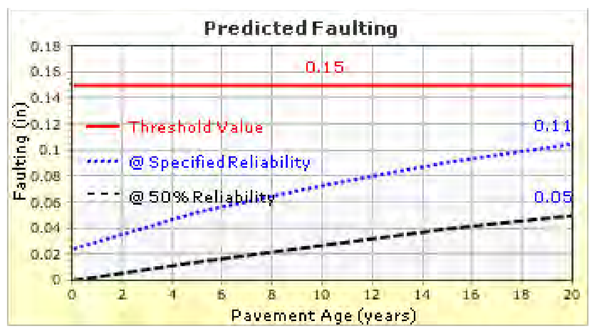
*Note: 0.25 inch slab thickness was removed by diamond grinding.

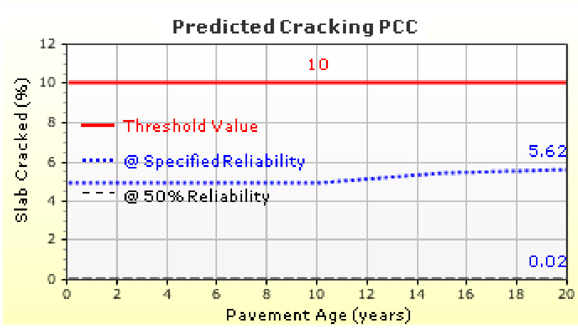
33.2.2.2.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	139.40	95.00	98.93	Pass
Mean joint faulting (in.)	0.15	0.11	95.00	99.85	Pass
JPCP transverse cracking (percent slabs)	10.00	5.62	95.00	99.83	Pass

33.2.2.2.4 Distress Charts







33.2.2.3 Second Rehabilitation –Diamond Grinding & Full Depth Repair

The second rehabilitation (restoration) was placed at 55 years with a design life of 10 years. A higher slab replacement of 12% is assumed due to long term environmental effects including PCC durability, subgrade movement, etc.

33.2.2.3.1 Traffic Inputs

Design period (from year 55 to 65)	10
Initial two-way AADTT	21,200
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	35,154,600

33.2.2.3.2 Pavement Structure That Meets Performance & Reliability Requirements

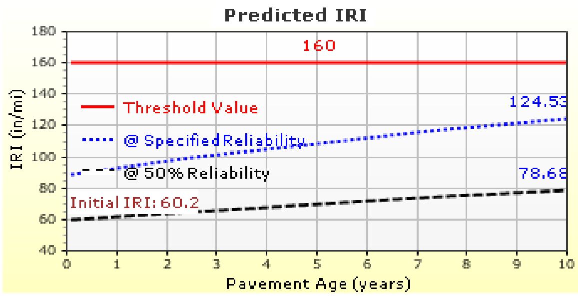
Layer Type	Material Type	Thickness (in)
JPCP-PCC	PCC	11*
Granular Base	A-1-a	6
Subgrade	A-7-6	Semi-infinite

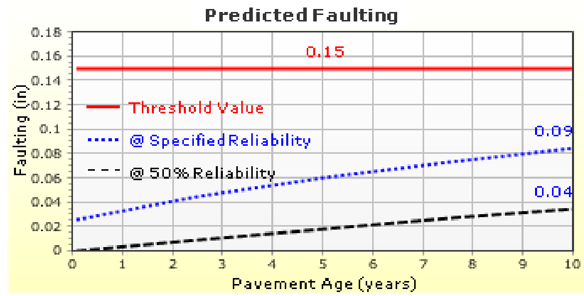
*Note: 0.25 inch slab thickness was removed by diamond grinding.

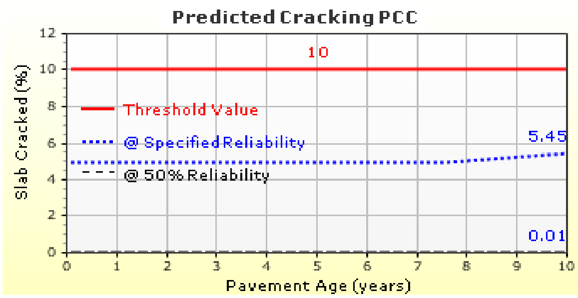
33.2.2.3.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	124.53	95.00	99.82	Pass
Mean joint faulting (in.)	0.15	0.09	95.00	99.99	Pass
JPCP transverse cracking (percent slabs)	10.00	5.45	95.00	99.87	Pass

33.2.2.3.4 Distress Charts







While the pavement passes all of the criteria at 75 years, given the long term environmental effects in this climatic zone, it is assumed that addition rehabilitation is needed at 65 years. This will consist of slab replacement of 17 percent and diamond grinding. At 75 years, given the age and deterioration of the pavement at this time no salvage value is included (other than the normal recycling of materials).

33.2.2.4 *Summary of Concrete Pavement Design and Life Cycle Rehabilitation based on DARWin-ME Predictions*

Pavement life cycle activities over a 75-year analysis period include the following as determined using the DARWin-ME based thresholds plus additional judgment on environmental related deterioration:

Year	Activity	Description
0	New construction	Place 11.5 in. PCC (with 1.625 in diameter dowel) over 6 in. crushed stone material
35	PCC Rehabilitation 1	¼ in. Diamond grinding & Full depth repair (6.2% slabs repaired in the travel lane)
55	PCC Rehabilitation 2	¼ inch diamond grinding and full depth repair (12% slab replacement is required in the travel lane)*
65	PCC Rehabilitation 3	¼ inch diamond grinding and full depth repair (17% slab replacement is required in the travel lane)*
Salvage at 75	End of analysis period (no salvage)	

*Note that a higher amount of slab replacement is specified for the 55 and 65 year rehabilitations. This estimate is based on expected long term environmental impacts including PCC material durability factors and subgrade movements that would require the removal and replacement of cracked or deteriorated slabs (non-fatigue cracks).

34 Detailed Information for Cell 11b

34.1 ASPHALT CONCRETE PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

34.1.1 MoDOT-Based Maintenance and Rehabilitation (M&R)

34.1.1.1 New Construction

34.1.1.1.1 Traffic Inputs

Design period	50
Initial two-way AADTT	8,000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period (design lane)	101,393,000

34.1.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	Material Type	Thickness (in)
AC Surface	HMA with PG 76-22	2
AC Binder	HMA with PG 76-22	3
AC Base	HMA with PG 64-22	8.5
Granular Base	A-1-a	24
Subgrade	A-7-6	Semi-infinite

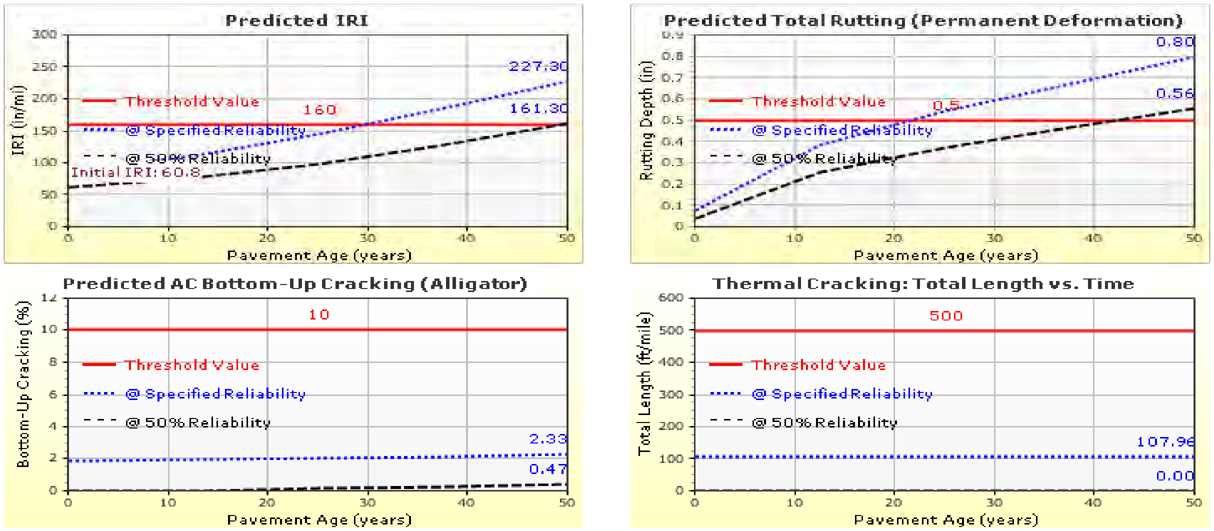
34.1.1.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.0	227.31	95.00	48.74*	Fail
Permanent deformation - total pavement (in.)	0.5	0.80	95.00	33.57**	Fail
AC bottom-up fatigue cracking (percent)	10.00	2.33	95.00	100.00	Pass
AC thermal fracture (ft/mile)	500.0	107.96	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.74	95.00	46.53	Pass

Note: * Predicted IRI at specified reliability is within 160 in/mile threshold until the placement of first rehabilitation overlay at 20 years.

** Predicted permanent deformation at specified reliability is within 0.5 in. threshold until the placement of first rehabilitation overlay at 20 years.

34.1.1.1.4 Distress Charts



34.1.1.2 MoDOT Rehabilitation – Mill & Overlay

The Missouri first rehabilitation is recommended at 20 years. The MoDOT expected life of the AC overlay is 15 years. This becomes the Design Period for the next overlay. The Missouri second rehabilitation was applied at 35 years with design period of 15 years. After 50 years in service, a major rehabilitation is recommended that includes milling half of the existing asphalt materials and replacing with new materials. A similar rehabilitation is also required after 75 years.

34.1.1.3 Summary of Asphalt Pavement Design and Life Cycle Rehabilitation using MoDOT M&R

Pavement life cycle activities over a 100-year analysis period include the following as determined using the Missouri DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 13.5 in. AC over 24 in. crushed stone base material
20	AC overlay 1	Mill 2 in. and replace 2 in. AC OL (Patching of 0.13% lane area is required in the travel lane)
35	AC overlay 2	Mill 2 in. and replace 2 in. AC OL (Patching of 0.26% lane area is required in the travel lane)
50	AC overlay 3	Mill 7 in existing asphalt materials and replace with 7 in. AC Overlay over existing asphalt
63	AC overlay 4	Mill 3 in. and replace 3 in. AC OL (Patching of 0.52% lane area is required in the travel lane)
75	AC overlay 5	Mill 8 in existing asphalt materials and replace with 8 in. AC Overlay over existing asphalt
90	AC overlay 6	Mill 4 in. and replace 4 in. AC OL (Patching of 0.77% lane area is required in the travel lane)
100	End of analysis period	

34.1.2 DARWin-ME-Based Maintenance and Rehabilitation (M&R)

34.1.2.1 New Construction

34.1.2.1.1 Traffic Inputs

Design period	50
Initial two-way AADTT	8,000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	101,393,000

34.1.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	Material Type	Thickness (in)
AC Surface	HMA with PG 76-22	2
AC Binder	HMA with PG 76-22	3
AC Base	HMA with PG 64-22	8.5
Granular Base	A-1-a	24
Subgrade	A-7-6	Semi-infinite

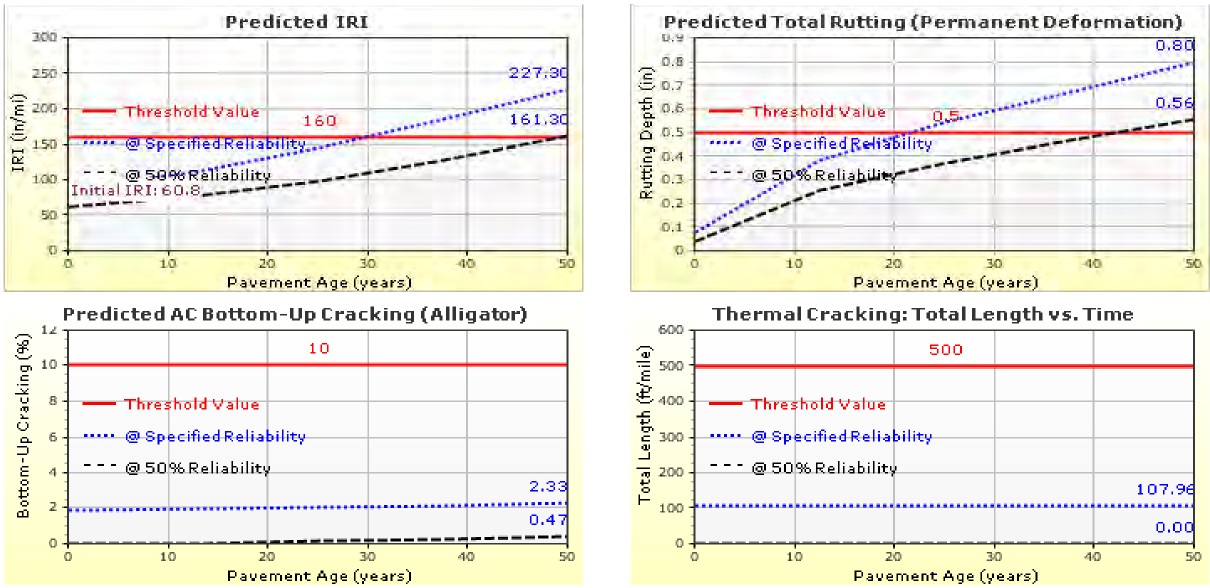
34.1.2.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.0	227.31	95.00	48.74*	Fail
Permanent deformation - total pavement (in.)	0.5	0.80	95.00	33.57**	Fail
AC bottom-up fatigue cracking (percent)	10.00	2.33	95.00	100.00	Pass
AC thermal fracture (ft/mile)	500.0	107.96	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.74	95.00	46.53	Pass

Note: * Predicted IRI at specified reliability is within 160 in/mile threshold until the placement of first rehabilitation overlay at 20 years.

** Predicted permanent deformation at specified reliability is within 0.5 in. threshold until the placement of first rehabilitation overlay at 20 years.

34.1.2.1.4 Distress Charts



34.1.2.2 11b.AC.B2 First Rehabilitation – Mill & Overlay

The DARWin-ME based thresholds were used to establish future rehabilitation activities. A reasonable maximum service life of 20 years for new AC and 17 years for AC overlay was assumed for this climate since DARWin-ME does not consider all durability related distresses that develop over time. The first overlay project was then run for 17 years design period instead of typical MoDOT design life. The mill and overlay then starts out rutting at 0 and IRI at 60 in/mile. Fatigue damage was low but is also determined and considered in the next overlay cracking prediction.

34.1.2.2.1 Rehabilitation Information

Rehabilitation strategy	Mill top 2 in. of AC surface course and place an AC overlay of 2 in. thick. Patching of 0.13% lane area is required in the travel lane.
Year of rehabilitation	20
Design period	17

34.1.2.2.2 Traffic Inputs

Design period (from year 20 to 37)	17
Initial two-way AADTT	12,800
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	39,421,300

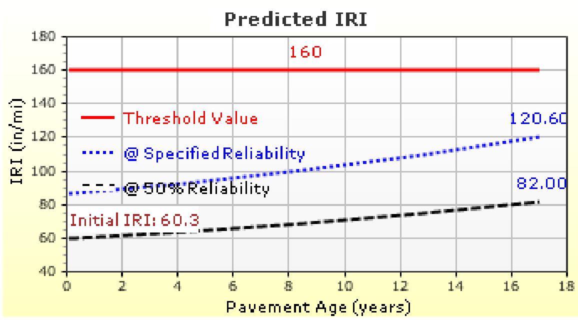
34.1.2.2.3 Pavement Structure

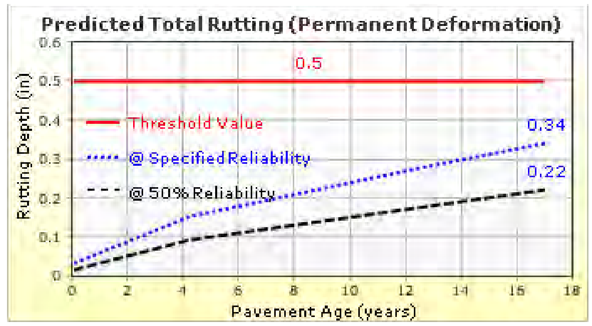
Layer Type	Material Type	Thickness (in)
AC Overlay (placed at 20 years)	HMA with PG 76-22	2
AC Binder	HMA with PG 76-22	3
AC Base	HMA with PG 64-22	8.5
Granular Base	A-1-a	24
Subgrade	A-7-6	Semi-infinite

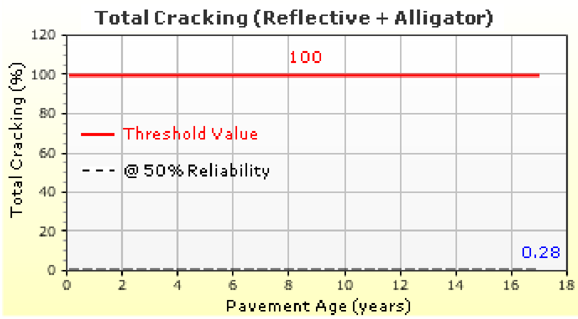
34.1.2.2.4 Distress Prediction & Reliability Summary

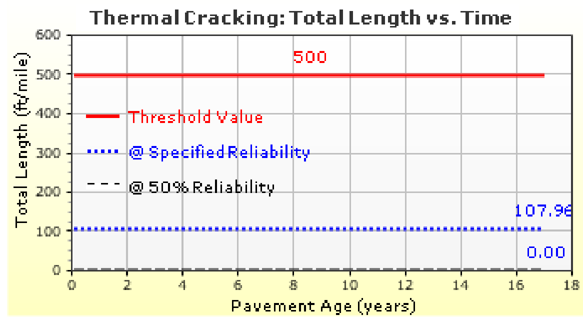
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	120.56	95.00	99.96	Pass
Permanent deformation - total pavement (in.)	0.5	0.34	95.00	99.99	Pass
Total Cracking (Reflective + Alligator) (percent)	5.00	0.28	95.00		Pass
AC thermal fracture (ft/mile)	500.00	107.96	95.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.86	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.34	95.00	99.99	Pass

34.1.2.2.5 Distress Charts









34.1.2.3 *Second Rehabilitation – Mill & Overlay*

The second rehabilitation was placed at 37 years with a design life of 13 years.

