

# **OPTIMIZING DESIGN USING AASHTO PAVEMENT ME**

**Feng Mu, PhD**

**Arizona Pavement and Materials Conference  
November, 2016**

# OUTLINE

1. AASHTO Pavement ME

2. How to Establish Inputs

3. Optimize the Design

# PAVEMENT ME IS THE MOST ADVANCED DESIGN PROCEDURE

Covers a wide range of applications, including nearly all new & rehabilitation options  
Can account of new and diverse materials and various failure mechanisms

## New Pavement

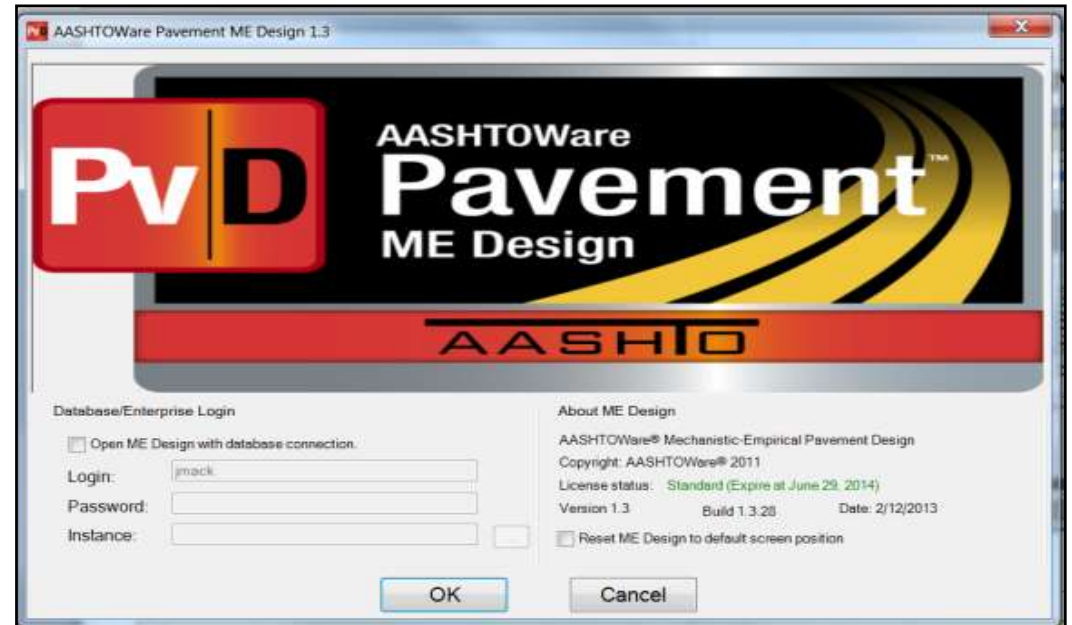
- Asphalt Concrete (AC)
- Jointed Plain Concrete Pavement (JPCP)
- Continuously Reinforced Concrete Pavement (CRCP)
- Semi-Rigid Pavement

## Overlays

- AC over AC (w/ & w/o seal coat/interlayer)
- AC over Semi-Rigid
- AC over JPCP (w/ & w/o fracture)
- AC over CRCP
- Bonded PCC over JPCP
- Bonded PCC over CRCP
- Unbound PCC over JPCP
- Unbound PCC over CRCP
- JPCP over AC
- CRCP over AC
- SJPCP over AC

## Restoration

- JPCP Restoration



Most Recent Version 2.3.1 (Revision 66, as of Oct 2016)