34.1.2.3.1 Rehabilitation Information

Rehabilitation strategy	Mill top 2 in. of AC surface course and place an AC overlay of 2 in. thick. Patching of 0.28% lane area is required in the travel lane.
Year of rehabilitation	37
Design period	13

34.1.2.3.2 Traffic Inputs

Design period (from year 37 to 50)	13
Initial two-way AADTT	16,880
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	37,831,000

34.1.2.3.3 Pavement Structure

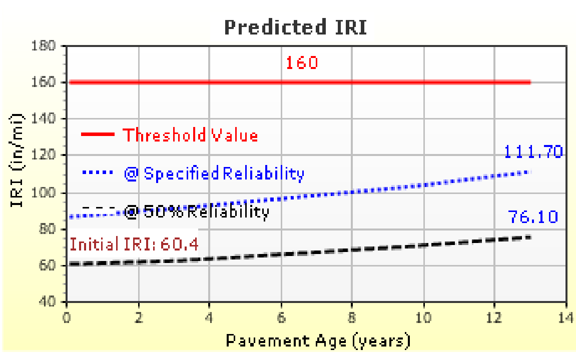
Layer Type	**Material Type**	**Thickness (in)**
AC Overlay (placed at 37 years)	HMA with PG 76-22	2

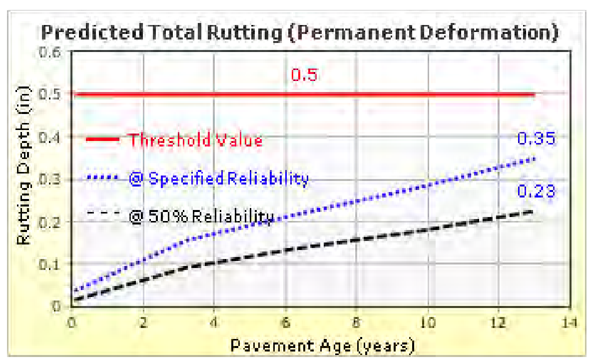
AC Binder	HMA with PG 76-22	3
AC Base	HMA with PG 64-22	8.5
Granular Base	A-1-a	24
Subgrade	A-7-6	Semi-infinite

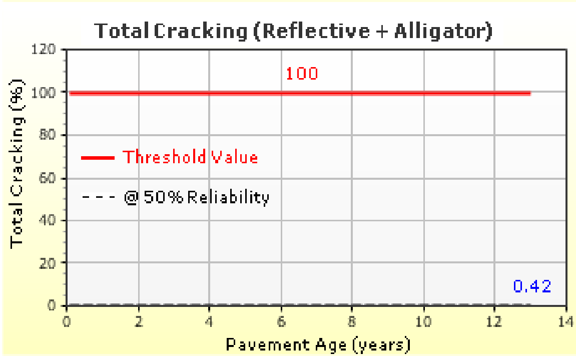
34.1.2.3.4 Distress Prediction & Reliability Summary

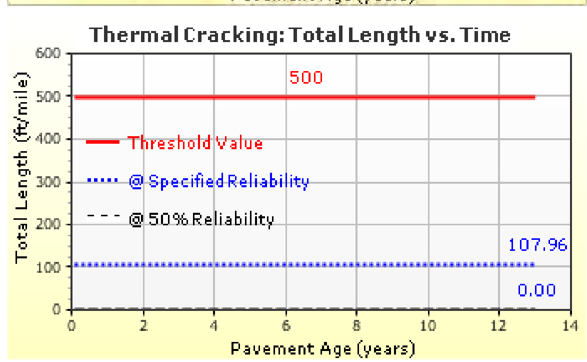
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	111.73	95.00	99.99	Pass
Permanent deformation - total pavement (in.)	0.5	0.35	95.00	99.99	Pass
Total Cracking (Reflective + Alligator) (percent)	5.00	0.42	95.00		Pass
AC thermal fracture (ft/mile)	500.00	107.96	95.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.86	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.35	95.00	99.99	Pass

34.1.2.3.5 Distress Charts









34.1.2.4 Third Rehabilitation – Mill & Overlay

The third rehabilitation was placed at 50 years instead of reconstruction. This major rehabilitation includes milling half of the existing asphalt materials (7 in.) and replacing with AC Overlay (7 in.) over existing asphalt. The third rehabilitation was then run for 15 years to see where it fails.

34.1.2.4.1 Rehabilitation Information

Rehabilitation strategy	Mill 7 in existing asphalt materials and replace with 7 in. AC Overlay over existing asphalt
Year of rehabilitation	50
Design period	15

34.1.2.4.2 Traffic Inputs

Design period	15
Initial two-way AADTT	20,000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	53,034,300

34.1.2.4.3 Pavement Structure

Layer Type	**Material Type**	**Thickness (in)**
AC Surface (placed at 50 years)	HMA with PG 76-22	3
AC Binder (placed at 50 years)	HMA with PG 76-22	4
AC Base	HMA with PG 64-22	6.5
Granular Base	A-1-a	24
Subgrade	A-7-6	Semi-infinite

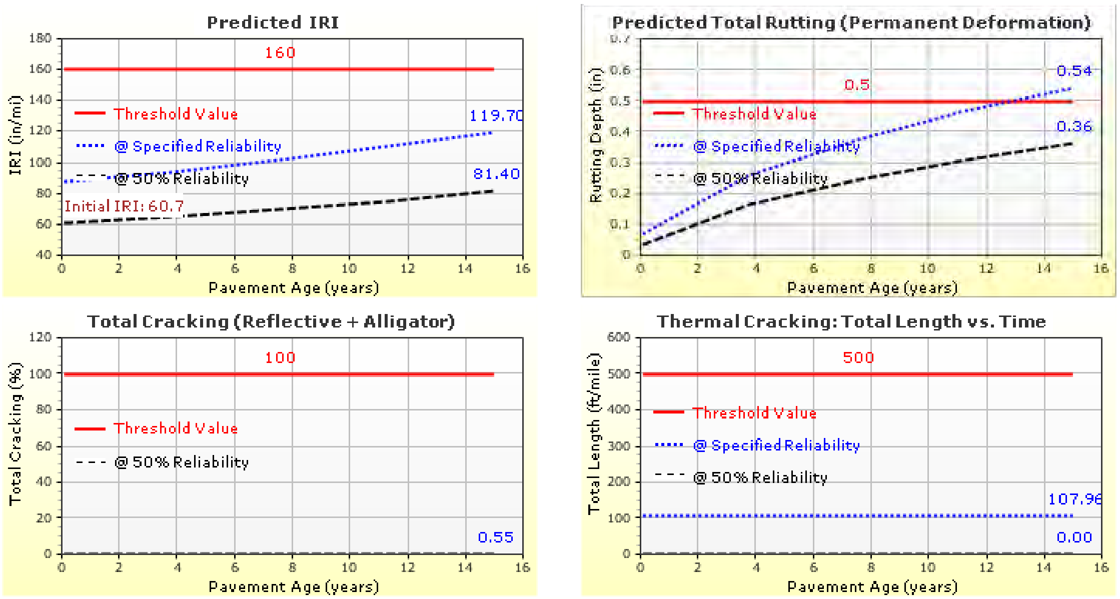
34.1.2.4.4 Distress Prediction & Reliability Summary

Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in./mile)	160.00	119.75	95.00	99.96	Pass
Permanent deformation - total pavement (in.)	0.5	0.54	95.00	89.57*	Fail
AC thermal fracture (ft/mile)	5.00	0.55	95.00		Pass

AC bottom-up fatigue cracking (percent)	500.00	107.96	95.00	100.00	Pass
Permanent deformation - AC only (in.)	10.00	1.87	95.00	100.00	Pass

Note: *Predicted permanent deformation at specified reliability is within 0.5 in. threshold until the placement of fourth rehabilitation overlay at 13 years.

34.1.2.4.5 Distress Charts



34.1.2.5 Fourth Rehabilitation – Mill & Overlay

The fourth rehabilitation was placed at 63 years with a design life of 12 years.

34.1.2.5.1 Rehabilitation Information

Rehabilitation strategy	Mill top 3 in. of AC surface course and place an AC overlay of 3 in. thick. Patching of 0.52% lane area is required in the travel lane.
Year of rehabilitation	63
Design period	12

34.1.2.5.2 Traffic Inputs

Design period (from year 63 to 75)	12
Initial two-way AADTT	23,120
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0

Percent of trucks in design lane (%)	80.0
Number of trucks over design period	47,222,100

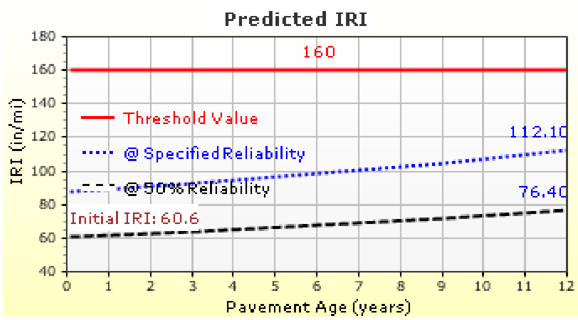
34.1.2.5.3 Pavement Structure

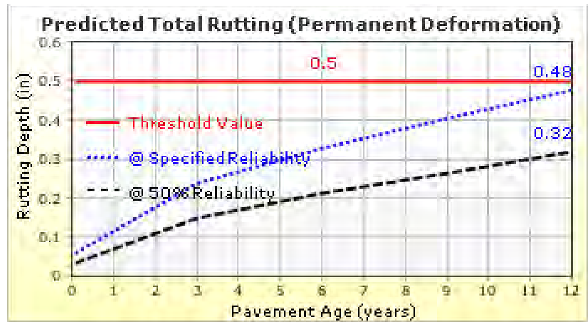
Layer Type	Material Type	Thickness (in)
AC Overlay (placed at 63 years)	HMA with PG 76-22	3
AC Binder	HMA with PG 76-22	4
AC Base	HMA with PG 64-22	6.5
Granular Base	A-1-a	24
Subgrade	A-7-6	Semi-infinite

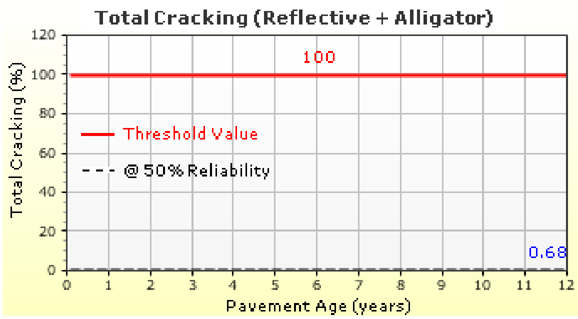
34.1.2.5.4 Distress Prediction & Reliability Summary

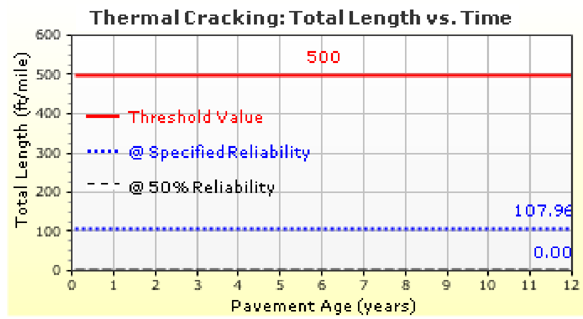
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	112.14	95.00	99.99	Pass
Permanent deformation - total pavement (in.)	0.5	0.48	95.00	96.85	Pass
Total Cracking (Reflective + Alligator) (percent)	5.00	0.68	95.00		Pass
AC thermal fracture (ft/mile)	500.00	107.96	95.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.86	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.48	95.00	96.85	Pass

34.1.2.5.5 Distress Charts









34.1.2.6 Fifth Rehabilitation – Mill & Overlay

The fifth rehabilitation was placed at 75 years instead of reconstruction. This major rehabilitation includes milling half of the existing asphalt materials (8 in.) and replacing with AC Overlay (8 in.) over existing asphalt. The third rehabilitation was then run for 15 years to see where it fails.

34.1.2.6.1 Rehabilitation Information

Rehabilitation strategy	Mill 8 in existing asphalt materials and replace with 8 in. AC Overlay over existing asphalt
Year of rehabilitation	75
Design period	15

34.1.2.6.2 Traffic Inputs

Design period (from year 75 to 90)	15
Initial two-way AADTT	26,000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	68,944,600

34.1.2.6.3 Pavement Structure

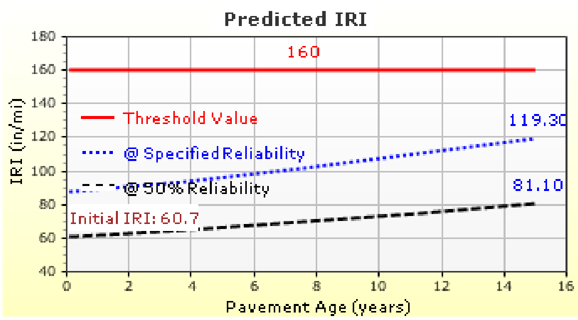
Layer Type	Material Type	Thickness (in)
AC Overlay (placed at 75 years)	HMA with PG 76-22	4
AC Binder (placed at 75 years)	HMA with PG 76-22	5
AC Base	HMA with PG 64-22	5.5
Granular Base	A-1-a	24
Subgrade	A-7-6	Semi-infinite

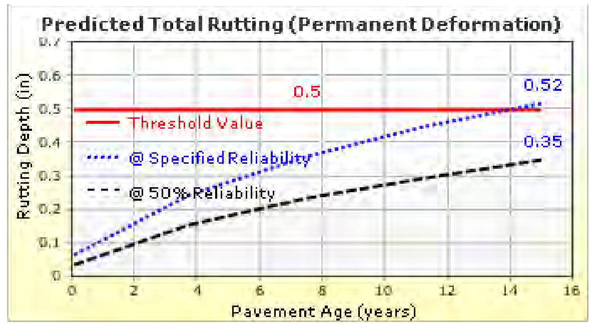
34.1.2.6.4 Distress Prediction & Reliability Summary

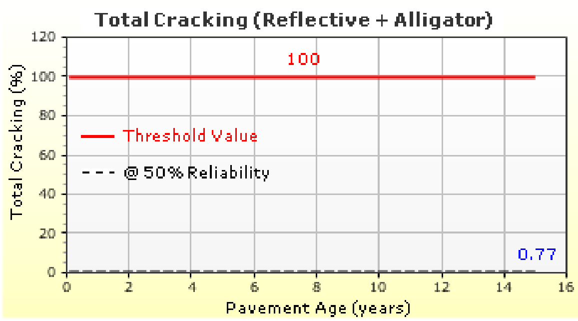
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	119.31	95.00	99.97	Pass
Permanent deformation - total pavement (in.)	0.5	0.52	95.00	92.83*	Fail
Total Cracking (Reflective + Alligator) (percent)	5.00	0.77	95.00		Pass
AC thermal fracture (ft/mile)	500.00	107.96	95.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.87	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.52	95.00	92.85*	Fail

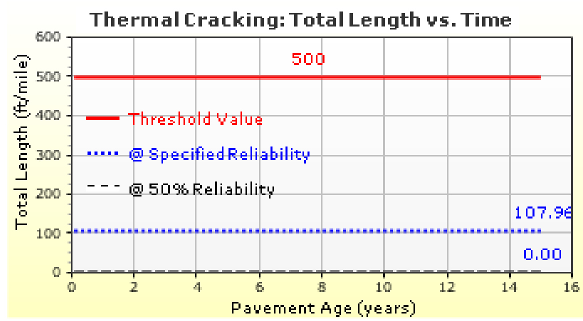
Note: *Predicted permanent deformation at specified reliability reaches the threshold 0.5 just before 15 years. Therefore, rehabilitation will require at 15 years.

34.1.2.6.5 Distress Charts









34.1.2.7 Sixth Rehabilitation – Mill & Overlay

The sixth rehabilitation was placed at 90 years with a design life of 10 years.

34.1.2.7.1 Rehabilitation Information

Rehabilitation strategy	Mill top 4 in. of AC surface course and place an AC overlay of 4 in. thick. Patching of 0.77% lane area is required in the travel lane.
Year of rehabilitation	90
Design period	10

34.1.2.7.2 Traffic Inputs

Design period (from year 90 to 100)	10
Initial two-way AADTT	29,600
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	49,083,800

34.1.2.7.3 Pavement Structure

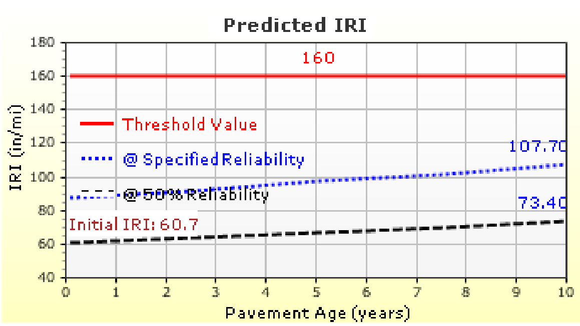
Layer Type	Material Type	Thickness (in)
AC Overlay (placed at 90 years)	HMA with PG 76-22	4
AC Binder	HMA with PG 76-22	5

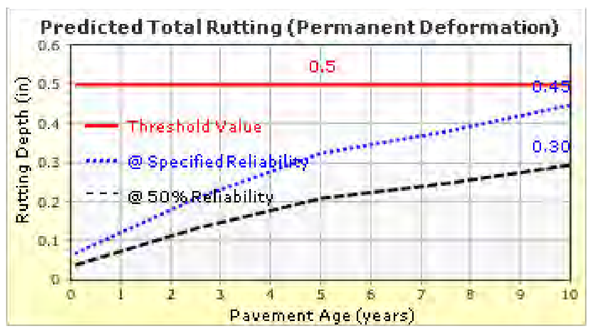
AC Base	HMA with PG 64-22	5.5
Granular Base	A-1-a	24
Subgrade	A-7-6	Semi-infinite

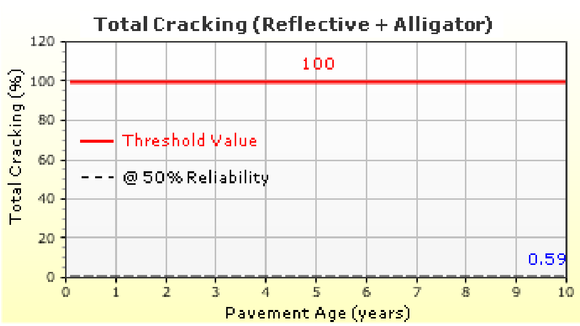
34.1.2.7.4 Distress Prediction & Reliability Summary

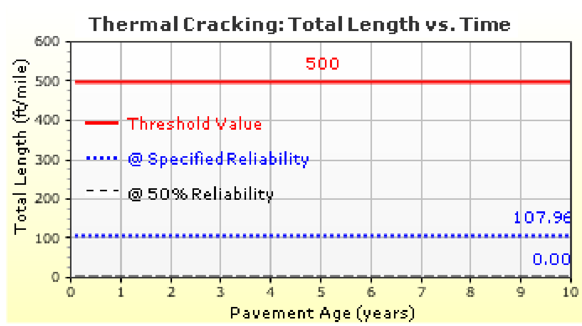
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	107.66	95.00	100.00	Pass
Permanent deformation - total pavement (in.)	0.5	0.45	95.00	98.63	Pass
Total Cracking (Reflective + Alligator) (percent)	5.00	0.59	95.00		Pass
AC thermal fracture (ft/mile)	500.00	107.96	95.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.87	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.45	95.00	98.63	Pass

34.1.2.7.5 Distress Charts









34.1.2.8 Summary of Asphalt Pavement Design and Life Cycle Rehabilitation based on DARWin-ME Predictions

Pavement life cycle activities over a 100-year analysis period include the following as determined using the DARWin-ME threshold criteria:

Year	Activity	Description
0	New construction	Place 13.5 in. AC over 24 in. crushed stone base material
20	AC overlay 1	Mill 2 in. and replace 2 in. AC OL (Patching of 0.13% lane area is required in the travel lane)
37	AC overlay 2	Mill 2 in. and replace 2 in. AC OL (Patching of 0.28% lane area is required in the travel lane)
50	AC overlay 3	Mill 7 in existing asphalt materials and replace with 7 in. AC Overlay over existing asphalt
63	AC overlay 4	Mill 3 in. and replace 3 in. AC OL (Patching of 0.52% lane area is required in the travel lane)
75	AC overlay 5	Mill 8 in existing asphalt materials and replace with 8 in. AC Overlay over existing asphalt
90	AC overlay 6	Mill 4 in. and replace 4 in. AC OL (Patching of 0.77% lane area is required in the travel lane)
Salvage at 100	End of Analysis (no salvage)	

34.2 PORTLAND CEMENT CONCRETE PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

The site conditions, design period and analysis period are exactly the same as that used for the AC design.