Available from AASHTO

<http://www.aashtoware.org/Pavement/Pages/default.aspx>

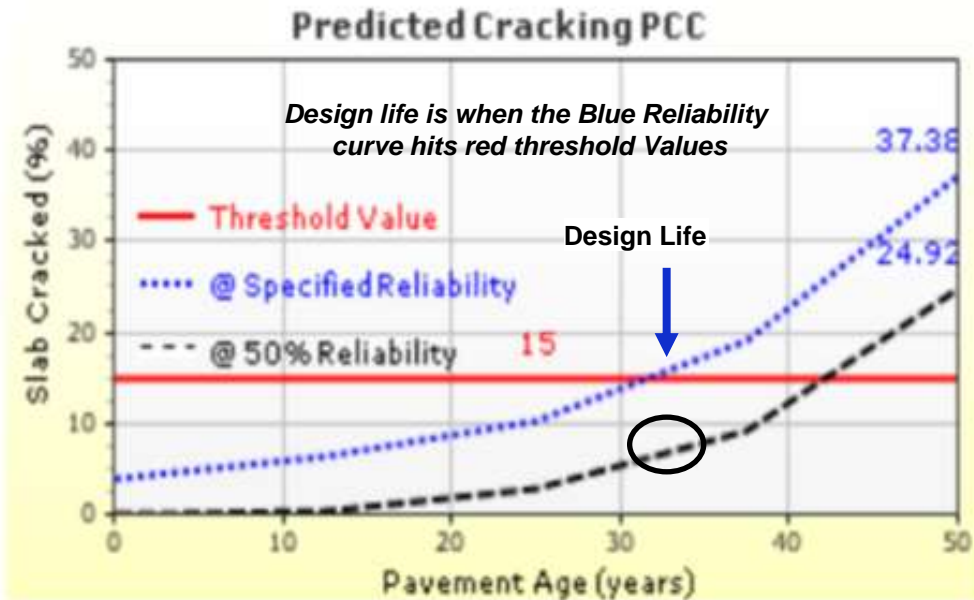
Individual License Cost = \$5,500 / year

Site License Costs = \$22,000 to \$44,000 / year

# PAVEMENT ME PROVIDES PERFORMANCE ESTIMATES

All other procedures (e.g. StreetPave) only provide thickness

## Pavement ME Performance Curve



**Red Line - Defined Distress Limit.** When major rehabilitation is needed (i.e. patching & DG or overlay).

**Black Dashed Line -** The actual (most likely) level of distresses predicted

**Blue Dotted Line -** The predicted distresses at the given reliability level (i.e. 90%). Designs are based on when this line hits the defined distress limit

*Design life is when the Blue Reliability curve hits red Predefined Distress level*

## Pavement ME Concrete Distresses Predicted



**Bottom up & Top Down Cracking (JPCP Only)**



**Faulting (JPCP Only)**



**Punchout (CRCP Only)**

- International Roughness index (IRI) – Smoothness

### Other precursors to distresses

- Cumulative damage → Cracking
- Load transfer → Faulting (JPCP) or punchouts (CRCP)
- Crack Spacing → Punchouts

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# PAVEMENT ME CONTAINS OVER 200 INPUT VARIABLES

broken down into five basic categories (most can use default values)

## Design Categories

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- 1 General information
  - Site/project Identification
  - Analysis parameters
- 2 Traffic
- 3 Climate
- 4 Design features
  - Layer definition & material properties
  - Drainage & surface properties
- 5 Calibration

Inputs are based on a Hierarchical levels (Level 1, 2 or 3)

Level	Input Values	Knowledge of Parameters
1	Segment or Project Specific Data (AVC, WIM, vehicle counts, soil properties, concrete and other material properties, etc)	Good
2	Regional/Statewide Data	Fair
3	National Data, Educated Guess based on local experience	Poor

It also helps knowing which inputs are the most sensitive/important and the difference between design variables and semi-constants

# KEY TRAFFIC INPUTS ARE TRUCK TRAFFIC, GROWTH RATE AND TTC GROUPS

**Truck traffic on the design lane**

- Number of lanes: 2
- Percent trucks in design dir: 50
- Percent trucks in design lan: 95
- Operational speed (mph): 60