34.2.1 MoDOT-Based Maintenance and Rehabilitation (M&R)

The MoDOT M&R strategy is to perform concrete pavement restoration at 25 years. This includes 1.5% cracked slabs replacement in the travel lane and diamond grinding of the surface to restore IRI and remove faulting.

34.2.1.1 New Construction

34.2.1.1.1 Traffic Inputs

Design period	50
Initial two-way AADTT	8,000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	101,393,000

34.2.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	Material Type	Thickness (in)	Dowel Dia. (in)
JPCP-PCC	PCC	12	1.625
Granular Base	A-1-a	6	
Subgrade	A-7-6	Semi-infinite	

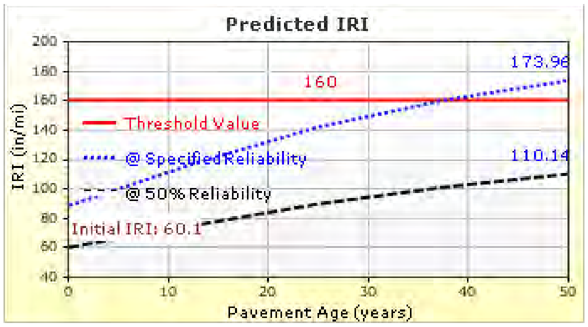
34.2.1.1.3 Distress Prediction & Reliability Summary

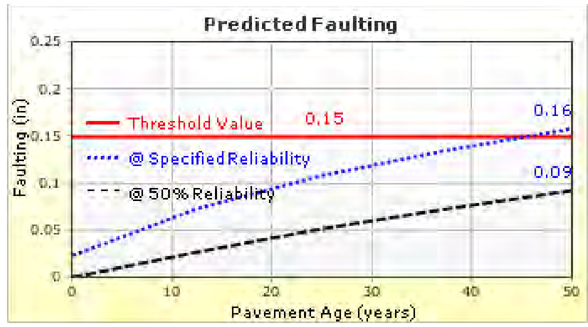
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	173.96	95.00	90.06*	Fail
Mean joint faulting (in.)	0.15	0.16	95.00	92.38**	Fail
JPCP transverse cracking (percent slabs)	10.00	6.18	95.00	99.63	Pass

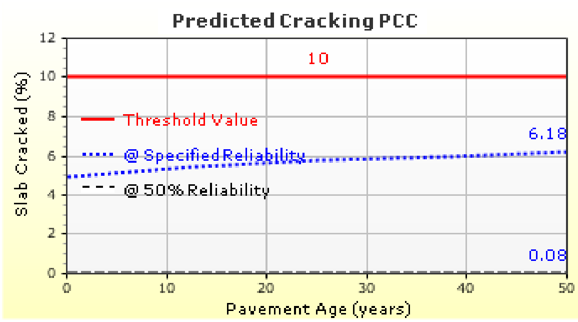
Note: * Predicted IRI at specified reliability is within 160 in/mile threshold until the placement of first restoration at 25 years.

** Predicted faulting at specified reliability is within 0.15 in. threshold until the placement of first restoration at 25 years.

34.2.1.1.4 Distress Charts







34.2.1.2 11b.PCC.A2 Summary of MoDOT Concrete Pavement Design and Life Cycle Rehabilitation

Pavement life cycle activities over a 100-year analysis period include the following as determined using the Missouri DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 12 in. PCC (with 1.625 in diameter dowel) over 6 in. crushed stone material
25	PCC Rehabilitation 1	¼ in. Diamond grinding and full depth repair (1.5% slab replacement is required in the travel lane as per MoDOT M&R strategy)
50	PCC Rehabilitation 2	¼ inch diamond grinding and full depth repair (10% slab replacement is required in the travel lane)*
70	PCC Rehabilitation 3	Removal & Replacement of JPCP
100	End of analysis period	

*Note that a higher amount of slab replacement is specified for the 50 year rehabilitation. This estimate is based on expected long term environmental impacts including PCC material durability factors and subgrade movements that would require the removal and replacement of cracked or deteriorated slabs (non-fatigue cracks).

34.2.2 DARWin-ME-Based Maintenance and Rehabilitation (M&R)

34.2.2.1 New Construction

34.2.2.1.1 Traffic Inputs

Design period	50
Initial two-way AADTT	8,000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	101,393,000

34.2.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	Material Type	Thickness (in)	Dowel Dia. (in)
JPCP-PCC	PCC	12	1.625
Granular Base	A-1-a	6	
Subgrade	A-7-6	Semi-infinite	

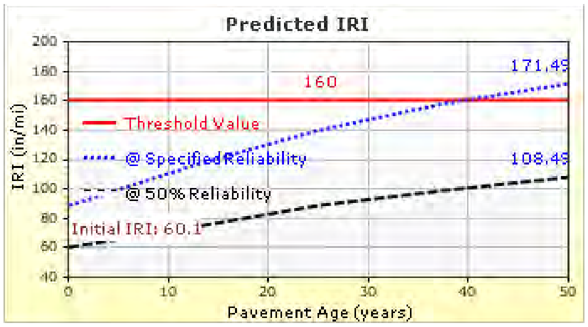
34.2.2.1.3 Distress Prediction & Reliability Summary

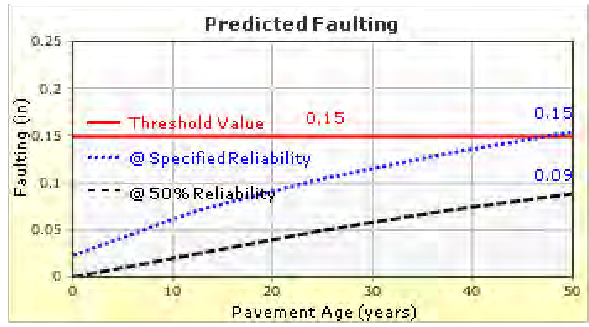
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	171.49	95.00	91.07*	Fail
Mean joint faulting (in.)	0.15	0.15	95.00	93.68**	Fail
JPCP transverse cracking (percent slabs)	10.00	5.86	95.00	99.76	Pass

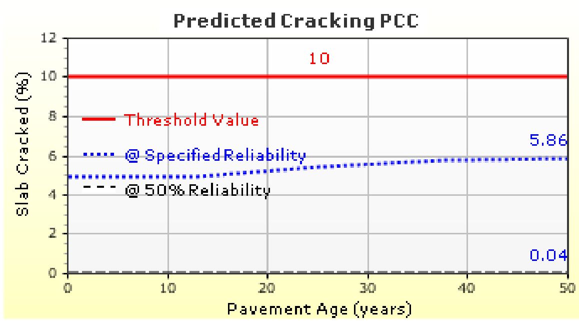
Note: * Predicted IRI at specified reliability is within 160 in/mile threshold until the placement of first restoration at 40 years.

** Predicted faulting at specified reliability is within 0.15 in. threshold until the placement of first restoration at 40 years.

34.2.2.1.4 Distress Charts







At 50 years, there is 5.86% fatigue cracking, 0.15 in faulting, and 171.49 in/mile IRI at 95% reliability. The faulting and IRI do not reach the threshold until 40 years. Thus, diamond grinding and full depth repair are the most logical M&R treatment at 40 years.

34.2.2.1.5 First Rehabilitation –Diamond Grinding & Full Depth Repair

At 40 years, all cracked slabs will be replaced. Past fatigue cracking damage will be considered in future cracking projections. A maximum JPCP restoration life of 20 years was assumed since DARWin-ME does not consider all durability related distresses that develop over time. A higher slab replacement of 10% is assumed due to long term environmental effects including PCC durability, subgrade movement, etc. The first restoration project was then run for 20 years design period.

34.2.2.1.6 Traffic Inputs

Design period (from year 40 to 60)	20
Initial two-way AADTT	17,600
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	66,084,000

34.2.2.1.7 Pavement Structure That Meets Performance & Reliability Requirements

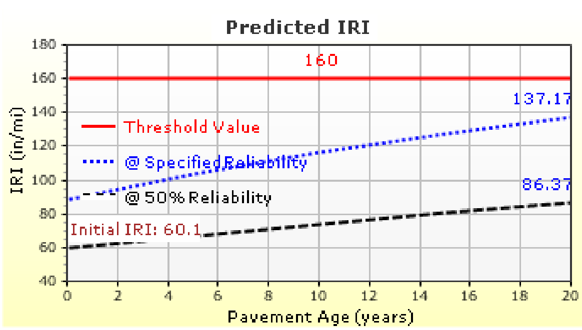
Layer Type	Material Type	Thickness (in)
JPCP-PCC	PCC	11.75*
Granular Base	A-1-a	6
Subgrade	A-7-6	Semi-infinite

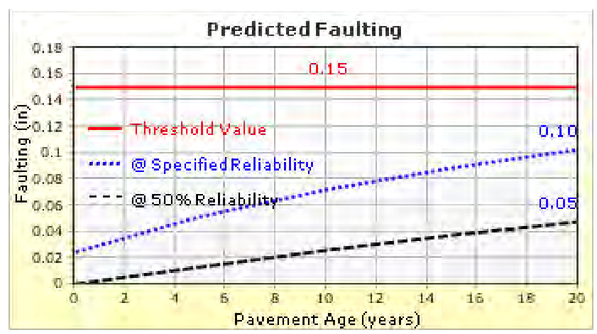
*Note: 0.25 inch slab thickness was removed by diamond grinding.

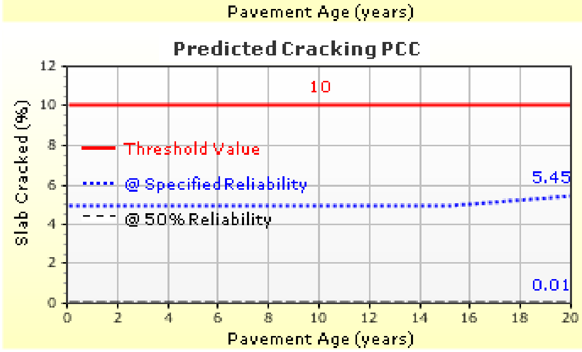
34.2.2.1.8 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	137.17	95.00	99.14	Pass
Mean joint faulting (in.)	0.15	0.10	95.00	99.90	Pass
JPCP transverse cracking (percent slabs)	10.00	5.45	95.00	99.87	Pass

34.2.2.1.9 Distress Charts







34.2.2.2 Second Rehabilitation –Diamond Grinding & Full Depth Repair

The second rehabilitation (restoration) was placed at 60 years with a design life of 15 years. A higher slab replacement of 15% is assumed due to long term environmental effects including PCC durability, subgrade movement, etc.

34.2.2.2.1 Traffic Inputs

Design period (from year 60 to 75)	15
Initial two-way AADTT	22,400
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	59,398,400

34.2.2.2.2 Pavement Structure That Meets Performance & Reliability Requirements

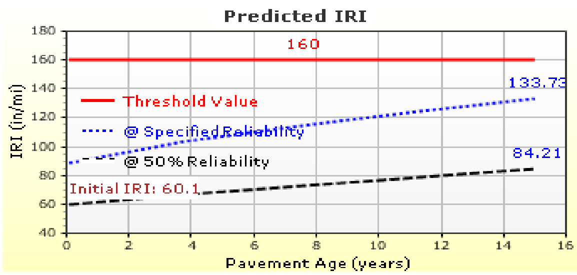
Layer Type	Material Type	Thickness (in)
JPCP-PCC	PCC	11.5*
Granular Base	A-1-a	6
Subgrade	A-7-6	Semi-infinite

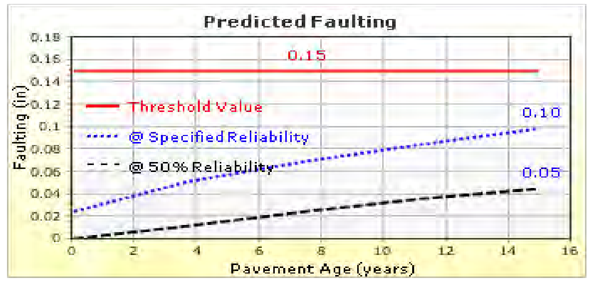
*Note: 0.25 inch slab thickness was removed by diamond grinding.

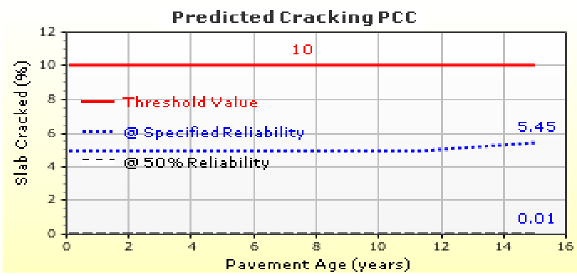
34.2.2.2.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	133.73	95.00	99.41	Pass
Mean joint faulting (in.)	0.15	0.10	95.00	99.94	Pass
JPCP transverse cracking (percent slabs)	10.00	5.45	95.00	99.87	Pass

34.2.2.2.4 Distress Charts







34.2.2.3 Third Rehabilitation –Diamond Grinding & Full Depth Repair

The third rehabilitation (restoration) was placed at 75 years with a design life of 15 years. A higher slab replacement of 20% is assumed due to long term environmental effects including PCC durability, subgrade movement, etc.

34.2.2.3.1 Traffic Inputs

Design period (from year 75 to 90)	15
Initial two-way AADTT	26,000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	68,944,600

34.2.2.3.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	**Material Type**	**Thickness (in)**
JPCP-PCC	PCC	11.25*
Granular Base	A-1-a	6
Subgrade	A-7-6	Semi-infinite

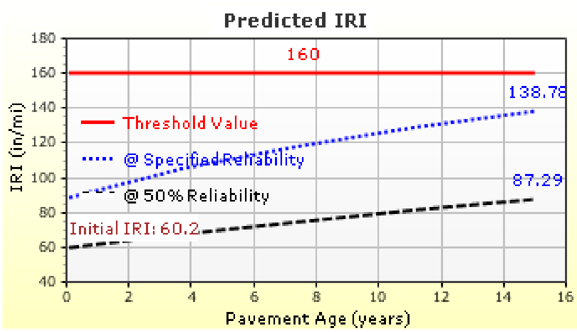
*Note: 0.25 inch slab thickness was removed by diamond grinding.

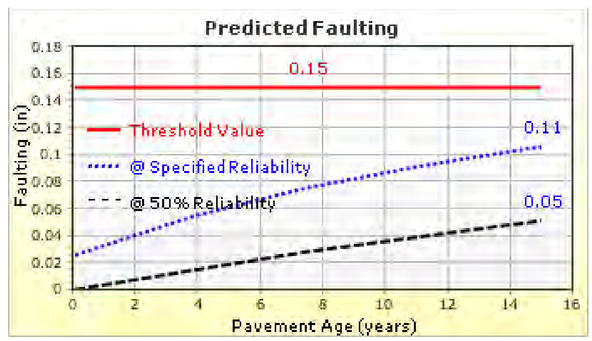
34.2.2.3.3 Distress Prediction & Reliability Summary

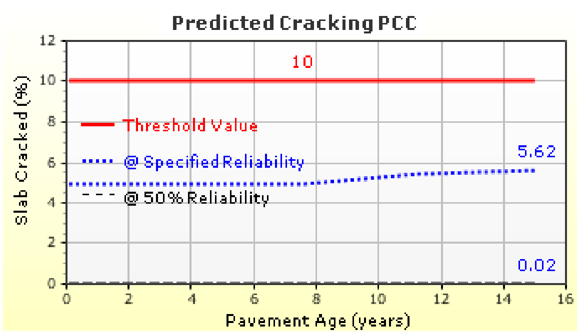
Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	

Terminal IRI (in./mile)	160.00	138.78	95.00	98.99	Pass
Mean joint faulting (in.)	0.15	0.11	95.00	99.83	Pass
JPCP transverse cracking (percent slabs)	10.00	5.62	95.00	99.83	Pass

34.2.2.3.4 Distress Charts







34.2.2.4 Fourth Rehabilitation –Diamond Grinding & Full Depth Repair

The fourth rehabilitation (restoration) was placed at 90 years with a design life of 10 years. A higher slab replacement of 30% is assumed due to long term environmental effects including PCC durability, subgrade movement, etc.

34.2.2.4.1 Traffic Inputs

Design period (from year 90 to 100)	10
Initial two-way AADTT	29,600
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	49,083,800

34.2.2.4.2 Pavement Structure That Meets Performance & Reliability Requirements

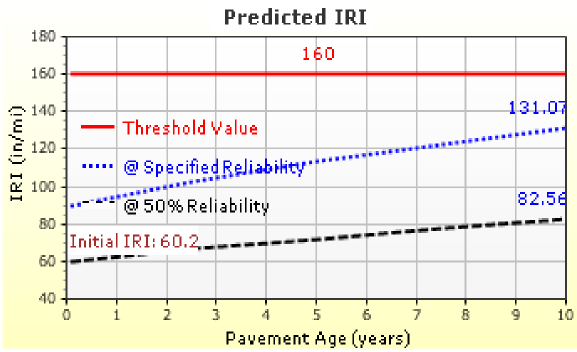
Layer Type	Material Type	Thickness (in)
JPCP-PCC	PCC	11*
Granular Base	A-1-a	6
Subgrade	A-7-6	Semi-infinite

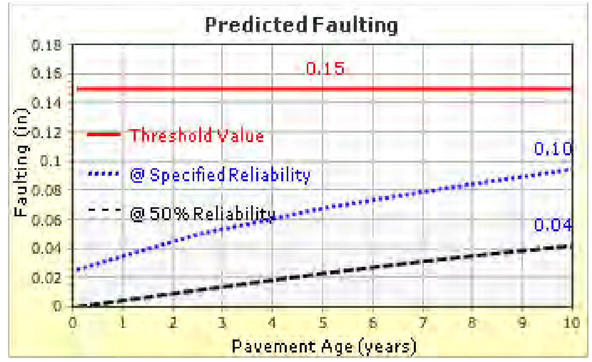
*Note: 0.25 inch slab thickness was removed by diamond grinding.