**Vehicle Configuration**

- Tire pressure (psi): 120
- Tandem axle spacing (in): 51.6
- Tridem axle spacing (in): 49.2
- Quad axle spacing (in): 49.2
- Mean wheel location (in): 18
- Traffic wander standard dev: 10
- Design lane width (ft): 12
- Average spacing of short ax: 12
- Average spacing of medium: 15
- Average spacing of long ax: 18
- Percent trucks with short ax: 17
- Percent trucks with medium: 22
- Percent trucks with long ax: 61

**Annual growth rate**

Vehicle Class	Distribution (%)	Growth Rate (%)	Growth Function
Class 4	3.3	3	Linear
Class 5	34	3	Linear
Class 6	11.7	3	Linear
Class 7	1.6	3	Linear
Class 8	9.9	3	Linear

**Monthly and hourly distr. - good default**

Month	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10
Jan	1	1	1	1	1	1	1
Febr...	1	1	1	1	1	1	1

Time of Day	Percent
12:00 ...	2.3
1:00 am	2.3
2:00 am	2.3
3:00 am	2.3
4:00 am	2.3
5:00 am	2.3
6:00 am	5
7:00 am	5
8:00 am	5
9:00 am	5.9
10:00 ...	5.9
11:00 ...	5.9
12:00 ...	5.9
1:00 pm	5.9
2:00 pm	5.9
3:00 pm	5.9
4:00 pm	4.6
5:00 pm	4.6
6:00 pm	4.6
7:00 pm	4.6
8:00 pm	3.1
9:00 pm	3.1

**Axle spectrum - already grouped**

Month	Class	Total	3000	4000	5000	6000	7000	8000	9000
January	4	100	1.8	0.96	2.91	3.99	6.8	11.47	11.3
January	5	100	10.05	13.21	16.42	10.61	9.22	8.27	7.12
January	6	100	3.45	3.95	6.7	8.45	11.85		
January	7	100	2.42	2.7	3.21	5.81	5.26		
January	8	100	7.84	6.99	7.99	9.63	9.93		
January	9	100	2.84	3.53	4.93	8.43	13.67		
January	10	100	3.64	1.24	2.36	3.38	5.18	8.35	13.85
January	11	100	3.55	2.91	5.19	5.27	6.32	6.96	8.08
January	12	100	6.68	2.29	4.87	5.86	5.97	8.86	9.58
January	13	100	8.88	2.67	3.81	5.23	6.03	8.1	8.35

# THREE OPTIONS FOR CLIMATIC INPUTS

## 1. Drop-down options for major US and Canadian cities

**Hourly climatic parameters**

Date/Hour	Temperature (deg F)	Wind Speed (mph)	Sunshine (%)	Precipitation (in.)	Humidity (%)	Water Table (ft)
7/1/1996 12:00:00	81	3	100	0	82	10
7/1/1996 1:00:00	81	3	100	0	82	10
7/1/1996 2:00:00	81	3	100	0	82	10
7/1/1996 3:00:00	81	0	75	0	79	10
7/1/1996 4:00:00	79	3	50	0	90	10
7/1/1996 5:00:00	78.1	0	50	0	93	10
7/1/1996 6:00:00	82	0	50	0	82	10
7/1/1996 7:00:00	84	5	100	0	74	10
7/1/1996 8:00:00	84	3	75	0	74	10
7/1/1996 9:00:00	87.1	3	75	0	67	10
7/1/1996 10:00:00	87.1	5	75	0	70	10
7/1/1996 11:00:00	87.1	5	100	0	67	10
7/1/1996 12:00:00	89.1	3	100	0.08	63	10
7/1/1996 1:00:00	89.1	4	100	0	63	10
7/1/1996 2:00:00	87.1	0	50	0	65	10
7/1/1996 3:00:00	86	0	0	0	67	10
7/1/1996 4:00:00	84	0	25	0	77	10
7/1/1996 5:00:00	84	0	50	0	77	10
7/1/1996 6:00:00	82.9	3	50	0	79	10
7/1/1996 7:00:00	79	0	25	0	94	10
7/1/1996 8:00:00	82	3	100	0	82	10
7/1/1996 9:00:00	82.9	0	100	0	79	10
7/1/1996 10:00:00	82.9	3	100	0	74	10
7/1/1996 11:00:00	82	0	100	0	77	10
7/2/1996 12:00:00	82	3	100	0	77	10

Climate station selected from hourly climatic database (optional)



# OPTION 2. WEATHER FILES FOR 2514 LTPP PROJECTS

## From LTPP InfoPave (US and Canada only)

Feng Mu | Sign Out | My LTPP | Data Bucket (0) | Customer Support | Site Map | Contact Us | About

**LTPP InfoPave: Tools**

HOME SEARCH MAP DATA ANALYSIS VISUALIZATION **TOOLS** LIBRARY HELP MY LTPP NON-LTPP

**Find Sections**

**MERRA Climate Data for MEPDG Inputs**

There are 2514 of 2514 sections currently selected.

By Section  By Map

Please select the location from map or type the address in search box below:

Selected Location

- Age (Since Original Construction)
- Experiment Type
- Study
- Monitoring Status
- Section
- Location
- Maintenance and Rehabilitation
- Roadway Functional Class

**Structure**

- Surface Type
- Base Type
- Subgrade Type

**Climate**

- Climatic Region
- Freezing Index (Annual)
- Precipitation (Annual)
- Temperature (Annual)

**Traffic**

- Avg. Annual Daily Traffic (AADT)
- Avg. Annual Daily Truck Traffic (AADTT)

**Performance**

- Deflection (9-kip, wheel path)
- Fatigue Cracking
- Faulting

# OPTION 3. MAKE WEATHER FILES BASED ON NASA MERRA DATA

Also from LTPP InfoPave (available soon worldwide)

Select Location in ~30 mile× ~40 mile grids



Download No-gap hourly Precipitation, Temperature, Wind, Sunshine , & Relative humidity since 1979

Please select the Date Range below:

From: 01/01/2006 To: 12/31/2015

Show Advanced Data Classification

**Collapse All**

- Basic MERRA Data
  - Precipitation
    - Annual
    - Monthly
    - Daily
    - Hourly
  - Temperature
    - Annual
    - Monthly
    - Daily
    - Hourly
  - Wind
    - Annual
    - Monthly
    - Daily
    - Hourly
  - Humidity
    - Annual
    - Monthly
    - Daily
    - Hourly
  - Solar
    - Annual
    - Monthly
    - Daily
    - Hourly
- Data Attributes
  - Basic
  - Additional
  - All
- Merra Solar Hour (1 Cells)
  - Date Time
  - Shortwave Surface ( $W\ m^{-2}$ )
  - Shortwave Toa ( $W\ m^{-2}$ )
  - Cloud Cover
  - Percent Sunshine (%)
  - Surface Emissivity
  - Surface Albedo

**Add to Selection**

Fill the data in Pavement ME

Date/Time	Temperature (deg F)	Wind Speed (mph)	Sunshine (%)	Precipitation (in.)	Humidity (%)	Wind Dir (deg)
1/1/2006 00:00	32	0	100	0	100	10
1/1/2006 01:00	35	0	100	0	100	10
1/1/2006 02:00	34.5	0	100	0	100.5	10
1/1/2006 03:00	35.5	0	100	0	101	10
1/1/2006 04:00	35.5	0	100	0	100	10
1/1/2006 05:00	35.5	0	100	0	100	10
1/1/2006 06:00	35.5	0	100	0	100	10
1/1/2006 07:00	35.5	0	100	0	100	10
1/1/2006 08:00	35.5	0	100	0	100	10
1/1/2006 09:00	35.5	0	100	0	100	10
1/1/2006 10:00	35.5	0	100	0	100	10
1/1/2006 11:00	35.5	0	100	0	100	10
1/1/2006 12:00	35.5	0	100	0	100	10
1/1/2006 13:00	35.5	0	100	0	100	10
1/1/2006 14:00	35.5	0	100	0	100	10
1/1/2006 15:00	35.5	0	100	0	100	10
1/1/2006 16:00	35.5	0	100	0	100	10
1/1/2006 17:00	35.5	0	100	0	100	10
1/1/2006 18:00	35.5	0	100	0	100	10
1/1/2006 19:00	35.5	0	100	0	100	10
1/1/2006 20:00	35.5	0	100	0	100	10
1/1/2006 21:00	35.5	0	100	0	100	10
1/1/2006 22:00	35.5	0	100	0	100	10
1/1/2006 23:00	35.5	0	100	0	100	10