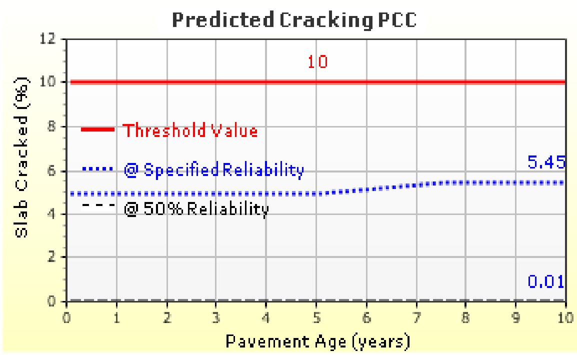
34.2.2.4.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	131.07	95.00	99.57	Pass
Mean joint faulting (in.)	0.15	0.10	95.00	99.96	Pass
JPCP transverse cracking (percent slabs)	10.00	5.45	95.00	99.87	Pass

34.2.2.4.4 Distress Charts







While the pavement passes all of the criteria at 100 years, given the long term environmental effects in this climatic zone. At 100 years, given the age and deterioration of the pavement at this time no salvage value is included (other than the normal recycling of materials).

34.2.2.5 Summary of Concrete Pavement Design and Life Cycle Rehabilitation based on DARWin-ME Predictions

Pavement life cycle activities over a 100-year analysis period include the following as determined using the DARWin-ME based thresholds:

Year	Activity	Description
0	New construction	Place 12 in. PCC (with 1.625 in diameter dowel) over 6 in. crushed stone material
40	PCC Rehabilitation 1	¼ in. Diamond grinding & Full depth repair (10% slab replacement is required in the travel lane)*
60	PCC Rehabilitation 2	¼ inch diamond grinding and full depth repair (15% slab replacement is required in the travel lane)*
75	PCC Rehabilitation 3	¼ inch diamond grinding and full depth repair (20% slab replacement is required in the travel lane)*

90	PCC Rehabilitation 4	¼ inch diamond grinding and full depth repair (30% slab replacement is required in the travel lane)*
Salvage at 100	End of Analysis (no salvage)	

*Note that a higher amount of slab replacement is specified for the 60, 75, and 90 year rehabilitations. This estimate is based on expected long term environmental impacts including PCC material durability factors and subgrade movements that would require the removal and replacement of cracked or deteriorated slabs (non-fatigue cracks).

35 Detailed Information for Cell 12

35.1 ASPHALT CONCRETE PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

35.1.1 ADOT-Based Maintenance and Rehabilitation (M&R)

35.1.1.1 New Construction

35.1.1.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	8000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period (design lane)	50,316,800

35.1.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	Material Type	Thickness (in)
AC Surface	HMA ½ in. mix with Asphalt Rubber (ARAC)	2.5
AC Binder	HMA ¾ in. mix with PG 76-16	3
AC Base	HMA ¾ in. mix with PG 64-22	8
Granular Base	A-1-a	12
Subgrade	A-2-4	Semi-infinite

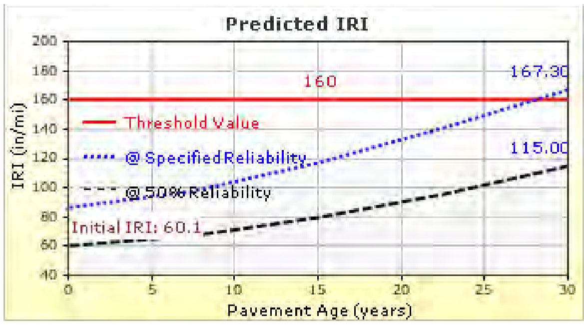
35.1.1.1.3 Distress Prediction & Reliability Summary

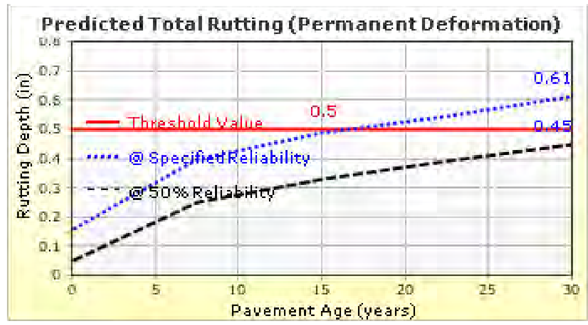
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.0	167.27	95.00	92.16*	Fail
Permanent deformation - total pavement (in.)	0.5	0.61	95.00	68.73**	Fail
AC bottom-up fatigue cracking (percent)	10.00	6.64	95.00	99.34	Pass
AC thermal fracture (ft/mile)	500.0	34.59	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.48	95.00	96.91	Pass

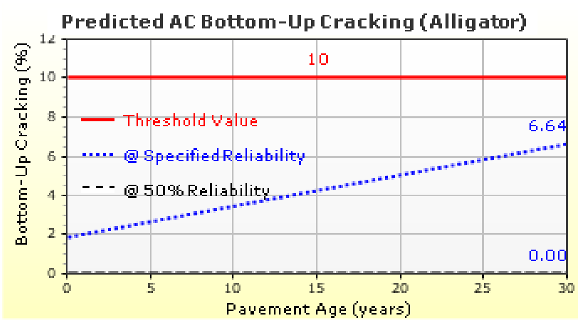
Note: * Predicted IRI at specified reliability is within 160 in/mile threshold until the placement of first rehabilitation overlay at 15 years.

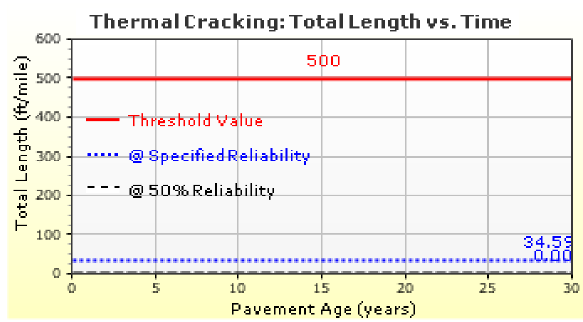
** Predicted permanent deformation at specified reliability is within 0.5 in. threshold until the placement of first rehabilitation overlay at 15 years.

35.1.1.1.4 Distress Charts









35.1.1.2 ADOT Rehabilitation – Mill & Overlay

The Arizona first rehabilitation is recommended at 15 years. The ADOT expected life of the AC overlay is 13 years. This becomes the Design Period for the next overlay. The Arizona second rehabilitation was applied at 28 years with design period of 13 years and third overlay was placed at 41 years with design period of 9 years.

35.1.1.3 Summary of Asphalt Pavement Design and Life Cycle Rehabilitation using ADOT M&R

Pavement life cycle activities over a 50-year analysis period include the following as determined using the Arizona DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 13.5 in. AC over 12 in. crushed stone base material
15	AC overlay 1	Mill 2.5 in. and replace 2.5 in. AC OL (Patching of 0.01% lane area is required in the travel lane)
28	AC overlay 2	Mill 2.5 in. and replace 2.5 in. AC OL (Patching of 0.01% lane area is required in the travel lane)
41	AC overlay 3	Mill 2.5 in. and replace 2.5 in. AC OL (Patching of 0.02% lane area is required in the travel lane)
50	End of analysis period	

35.1.2 DARWin-ME-Based Maintenance and Rehabilitation (M&R)

35.1.2.1 New Construction

35.1.2.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	8000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	50,316,800

35.1.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	Material Type	Thickness (in)
AC Surface	HMA ½ in. mix with Asphalt Rubber (ARAC)	2.5
AC Binder	HMA ¾ in. mix with PG 76-16	3
AC Base	HMA ¾ in. mix with PG 64-22	8
Granular Base	A-1-a	12
Subgrade	A-2-4	Semi-infinite

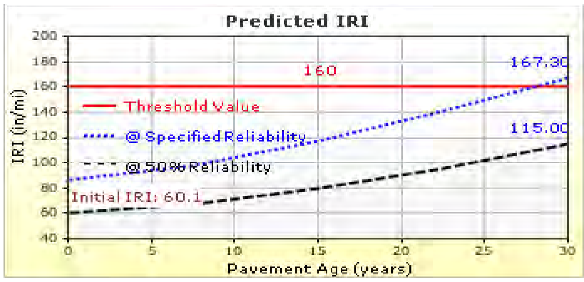
35.1.2.1.3 Distress Prediction & Reliability Summary

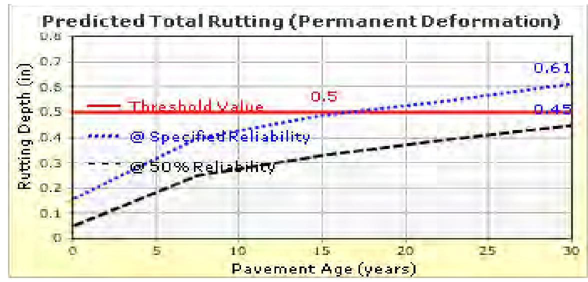
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.0	167.27	95.00	92.16*	Fail
Permanent deformation - total pavement (in.)	0.5	0.61	95.00	68.73**	Fail
AC bottom-up fatigue cracking (percent)	10.00	6.64	95.00	99.34	Pass
AC thermal fracture (ft/mile)	500.0	34.59	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.48	95.00	96.91	Pass

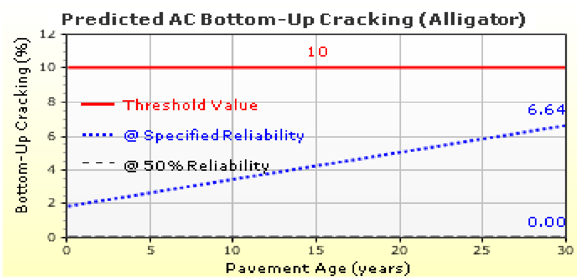
Note: * Predicted IRI at specified reliability is within 160 in/mile threshold until the placement of first rehabilitation overlay at 16 years.

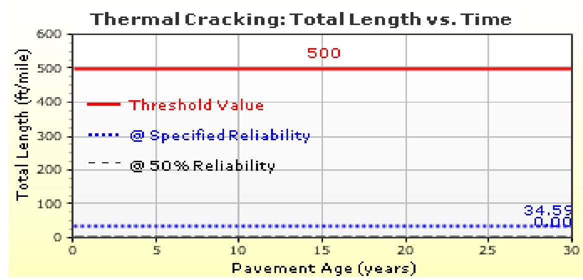
** Predicted permanent deformation at specified reliability is within 0.5 in. threshold until the placement of first rehabilitation overlay at 16 years.

35.1.2.1.4 Distress Charts









35.1.2.2 12. First Rehabilitation – Mill & Overlay

The DARWin-ME based thresholds were used to establish future rehabilitation activities. A reasonable maximum service life of 20 years for new AC (the Arizona survival shows a mean life ranging from 17 to 24 years for this climate) and 13 years for AC overlay (the Arizona survival shows a mean life of 13 years for this climate) was assumed for this climate since DARWin-ME does not consider all durability related distresses that develop over time. The first overlay project was then run for 13 years design period. The mill and overlay then starts out rutting at 0 and IRI at 60 in/mile. Fatigue damage was low but is also determined and considered in the next overlay cracking prediction.

35.1.2.2.1 Rehabilitation Information

Rehabilitation strategy	Mill top 2.5 in. of AC surface course and place an AC overlay of 2.5 in. thick. Patching of 0.01% lane area is required in the travel lane.
Year of rehabilitation	16
Design period	13

35.1.2.2.2 Traffic Inputs

Design period (from year 16 to 29)	13
Initial two-way AADTT	11,840
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	26,535,500

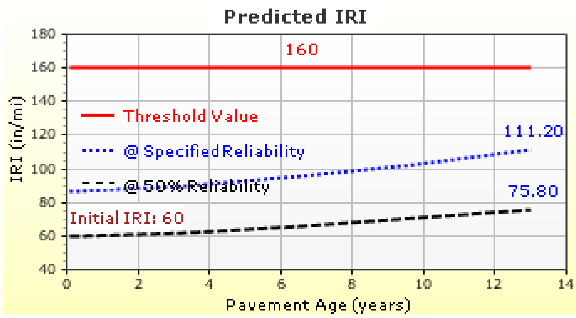
35.1.2.2.3 Pavement Structure

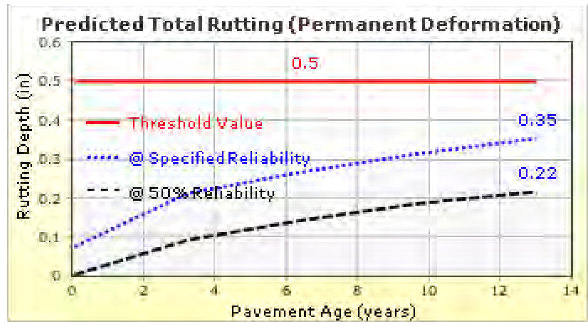
Layer Type	Material Type	Thickness (in)
AC Overlay (placed at 16 years)	HMA ½ in. mix with Asphalt Rubber (ARAC)	2.5
AC Binder	HMA ¾ in. mix with PG 76-16	3
AC Base	HMA ¾ in. mix with PG 64-22	8
Granular Base	A-1-a	12
Subgrade	A-2-4	Semi-infinite

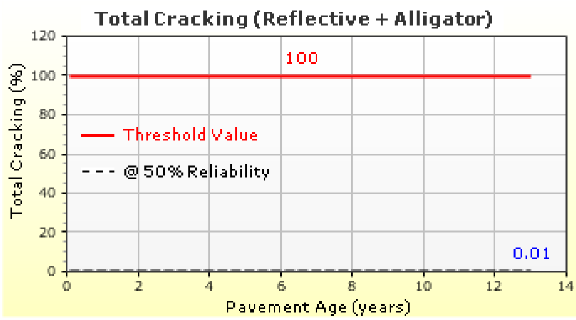
35.1.2.2.4 Distress Prediction & Reliability Summary

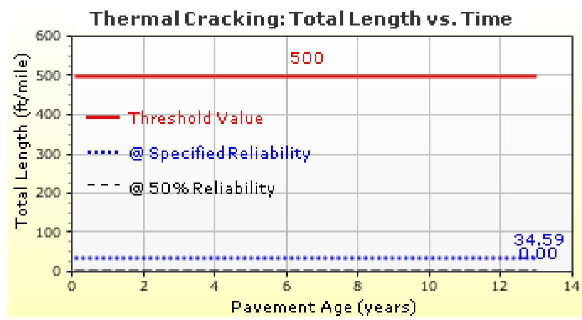
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	111.24	95.00	100.00	Pass
Permanent deformation - total pavement (in.)	0.5	0.35	95.00	99.97	Pass
Total Cracking (Reflective + Alligator) (percent)	5.00	0.01	50.00		Pass
AC thermal fracture (ft/mile)	500.00	34.59	95.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.85	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.35	95.00	99.98	Pass

35.1.2.2.5 Distress Charts









35.1.2.3 Second Rehabilitation – Mill & Overlay

The second rehabilitation was placed at 29 years with a design life of 13 years.

35.1.2.3.1 Rehabilitation Information

Rehabilitation strategy	Mill top 2.5 in. of AC surface course and place an AC overlay of 2.5 in. thick. Patching of 0.01% lane area is required in the travel lane.
Year of rehabilitation	29
Design period	13

35.1.2.3.2 Traffic Inputs

Design period (from year 29 to 42)	13
Initial two-way AADTT	14,960
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	33,528,000

35.1.2.3.3 Pavement Structure

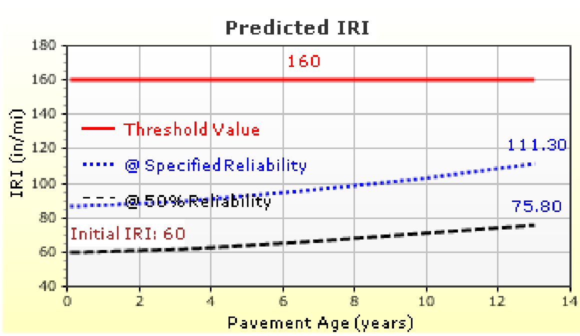
Layer Type	**Material Type**	**Thickness (in)**
AC Overlay (placed at 29 years)	HMA ½ in. mix with Asphalt Rubber (ARAC)	2.5

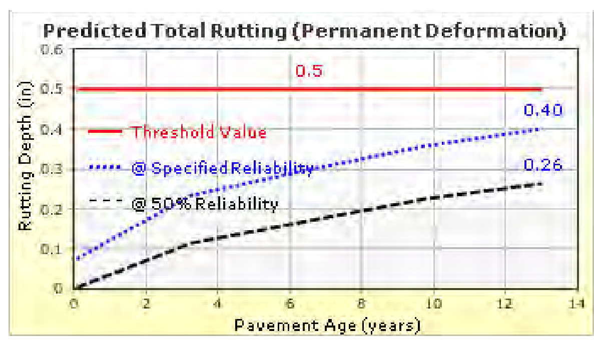
AC Binder	HMA ¾ in. mix with PG 76-16	3
AC Base	HMA ¾ in. mix with PG 64-22	8
Granular Base	A-1-a	12
Subgrade	A-2-4	Semi-infinite

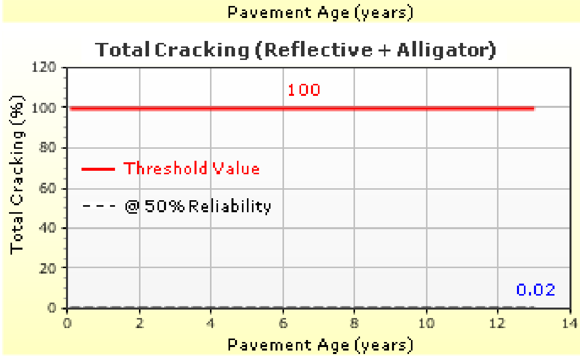
35.1.2.3.4 Distress Prediction & Reliability Summary

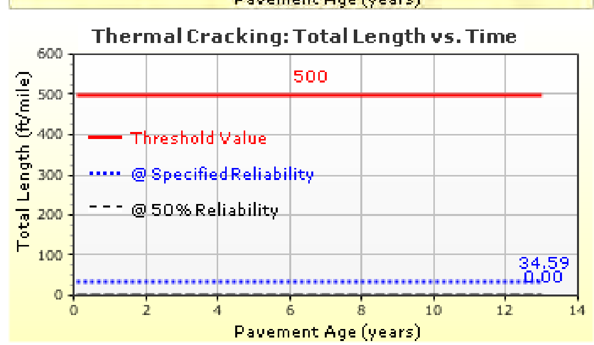
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	111.32	95.00	100.00	Pass
Permanent deformation - total pavement (in.)	0.5	0.40	95.00	99.77	Pass
Total Cracking (Reflective + Alligator) (percent)	5.00	0.02	50.00		Pass
AC thermal fracture (ft/mile)	500.00	34.59	95.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.85	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.40	95.00	99.84	Pass

35.1.2.3.5 Distress Charts









35.1.2.4 Third Rehabilitation – Mill & Overlay

The second rehabilitation was placed at 42 years with a design life of 8 years.

35.1.2.5 Rehabilitation Information

Rehabilitation strategy	Mill top 2.5 in. of AC surface course and place an AC overlay of 2.5 in. thick. Patching of 0.02% lane area is required in the travel lane.
Year of rehabilitation	42
Design period	8

35.1.2.5.1 Traffic Inputs

Design period (from year 42 to 50)	8
Initial two-way AADTT	18,080
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	23,350,800

35.1.2.5.2 Pavement Structure

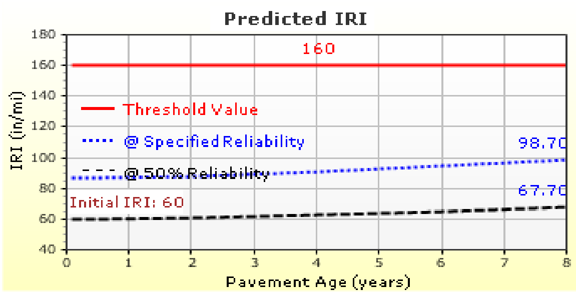
Layer Type	**Material Type**	**Thickness (in)**
AC Overlay (placed at 42 years)	HMA ½ in. mix with Asphalt Rubber (ARAC)	2.5
AC Binder	HMA ¾ in. mix with PG 76-16	3
AC Base	HMA ¾ in. mix with PG 64-22	8
Granular Base	A-1-a	12
Subgrade	A-2-4	Semi-infinite

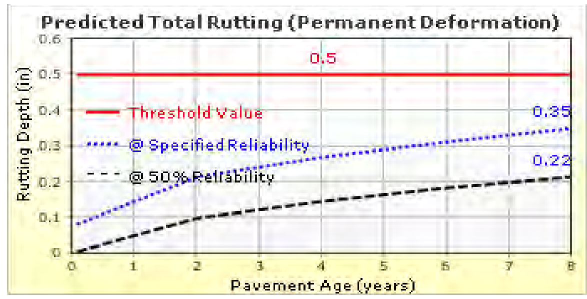
35.1.2.5.3 Distress Prediction & Reliability Summary

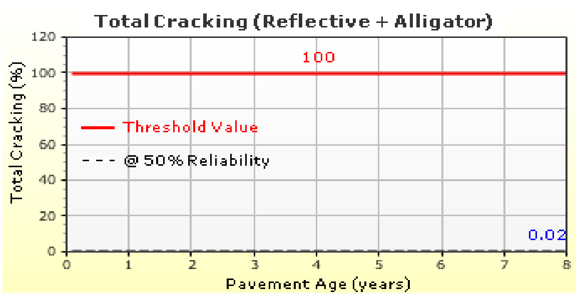
Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in./mile)	160.00	98.69	95.00	100.00	Pass
Permanent deformation - total pavement (in.)	0.5	0.35	95.00	99.98	Pass
Total Cracking (Reflective + Alligator) (percent)	5.00	0.02	50.00		Pass

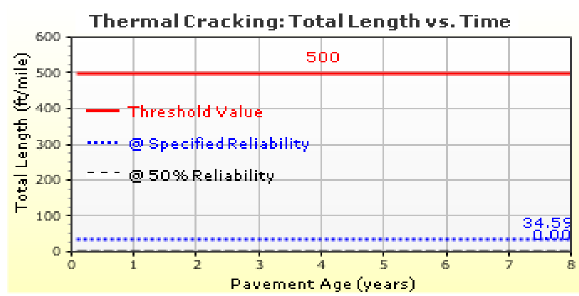
AC thermal fracture (ft/mile)	500.00	34.59	95.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.84	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.34	95.00	99.99	Pass

35.1.2.5.4 Distress Charts









35.1.2.6 Summary of Asphalt Pavement Design and Life Cycle Rehabilitation based on DARWin-ME Predictions

Pavement life cycle activities over a 50-year analysis period include the following as determined using the DARWin-ME threshold criteria:

Year	Activity	Description
0	New construction	Place 13.5 in. AC over 12 in. crushed stone base material
16	AC overlay 1	Mill 2.5 in. and replace 2.5 in. AC OL (Patching of 0.01% lane area is required in the travel lane).
29	AC overlay 2	Mill 2.5 in. and replace 2.5 in. AC OL (Patching of 0.01% lane area is required in the travel lane).
42	AC overlay 3	Mill 2.5 in. and replace 2.5 in. AC OL (Patching of 0.02% lane area is required in the travel lane).
Salvage at 50	5 years (maximum 13 years overlay life)	

35.2 PORTLAND CEMENT CONCRETE PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

The site conditions, design period and analysis period are exactly the same as that used for the AC design.

35.2.1 ADOT-Based Maintenance and Rehabilitation (M&R)

The ADOT M&R strategy is to perform concrete pavement restoration at 20 years. This includes cracked slabs replacement in the travel lane and diamond grinding of the surface to restore IRI and remove faulting.

35.2.1.1 New Construction

35.2.1.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	8000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	50,316,800

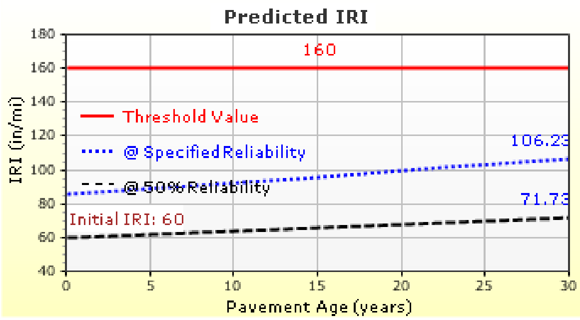
35.2.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

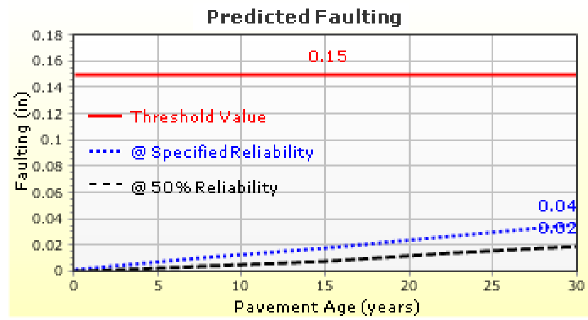
Layer Type	Material Type	Thickness (in)	Dowel Dia. (in)
JPCP-PCC	PCC	11	1.5
Granular Base	A-1-a	6	
Subgrade	A-2-4	Semi-infinite	

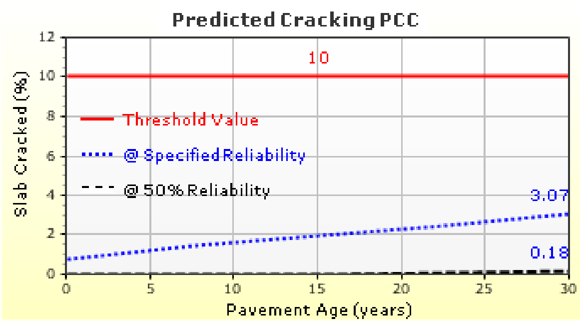
35.2.1.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	106.23	95.00	100.00	Pass
Mean joint faulting (in.)	0.15	0.04	95.00	100.00	Pass
JPCP transverse cracking (percent slabs)	10.00	3.07	95.00	100.00	Pass

35.2.1.1.4 Distress Charts







35.2.1.2 Summary of ADOT Concrete Pavement Design and Life Cycle Rehabilitation

Pavement life cycle activities over a 50-year analysis period include the following as determined using the Arizona DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 11 in. PCC (with 1.5 in diameter dowel) over 6 in. crushed stone material
20	PCC Rehabilitation 1	¼ in. Diamond grinding and full depth repair (0.08% slabs repaired in the travel lane as per ADOT M&R strategy)
40	PCC Rehabilitation 2	¼ in. Diamond grinding and full depth repair (0.23% slabs repaired in the travel lane as per ADOT M&R strategy)
50	End of analysis period	

35.2.2 DARWin-ME-Based Maintenance and Rehabilitation (M&R)

35.2.2.1 New Construction

35.2.2.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	8000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0

Percent of trucks in design lane (%)	80.0
Number of trucks over design period	50,316,800

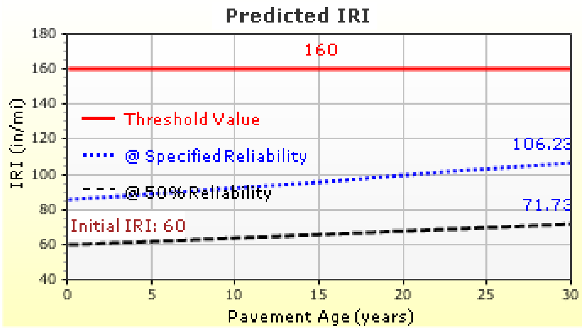
35.2.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

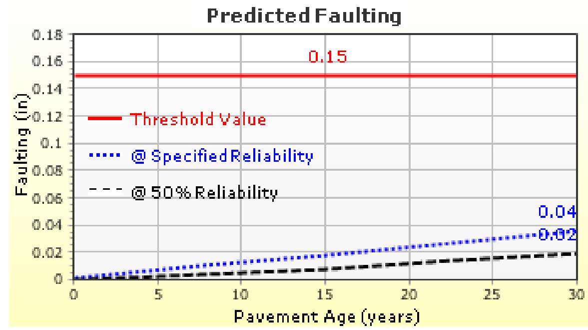
Layer Type	Material Type	Thickness (in)	Dowel Dia. (in)
JPCP-PCC	PCC	11	1.5
Granular Base	A-1-a	6	
Subgrade	A-2-4	Semi-infinite	

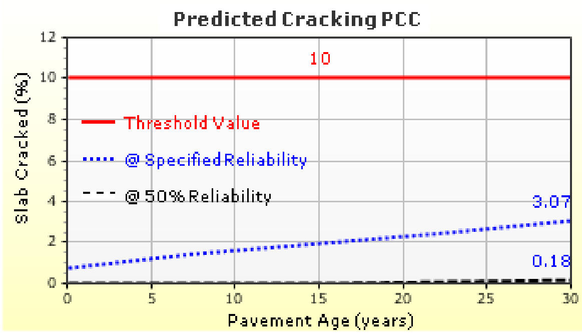
35.2.2.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	106.23	95.00	100.00	Pass
Mean joint faulting (in.)	0.15	0.04	95.00	100.00	Pass
JPCP transverse cracking (percent slabs)	10.00	3.07	95.00	100.00	Pass

35.2.2.1.4 Distress Charts







This design passes the DARWin-ME threshold criteria over 30 years. At 30 years, there is 3.07% fatigue cracking, 0.04 in faulting and 106.23 in/mile IRI at 95% reliability. Thus, diamond grinding and full depth repair are the most logical M&R treatment at 30 years.

35.2.2.2 First Rehabilitation –Diamond Grinding & Full Depth Repair

At 30 years, all cracked slabs will be replaced. Past fatigue cracking damage will be considered in future cracking projections. A maximum JPCP restoration life of 20 years was assumed since DARWin-ME does not consider all durability related distresses that develop over time. The first restoration project was then run for 20 years design period.

35.2.2.2.1 Traffic Inputs

Design period (from year 30 to 50)	20
Initial two-way AADTT	15,200
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	57,072,500

35.2.2.2.2 Pavement Structure That Meets Performance & Reliability Requirements

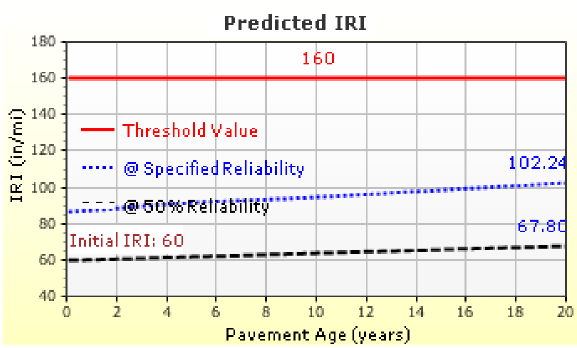
Layer Type	Material Type	Thickness (in)
JPCP-PCC	PCC	10.75*
Granular Base	A-1-a	6
Subgrade	A-2-4	Semi-infinite

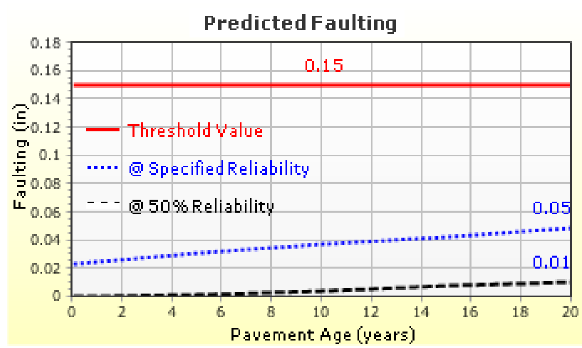
*Note: 0.25 inch slab thickness was removed by diamond grinding.

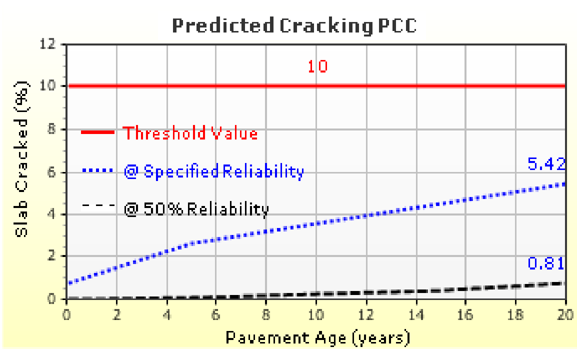
35.2.2.2.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	102.24	95.00	100.00	Pass
Mean joint faulting (in.)	0.15	0.05	95.00	100.00	Pass
JPCP transverse cracking (percent slabs)	10.00	5.42	95.00	99.95	Pass

35.2.2.2.4 Distress Charts







35.2.2.3 Summary of Concrete Pavement Design and Life Cycle Rehabilitation based on DARWin-ME Predictions

Pavement life cycle activities over a 50-year analysis period include the following as determined using the DARWin-ME based thresholds:

Year	Activity	Description
0	New construction	Place 11 in. PCC (with 1.5 in diameter dowel) over 6 in. crushed stone material
30	PCC Rehabilitation 1	¼ in. Diamond grinding & Full depth repair (0.18% slabs repaired in the travel lane)
Salvage at 50	0 years (maximum 20 years restoration life)	

36 Detailed Information for Cell 13

36.1 ASPHALT CONCRETE PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

36.1.1 CDOT-Based Maintenance and Rehabilitation (M&R)

36.1.1.1 New Construction

36.1.1.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	8000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period (design lane)	50,316,800

36.1.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	Material Type	Thickness (in)
AC Surface	HMA ½ in. mix (SMA) with PG 76-28	2
AC Binder	HMA ½ in. mix (SX 100) with PG 76-28	4
AC Base	HMA ¾ in. mix (S 100) with PG 64-22	8
Granular Base	A-1-a	4
Subbase	A-1-a	6
Subgrade	A-2-4	Semi-infinite

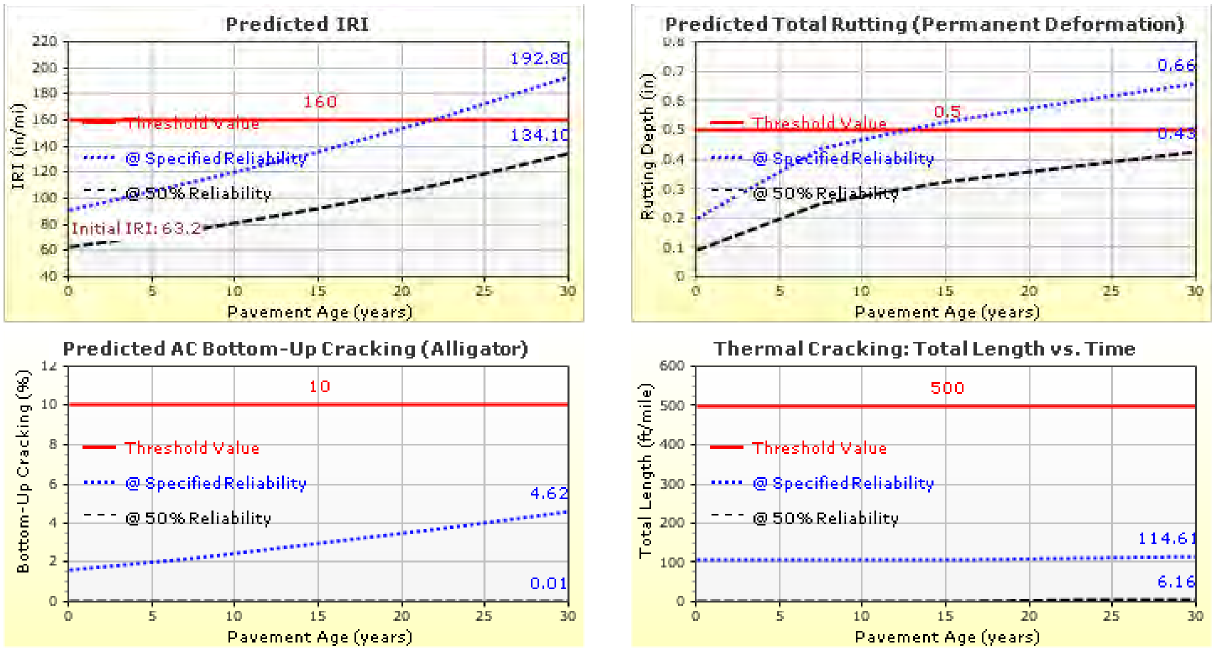
36.1.1.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.0	192.77	95.00	76.60*	Fail
Permanent deformation - total pavement (in.)	0.5	0.66	95.00	69.21**	Fail
AC bottom-up fatigue cracking (percent)	10.00	4.62	95.00	99.98	Pass
AC thermal fracture (ft/mile)	500.0	114.61	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.48	95.00	96.62	Pass

Note: * Predicted IRI at specified reliability is within 160 in/mile threshold until the placement of first rehabilitation overlay at 13 years.

** Predicted permanent deformation at specified reliability is within 0.5 in. threshold until the placement of first rehabilitation overlay at 13 years.

36.1.1.1.4 Distress Charts



36.1.1.2 CDOT Rehabilitation – Mill & Overlay

The Colorado first rehabilitation is recommended at 13 years. The CDOT expected life of the AC overlay is 13 years. This becomes the Design Period for the next overlay. The Colorado second rehabilitation was applied at 26 years with design period of 12 years and third overlay was placed at 38 years with design period of 12 years.

36.1.1.3 Summary of Asphalt Pavement Design and Life Cycle Rehabilitation using CDOT M&R

Pavement life cycle activities over a 50-year analysis period include the following as determined using the Colorado DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 14 in. AC over 4 in. aggregate base material
13	AC overlay 1	Mill 2 in. and replace 2 in. AC OL (Patching of 0.01% lane area is required in the travel lane)
26	AC overlay 2	Mill 2 in. and replace 2 in. AC OL (Patching of 0.01% lane area is required in the travel lane)
38	AC overlay 3	Mill 2 in. and replace 2 in. AC OL (Patching of 0.02% lane area is required in the travel lane)
50	End of analysis period	

36.1.2 DARWin-ME-Based Maintenance and Rehabilitation (M&R)

36.1.2.1 New Construction

36.1.2.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	8000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	50,316,800

36.1.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	**Material Type**	**Thickness (in)**
AC Surface	HMA ½ in. mix (SMA) with PG 76-28	2
AC Binder	HMA ½ in. mix (SX 100) with PG 76-28	4
AC Base	HMA ¾ in. mix (S 100) with PG 64-22	8
Granular Base	A-1-a	4
Subbase	A-1-a	6
Subgrade	A-2-4	Semi-infinite

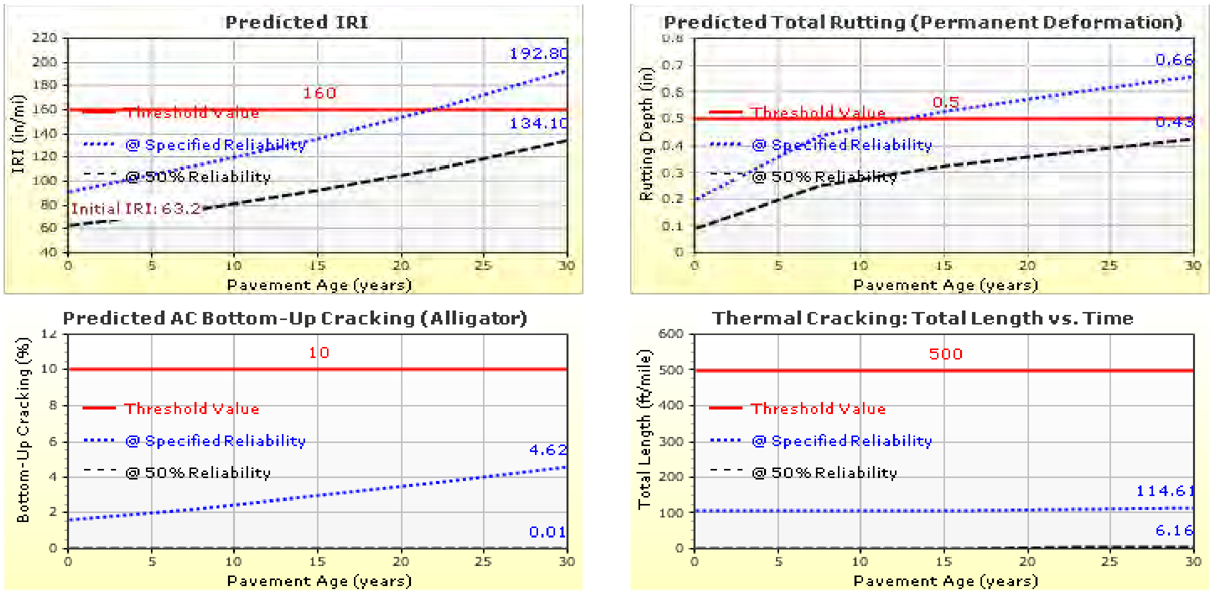
36.1.2.1.3 Distress Prediction & Reliability Summary

Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in./mile)	160.0	192.77	95.00	76.60*	Fail
Permanent deformation - total pavement (in.)	0.5	0.66	95.00	69.21**	Fail
AC bottom-up fatigue cracking (percent)	10.00	4.62	95.00	99.98	Pass
AC thermal fracture (ft/mile)	500.0	114.61	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.48	95.00	96.62	Pass

Note: * Predicted IRI at specified reliability is within 160 in/mile threshold until the placement of first rehabilitation overlay at 13 years.

** Predicted permanent deformation at specified reliability is within 0.5 in. threshold until the placement of first rehabilitation overlay at 13 years.

36.1.2.1.4 Distress Charts



36.1.2.2 First Rehabilitation – Mill & Overlay

The DARWin-ME based thresholds were used to establish future rehabilitation activities. A reasonable maximum service life of 20 years for new AC and 17 years for AC overlay was assumed for this climate since DARWin-ME does not consider all durability related distresses that develop over time. The first overlay project was then run for 17 years design period instead of typical CDOT design life. The mill and overlay then starts out rutting at 0 and IRI at 60 in/mile. Fatigue damage was low but is also determined and considered in the next overlay cracking prediction.

36.1.2.2.1 Rehabilitation Information

Rehabilitation strategy	Mill top 2 in. of AC surface course and place an AC overlay of 2 in. thick. Patching of 0.01% lane area is required in the travel lane.
Year of rehabilitation	13
Design period	17

36.1.2.2.2 Traffic Inputs

Design period (from year 13 to 30)	17
Initial two-way AADTT	11,120
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	34,247,200

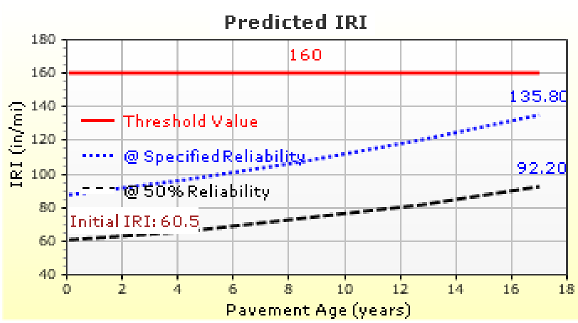
36.1.2.2.3 Pavement Structure

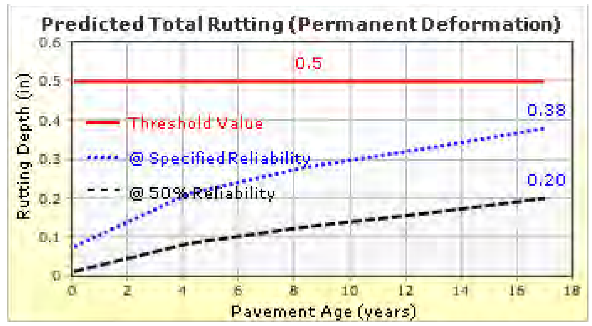
Layer Type	Material Type	Thickness (in)
AC Overlay (placed at 13 years)	HMA ½ in. mix (SMA) with PG 76-28	2
AC Existing Binder	HMA ½ in. mix (SX 100) with PG 76-28	4
AC Existing Base	HMA ¾ in. mix (S 100) with PG 64-22	8
Granular Base	A-1-a	4
Subbase	A-1-a	6
Subgrade	A-2-4	Semi-infinite

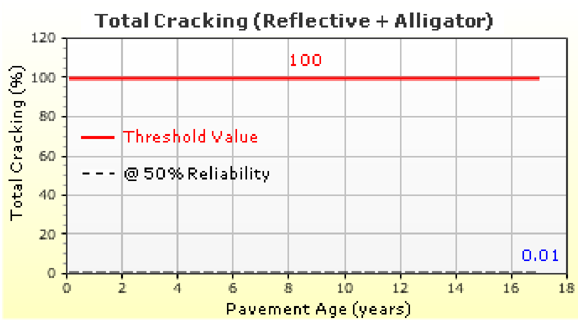
36.1.2.2.4 Distress Prediction & Reliability Summary

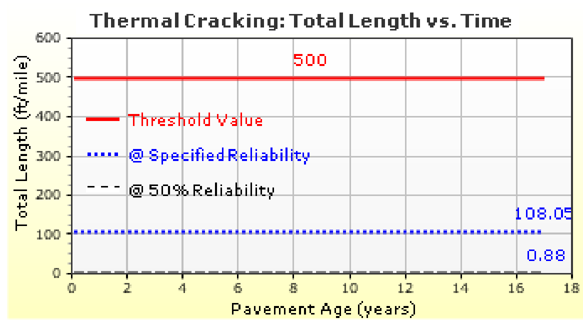
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	135.78	95.00	99.48	Pass
Permanent deformation - total pavement (in.)	0.5	0.38	95.00	99.69	Pass
Total Cracking (Reflective + Alligator) (percent)	5.00	0.01	50.00		Pass
AC thermal fracture (ft/mile)	500.00	108.05	95.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.65	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.37	95.00	99.77	Pass

36.1.2.2.5 Distress Charts









36.1.2.3 Second Rehabilitation – Mill & Overlay

The second rehabilitation was placed at 30 years with a design life of 10 years.

36.1.2.3.1 Rehabilitation Information

Rehabilitation strategy	Mill top 2 in. of AC surface course and place an AC overlay of 2 in. thick. Patching of 0.01% lane area is required in the travel lane.
Year of rehabilitation	30
Design period	10

36.1.2.3.2 Traffic Inputs

Design period (from year 30 to 40)	10
Initial two-way AADTT	15,200
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	25,205,200

36.1.2.3.3 Pavement Structure

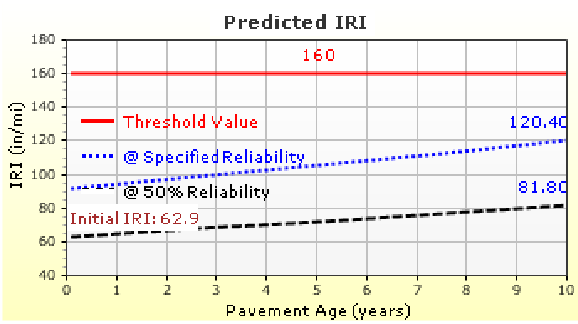
Layer Type	**Material Type**	**Thickness (in)**
AC Overlay (placed at 30 years)	HMA ½ in. mix (SMA) with PG 76-28	2
AC Existing Binder	HMA ½ in. mix (SX 100) with PG 76-28	4

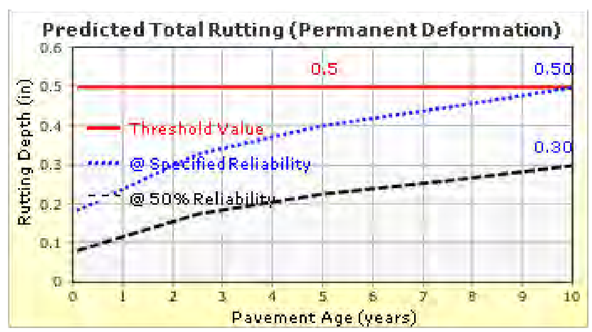
AC Existing Base	HMA ¾ in. mix (S 100) with PG 64-22	8
Granular Base	A-1-a	4
Subbase	A-1-a	6
Subgrade	A-2-4	Semi-infinite

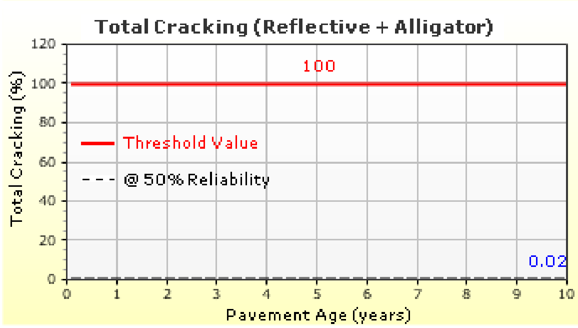
36.1.2.3.4 Distress Prediction & Reliability Summary

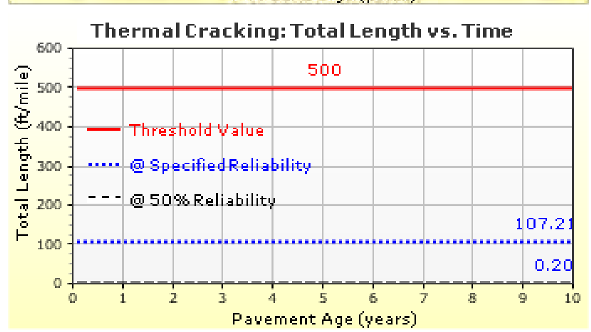
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	120.43	95.00	99.96	Pass
Permanent deformation - total pavement (in.)	0.5	0.50	95.00	95.17	Pass
Total Cracking (Reflective + Alligator) (percent)	5.00	0.02	50.00		Pass
AC thermal fracture (ft/mile)	500.00	107.21	95.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.65	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.34	95.00	99.94	Pass

36.1.2.3.5 Distress Charts









36.1.2.4 Third Rehabilitation – Mill & Overlay

The second rehabilitation was placed at 40 years with a design life of 10 years.

36.1.2.4.1 Rehabilitation Information

Rehabilitation strategy	Mill top 2 in. of AC surface course and place an AC overlay of 2 in. thick. Patching of 0.02% lane area is required in the travel lane.
Year of rehabilitation	40
Design period	10

36.1.2.4.2 Traffic Inputs

Design period (from year 40 to 40)	10
Initial two-way AADTT	17,600
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	29,184,900

36.1.2.4.3 Pavement Structure

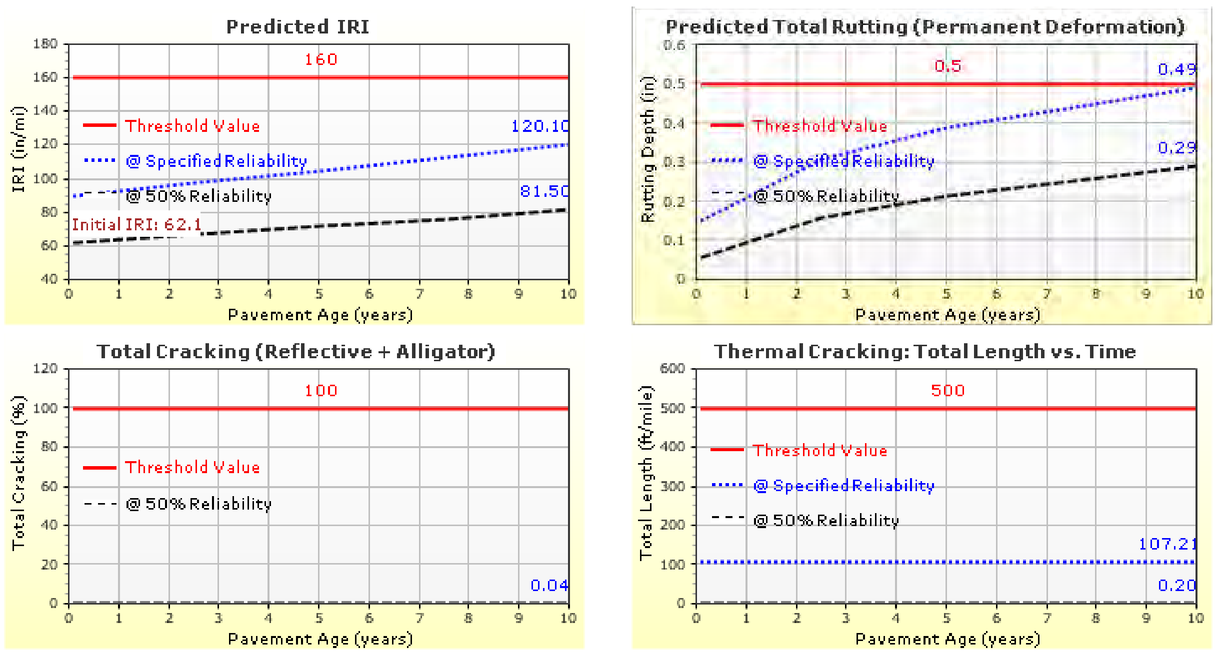
Layer Type	**Material Type**	**Thickness (in)**
AC Overlay (placed at 40 years)	HMA ½ in. mix (SMA) with PG 76-28	2
AC Existing Binder	HMA ½ in. mix (SX 100) with PG 76-28	4
AC Existing Base	HMA ¾ in. mix (S 100) with PG 64-22	8
Granular Base	A-1-a	4
Subbase	A-1-a	6
Subgrade	A-2-4	Semi-infinite

36.1.2.4.4 Distress Prediction & Reliability Summary

Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in./mile)	160.00	120.08	95.00	99.96	Pass
Permanent deformation - total pavement (in.)	0.5	0.49	95.00	95.77	Pass
Total Cracking (Reflective + Alligator) (percent)	5.00	0.04	50.00		Pass

AC thermal fracture (ft/mile)	500.00	107.21	95.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.65	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.36	95.00	99.84	Pass

36.1.2.4.5 Distress Charts



36.1.2.5 Summary of Asphalt Pavement Design and Life Cycle Rehabilitation based on DARWin-ME Predictions

Pavement life cycle activities over a 50-year analysis period include the following as determined using the DARWin-ME threshold criteria:

Year	Activity	Description
0	New construction	Place 14 in. AC over 4 in. aggregate base material
13	AC overlay 1	Mill 2 in. and replace 2 in. AC OL (Patching of 0.01% lane area is required in the travel lane).
30	AC overlay 2	Mill 2 in. and replace 2 in. AC OL (Patching of 0.01% lane area is required in the travel lane).
40	AC overlay 3	Mill 2 in. and replace 2 in. AC OL (Patching of 0.02% lane area is required in the travel lane).
Salvage at 50	0 years	

36.2 PORTLAND CEMENT CONCRETE PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

The site conditions, Design period and analysis period are exactly the same as that used for the AC design.

36.2.1 CDOT-Based Maintenance and Rehabilitation (M&R)

The CDOT M&R strategy is to perform concrete pavement restoration at 27 years. This includes 0.5% cracked slabs replacement in the travel lane and diamond grinding of the surface to restore IRI and remove faulting.

36.2.1.1 New Construction

36.2.1.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	8000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	50,316,800

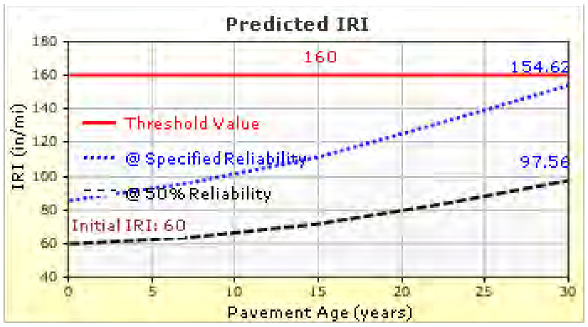
36.2.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

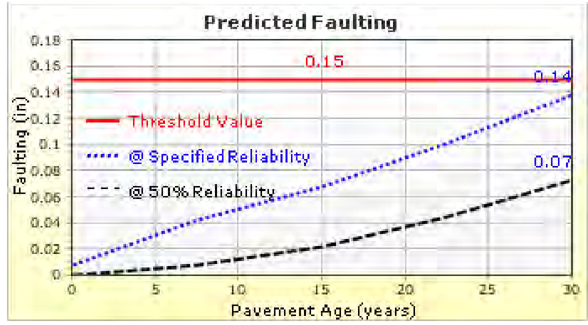
Layer Type	Material Type	Thickness (in)	Dowel Dia. (in)
JPCP-PCC	PCC	10	1.25
Granular Base	A-1-a	4	
Subgrade	A-2-4	Semi-infinite	

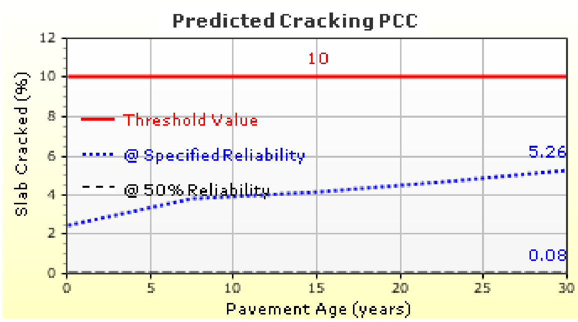
36.2.1.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	154.62	95.00	96.41	Pass
Mean joint faulting (in.)	0.15	0.14	95.00	97.37	Pass
JPCP transverse cracking (percent slabs)	10.00	5.26	95.00	99.92	Pass

36.2.1.1.4 Distress Charts







36.2.1.2 Summary of CDOT Concrete Pavement Design and Life Cycle Rehabilitation

Pavement life cycle activities over a 50-year analysis period include the following as determined using the Colorado DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 10 in. PCC (with 1.25 in diameter dowel) over 4 in. aggregate base material
27	PCC Rehabilitation 1	¼ in. Diamond grinding and full depth repair (0.5% slabs repaired in the travel lane as per CDOT M&R strategy)
50	End of analysis period	

36.2.2 DARWin-ME-Based Maintenance and Rehabilitation (M&R)

36.2.2.1 New Construction

36.2.2.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	8000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	50,316,800

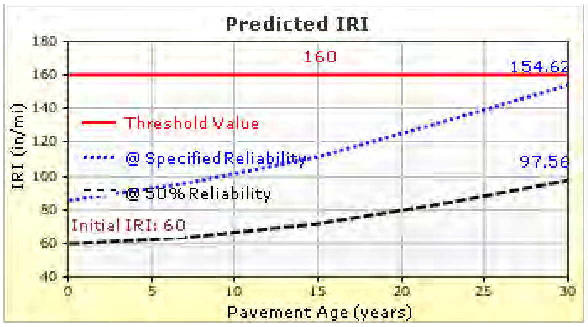
36.2.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

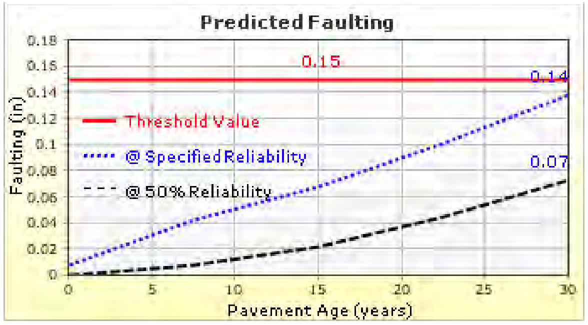
Layer Type	**Material Type**	**Thickness (in)**	**Dowel Dia. (in)**
JPCP-PCC	PCC	10	1.25
Granular Base	A-1-a	4	
Subgrade	A-2-4	Semi-infinite	

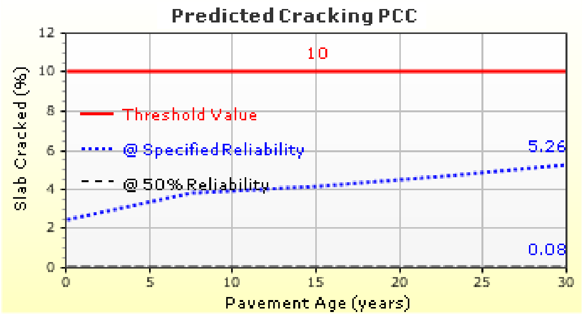
36.2.2.1.3 Distress Prediction & Reliability Summary

Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in./mile)	160.00	154.62	95.00	96.41	Pass
Mean joint faulting (in.)	0.15	0.14	95.00	97.37	Pass
JPCP transverse cracking (percent slabs)	10.00	5.26	95.00	99.92	Pass

36.2.2.1.4 Distress Charts







This design passes the DARWin-ME threshold criteria over 30 years. At 30 years, there is 5.26% fatigue cracking, 0.14 in faulting and 154.62 in/mile IRI at 95% reliability. Thus, diamond grinding and full depth repair are the most logical M&R treatment at 30 years.

36.2.2.2 First Rehabilitation –Diamond Grinding & Full Depth Repair

At 30 years, all cracked slabs will be replaced. Past fatigue cracking damage will be considered in future cracking projections. A maximum JPCP restoration life of 25 years was assumed since DARWin-ME does not consider all durability related distresses that develop over time. The first restoration project was then run for 20 years design period.

36.2.2.2.1 Traffic Inputs

Design period (from year 30 to 50)	20
Initial two-way AADTT	15,200
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	57,072,500

36.2.2.2.2 Pavement Structure That Meets Performance & Reliability Requirements

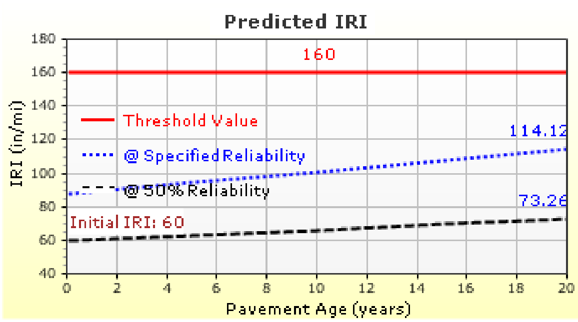
Layer Type	Material Type	Thickness (in)
JPCP-PCC	PCC	9.75*
Granular Base	A-1-a	4
Subgrade	A-2-4	Semi-infinite

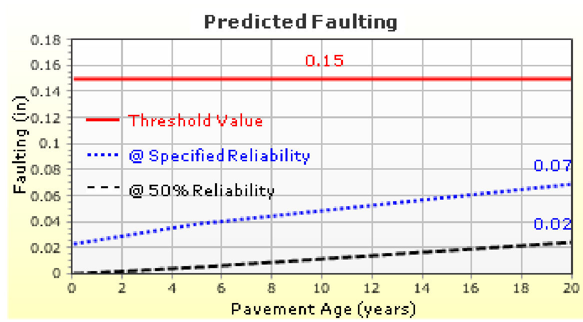
*Note: 0.25 inch slab thickness was removed by diamond grinding.

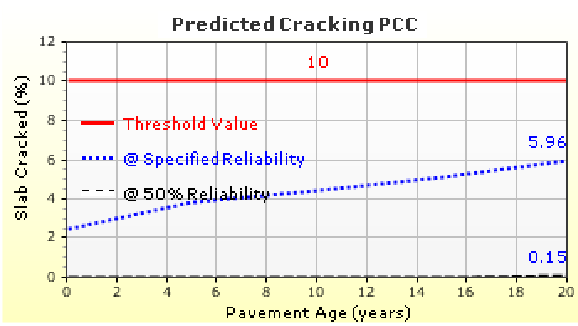
36.2.2.2.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	114.12	95.00	99.98	Pass
Mean joint faulting (in.)	0.15	0.07	95.00	100.00	Pass
JPCP transverse cracking (percent slabs)	10.00	5.96	95.00	99.74	Pass

36.2.2.2.4 Distress Charts







The pavement passes all of the criteria at 50 years. The restoration of the pavement actually will last 25 years or 5 years longer than the 50-year analysis period and some salvage value can be considered in the LCCA.

36.2.2.3 Summary of Concrete Pavement Design and Life Cycle Rehabilitation based on DARWin-ME Predictions

Pavement life cycle activities over a 50-year analysis period include the following as determined using the DARWin-ME based thresholds:

Year	Activity	Description
0	New construction	Place 10 in. PCC (with 1.25 in diameter dowel) over 4 in. aggregate base material
30	PCC Rehabilitation 1	¼ in. Diamond grinding & Full depth repair (0.08% slabs repaired in the travel lane)
Salvage at 50	5 years (maximum 25 years restoration life)	

37 Detailed Information Cell 14

37.1 ASPHALT CONCRETE PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

37.1.1 FDOT-Based Maintenance and Rehabilitation (M&R)

37.1.1.1 New Construction

37.1.1.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	8000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period (design lane)	50,316,800

37.1.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	Material Type	Thickness (in)
AC Surface	HMA ½ in. mix with PG 76-22	2.5 (including friction course FC12.5 = 0.5 in)
AC Binder	HMA ¾ in. mix with AC-30 (PG 67-22)	4
AC Base	HMA 1 in. mix with PG 64-22	6
Granular Base	Limerock Base	6
Subbase	Stabilized Embankment	12
Subgrade	A-3	Semi-infinite

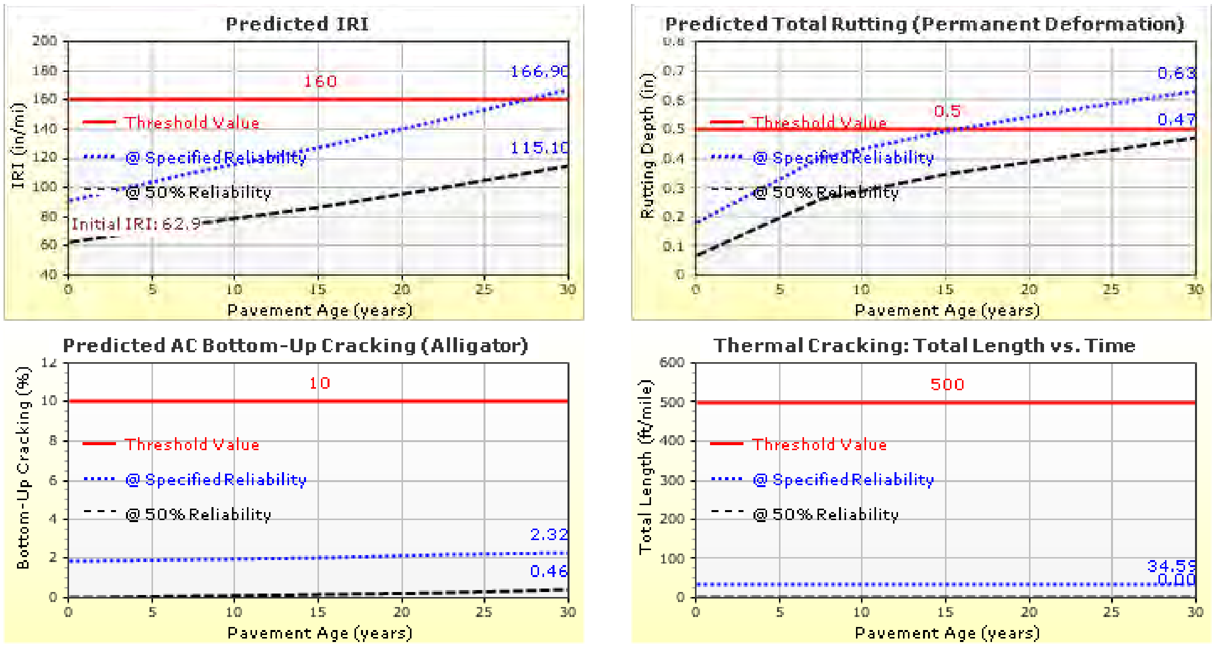
37.1.1.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.0	166.93	95.00	92.29*	Fail
Permanent deformation - total pavement (in.)	0.5	0.63	95.00	60.86**	Fail
AC bottom-up fatigue cracking (percent)	10.00	2.32	95.00	100.00	Pass
AC thermal fracture (ft/mile)	500.0	34.59	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.51	95.00	93.19**	Fail

Note: * Predicted IRI at specified reliability is within 160 in/mile threshold until the placement of first rehabilitation overlay at 14 years.

** Predicted permanent deformation at specified reliability is within 0.5 in. threshold until the placement of first rehabilitation overlay at 14 years.

37.1.1.1.4 Distress Charts



37.1.1.2 FDOT Rehabilitation – Mill & Overlay

The Florida first rehabilitation is recommended at 14 years. The FDOT expected life of the AC overlay is 14 years. This becomes the Design Period for the next overlay. The Florida second rehabilitation was applied at 28 years with design period of 12 years and third overlay was placed at 40 years with design period of 10 years.

37.1.1.3 Summary of Asphalt Pavement Design and Life Cycle Rehabilitation using FDOT M&R

Pavement life cycle activities over a 50-year analysis period include the following as determined using the Florida DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 12.5 in. AC over 6 in. limerock base material
14	AC overlay 1	Mill 2.5 in. and replace 2.5 in. AC OL (Patching of 0.161% lane area is required in the travel lane)
28	AC overlay 2	Mill 2.5 in. and replace 2.5 in. AC OL (Patching of 0.373% lane area is required in the travel lane)
40	AC overlay 3	Mill 2.5 in. and replace 2.5 in. AC OL (Patching of 0.58% lane area is required in the travel lane)
50	End of analysis period	

37.1.2 DARWin-ME-Based Maintenance and Rehabilitation (M&R)

37.1.2.1 New Construction

37.1.2.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	8000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	50,316,800

37.1.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

Layer Type	**Material Type**	**Thickness (in)**
AC Surface	HMA ½ in. mix with PG 76-22	2.5 (including friction course FC12.5 = 0.5 in)
AC Binder	HMA ¾ in. mix with AC-30 (PG 67-22)	4
AC Base	HMA 1 in. mix with PG 64-22	6
Granular Base	Limerock Base	6
Subbase	Stabilized Embankment	12
Subgrade	A-3	Semi-infinite

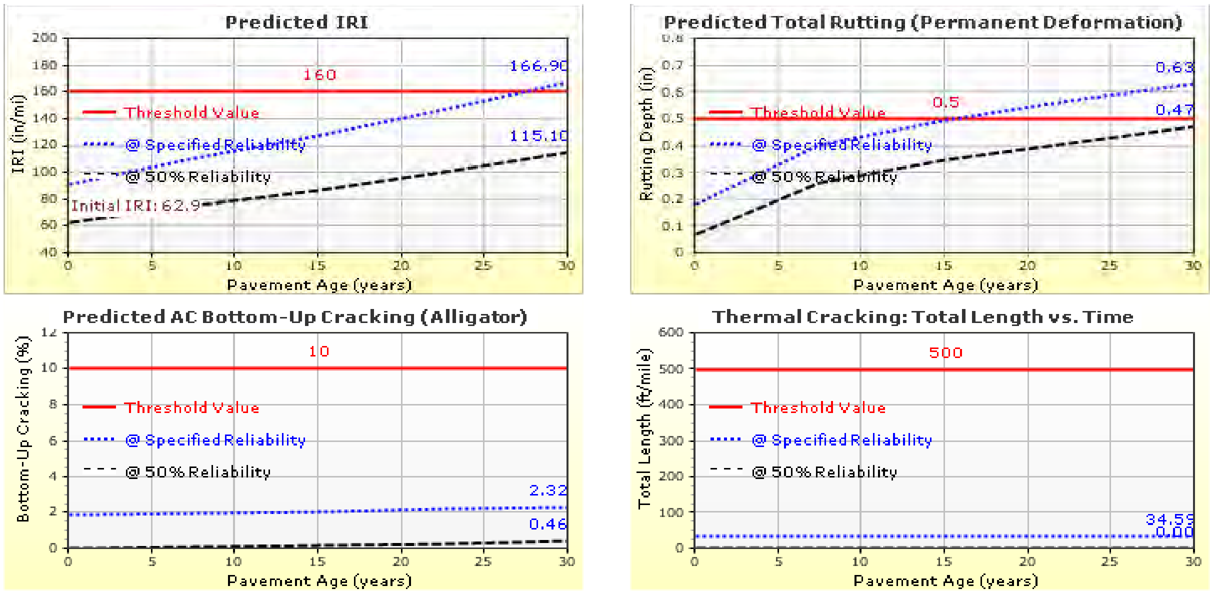
37.1.2.1.3 Distress Prediction & Reliability Summary

Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in./mile)	160.0	166.93	95.00	92.29*	Fail
Permanent deformation - total pavement (in.)	0.5	0.63	95.00	60.86**	Fail
AC bottom-up fatigue cracking (percent)	10.00	2.32	95.00	100.00	Pass
AC thermal fracture (ft/mile)	500.0	34.59	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.51	95.00	93.19**	Fail

Note: * Predicted IRI at specified reliability is within 160 in/mile threshold until the placement of first rehabilitation overlay at 16 years.

** Predicted permanent deformation at specified reliability is within 0.5 in. threshold until the placement of first rehabilitation overlay at 16 years.

37.1.2.1.4 Distress Charts



37.1.2.2 First Rehabilitation – Mill & Overlay

The DARWin-ME based thresholds were used to establish future rehabilitation activities. A reasonable maximum service life of 20 years for new AC and 17 years for AC overlay was assumed for this climate since DARWin-ME does not consider all durability related distresses that develop over time. The first overlay project was then run for 17 years design period instead of typical FDOT design life. The mill and overlay then starts out rutting at 0 and IRI at 60 in/mile. Fatigue damage was low but is also determined and considered in the next overlay cracking prediction.

37.1.2.2.1 Rehabilitation Information

Rehabilitation strategy	Mill top 2.5 in. of AC surface course and place an AC overlay of 2.5 in. thick. Patching of 0.206% lane area is required in the travel lane.
Year of rehabilitation	16
Design period	17

37.1.2.2.2 Traffic Inputs

Design period (from year 16 to 33)	17
Initial two-way AADTT	11,840
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	36,464,700

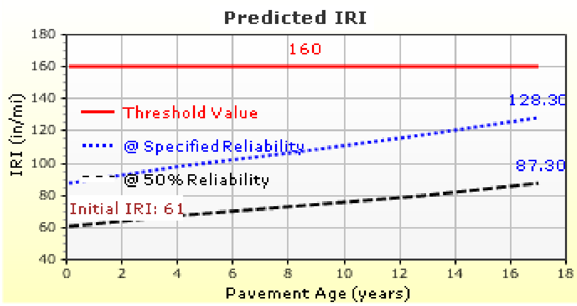
37.1.2.2.3 Pavement Structure

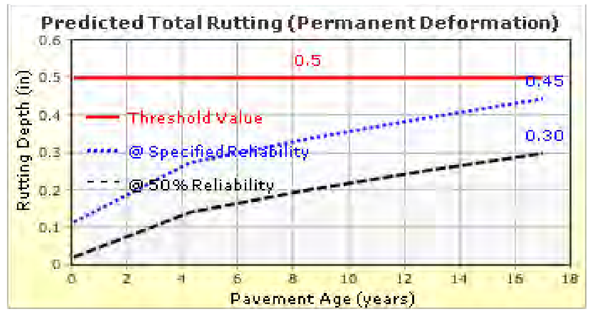
Layer Type	Material Type	Thickness (in)
AC Overlay (placed at 20 years)	HMA ½ in. mix with PG 76-22	2.5 (including friction course FC12.5 = 0.5 in)
AC Binder Existing	HMA ¾ in. mix with AC-30 (PG 67-22)	4
AC Base Existing	HMA 1 in. mix with PG 64-22	6
Granular Base	Limerock Base	6
Subbase	Stabilized Embankment	12
Subgrade	A-3	Semi-infinite

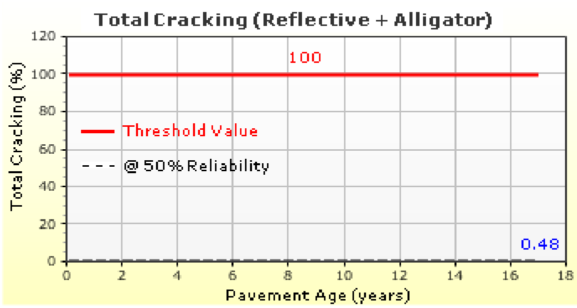
37.1.2.2.4 Distress Prediction & Reliability Summary

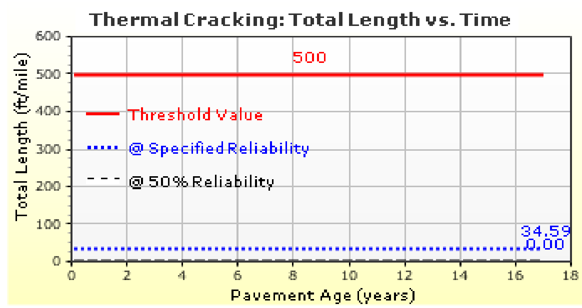
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	128.25	95.00	99.83	Pass
Permanent deformation - total pavement (in.)	0.5	0.45	95.00	98.82	Pass
Total Cracking (Reflective + Alligator) (percent)	5.00	0.48	50.00		Pass
AC thermal fracture (ft/mile)	500.00	34.59	95.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.86	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.43	95.00	99.47	Pass

37.1.2.2.5 Distress Charts









37.1.2.3 Second Rehabilitation – Mill & Overlay

The second rehabilitation was placed at 33 years with a design life of 17 years.

37.1.2.3.1 Rehabilitation Information

Rehabilitation strategy	Mill top 2.5 in. of AC surface course and place an AC overlay of 2.5 in. thick. Patching of 0.48% lane area is required in the travel lane.
Year of rehabilitation	33
Design period	17

37.1.2.3.2 Traffic Inputs

Design period (from year 33 to 50)	17
Initial two-way AADTT	15,920
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	49,030,200

37.1.2.3.3 Pavement Structure

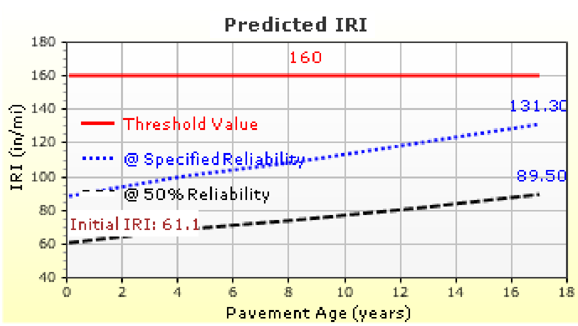
Layer Type	**Material Type**	**Thickness (in)**
AC Overlay (placed at 33 years)	HMA ½ in. mix with PG 76-22	2.5 (including friction course FC12.5 = 0.5 in)
AC Binder Existing	HMA ¾ in. mix with AC-30 (PG 67-22)	4

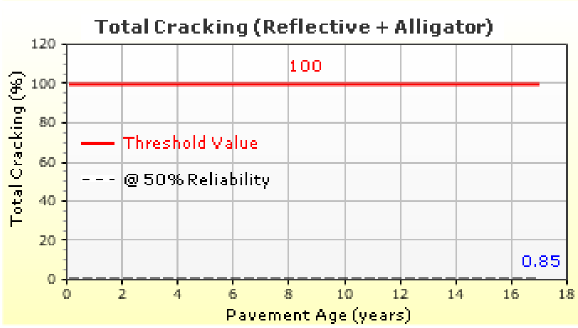
AC Base Existing	HMA 1 in. mix with PG 64-22	6
Granular Base	Limerock Base	6
Subbase	Stabilized Embankment	12
Subgrade	A-3	Semi-infinite

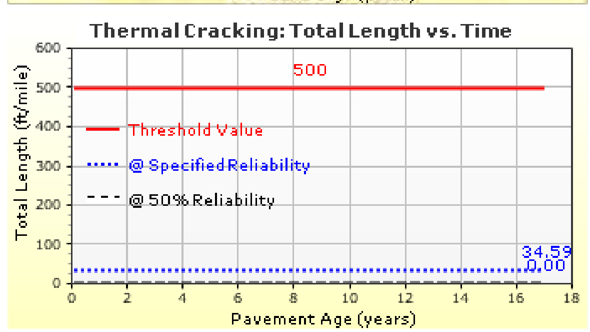
37.1.2.3.4 Distress Prediction & Reliability Summary

Distress Type	**Distress @ Specified Reliability**		**Reliability (%)**		**Criterion Satisfied?**
	Target	**Predicted**	**Target**	**Achieved**	
Terminal IRI (in./mile)	160.00	131.35	95.00	99.72	Pass
Permanent deformation - total pavement (in.)	0.5	0.50	95.00	94.59	Fail
Total Cracking (Reflective + Alligator) (percent)	5.00	0.85	50.00		Pass
AC thermal fracture (ft/mile)	500.00	34.59	95.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.86	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.5	0.48	95.00	96.61	Pass

37.1.2.3.5 Distress Charts







37.1.2.4 Summary of Asphalt Pavement Design and Life Cycle Rehabilitation based on DARWin-ME Predictions

Pavement life cycle activities over a 50-year analysis period include the following as determined using the DARWin-ME threshold criteria:

Year	Activity	Description
0	New construction	Place 12.5 in. AC over 6 in. limerock base material
16	AC overlay 1	Mill 2.5 in. and replace 2.5 in. AC OL (Patching of 0.206% lane area is required in the travel lane).
33	AC overlay 2	Mill 2.5 in. and replace 2.5 in. AC OL (Patching of 0.48% lane area is required in the travel lane).
Salvage at 50	0 years	

37.2 PORTLAND CEMENT CONCRETE PAVEMENT DESIGN & LIFE CYCLE REHABILITATION

The site conditions, Design period and analysis period are exactly the same as that used for the AC design.

37.2.1 FDOT-Based Maintenance and Rehabilitation (M&R)

The FDOT M&R strategy is to perform concrete pavement restoration at 20 years and 35 years. This includes 3% and 5% respectively, cracked slabs replacement in the travel lane and diamond grinding of the surface to restore IRI and remove faulting.

37.2.1.1 New Construction

37.2.1.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	8000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	50,316,800

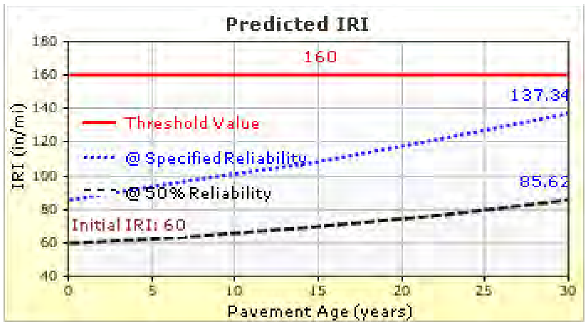
37.2.1.1.2 Pavement Structure That Meets Performance & Reliability Requirements

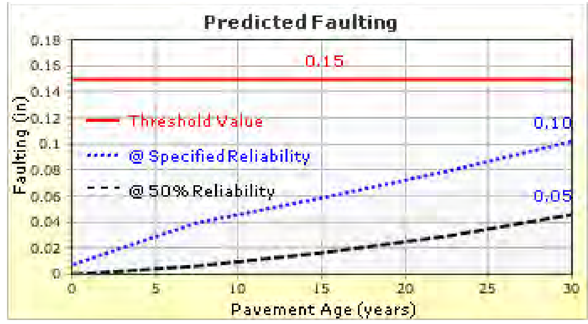
Layer Type	Material Type	Thickness (in)	Dowel Dia. (in)
JPCP-PCC	PCC	9	1.25
Treated Base	Asphalt Treated Base	4	
Subbase	Stabilized Embankment	12	
Subgrade	A-3	Semi-infinite	

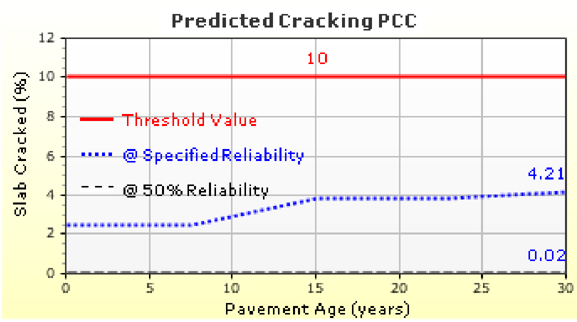
37.2.1.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	137.34	95.00	99.10	Pass
Mean joint faulting (in.)	0.15	0.10	95.00	99.87	Pass
JPCP transverse cracking (percent slabs)	10.00	4.21	95.00	100.00	Pass

37.2.1.1.4 Distress Charts







37.2.1.2 Summary of FDOT Concrete Pavement Design and Life Cycle Rehabilitation

Pavement life cycle activities over a 50-year analysis period include the following as determined using the Florida DOT pavement selection guidelines:

Year	Activity	Description
0	New construction	Place 9 in. PCC (with 1.25 in diameter dowel) over 4 in. asphalt treated base
20	PCC Rehabilitation 1	¼ in. Diamond grinding and full depth repair (3% slabs repaired in the travel lane as per FDOT M&R strategy)
35	PCC Rehabilitation 2	¼ in. Diamond grinding and full depth repair (5% slabs repaired in the travel lane as per FDOT M&R strategy)
50	End of analysis period	

37.2.2 DARWin-ME-Based Maintenance and Rehabilitation (M&R)

37.2.2.1 New Construction

37.2.2.1.1 Traffic Inputs

Design period	30
Initial two-way AADTT	8000
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	50,316,800

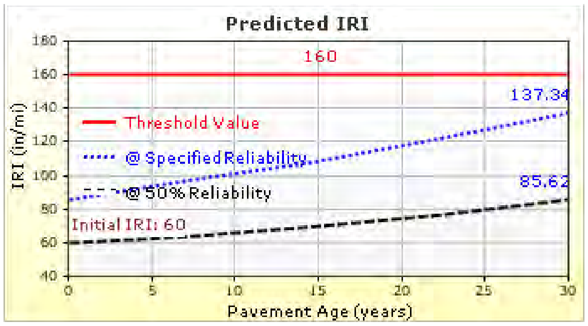
37.2.2.1.2 Pavement Structure That Meets Performance & Reliability Requirements

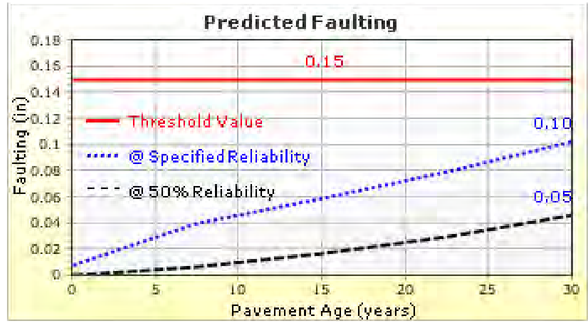
Layer Type	Material Type	Thickness (in)	Dowel Dia. (in)
JPCP-PCC	PCC	9	1.25
Treated Base	Asphalt Treated Base	4	
Subbase	Stabilized Embankment	12	
Subgrade	A-3	Semi-infinite	

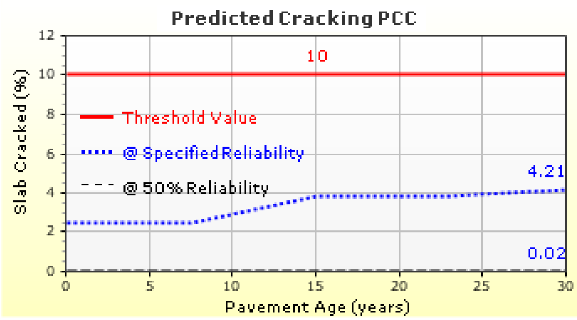
37.2.2.1.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	137.34	95.00	99.10	Pass
Mean joint faulting (in.)	0.15	0.10	95.00	99.87	Pass
JPCP transverse cracking (percent slabs)	10.00	4.21	95.00	100.00	Pass

37.2.2.1.4 Distress Charts







This design passes the DARWin-ME threshold criteria over 30 years. At 30 years, there is 4.21% fatigue cracking, 0.10 in faulting and 137.34 in/mile IRI at 95% reliability. Thus, diamond grinding and full depth repair are the most logical M&R treatment at 30 years.

37.2.2.2 First Rehabilitation –Diamond Grinding & Full Depth Repair

At 30 years, all cracked slabs will be replaced. Past fatigue cracking damage will be considered in future cracking projections. A maximum JPCP restoration life of 25 years was assumed since DARWin-ME does not consider all durability related distresses that develop over time. The first restoration project was then run for 20 years design period.

37.2.2.2.1 Traffic Inputs

Design period (from year 30 to 50)	20
Initial two-way AADTT	15,200
Number of lanes in design direction	3
Percent of trucks in design direction (%)	50.0
Percent of trucks in design lane (%)	80.0
Number of trucks over design period	57,072,500

37.2.2.2.2 Pavement Structure That Meets Performance & Reliability Requirements

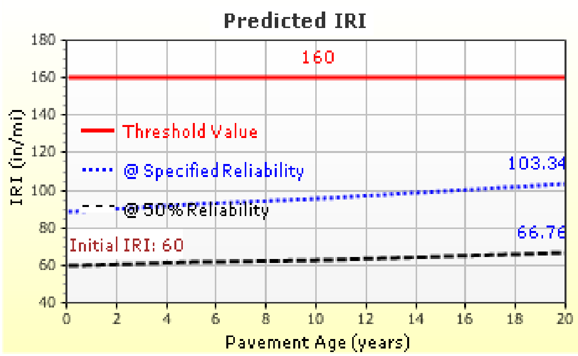
Layer Type	Material Type	Thickness (in)
JPCP-PCC	PCC	8.75*
Treated Base	Asphalt Treated Base	4
Subbase	Stabilized Embankment	12
Subgrade	A-3	Semi-infinite

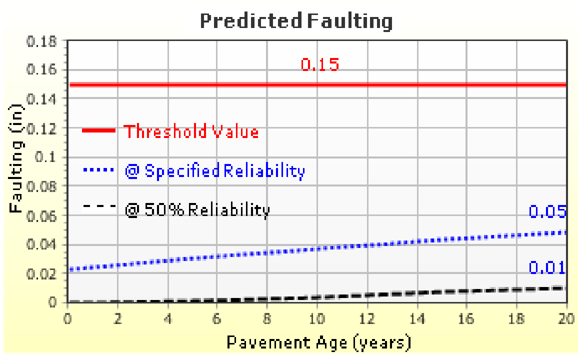
*Note: 0.25 inch slab thickness was removed by diamond grinding.

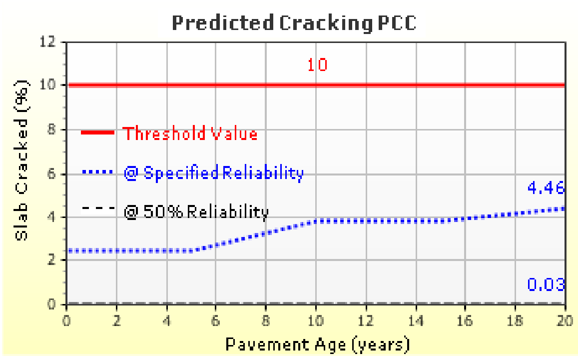
37.2.2.2.3 Distress Prediction & Reliability Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	103.34	95.00	100.00	Pass
Mean joint faulting (in.)	0.15	0.05	95.00	100.00	Pass
JPCP transverse cracking (percent slabs)	10.00	4.46	95.00	99.99	Pass

37.2.2.2.4 Distress Charts







The pavement passes all of the criteria at 50 years. The restoration of the pavement actually will last 25 years or 5 years longer than the 50-year analysis period and some salvage value can be considered in the LCCA.

37.2.2.3 Summary of Concrete Pavement Design and Life Cycle Rehabilitation based on DARWin-ME Predictions

Pavement life cycle activities over a 50-year analysis period include the following as determined using the DARWin-ME based thresholds:

Year	Activity	Description
0	New construction	Place 9 in. PCC (with 1.25 in diameter dowel) over 4 in. asphalt treated base
30	PCC Rehabilitation 1	¼ in. Diamond grinding & Full depth repair (0.02% slabs repaired in the travel lane)
Salvage at 50	5 years (maximum 25 years restoration life)	