# ONLY THREE SENSITIVE INPUTS FOR PCC LAYER Thickness, CTE and Strength

**Density, Poisson's-semi-constants**

**Thermal properties-semi-constants**

**Shrinkage-good defaults**

**Stiffness-correlations**

**Layer 1 PCC: JPCP Default**

PCC strength input level: 3

- 28-Day PCC modulus of rupture (psi): 690
- 28-Day PCC compressive strength (psi)
- 28-Day PCC elastic modulus (psi)

**Thermal**

- PCC coefficient of thermal expansion (in/in/deg F x 10<sup>4</sup>): 4.9
- PCC thermal conductivity (BTU/hr-ft-deg F): 1.25
- PCC heat capacity (BTU/lb-deg F): 0.28

**Mix**

- Cement type: Type 1 (1)
- Cementitious material content (lb/yd<sup>3</sup>):  600
- Water to cement ratio:  0.42
- Aggregate type: Dolomite (2)
- Calculated
- 632.3 (calculated)
- Ultimate shrinkage (microstrain):  50
- Reversible shrinkage (%):  50
- Time to develop 50% of ultimate shrinkage (days):  35
- Curing method: Curing Compound

**Strength**

- PCC strength and modulus: Level:3 Rupture(690)

**PCC strength and modulus**  
This entry is used to determine PCC strength and modulus.

# BASE/SUBGRADE MATERIAL PROPERTIES

Material Layer Selection

Insert layer below: Layer 2 Subgrade : A-1-b

Layer type: Subgrade (5)

Select material type

Select from default list  Import from database   Import from file

- A-1-a.xml
- A-1-b.xml
- A-2-4.xml
- A-2-5.xml
- A-2-6.xml
- A-2-7.xml
- A-3.xml
- A-4.xml
- A-5.xml**
- A-6.xml
- A-7-5.xml
- A-7-6.xml

**Unbound**

- Coefficient of lateral earth pres  0.5
- Layer thickness (in)  10
- Poisson's ratio  0.35

**Modulus**

- Resilient modulus (psi)  8000

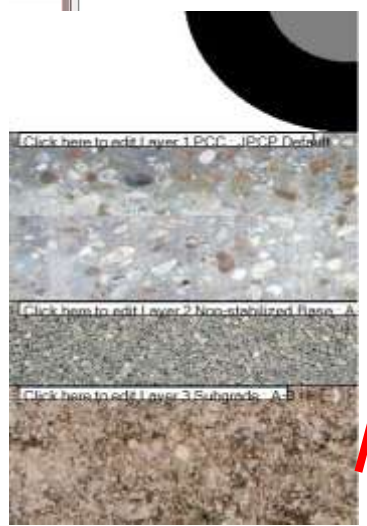
**Sieve**

- Gradation & other engineering  A-5

**Identifiers**

- Approver
- Author: AASHTO
- County

Coefficient of earth pressure, Poisson's-semi-constants



Bound/Unbound subbase/subgradematerials

Sieve	Percent Passing
#50	
#40	20
#30	
#20	
#16	
#10	33.8
#8	
#4	44.7
3/8-in.	57.2
1/2-in.	63.1
3/4-in.	72.7
1-in.	78.8
1 1/2-in.	85.8
2-in.	91.6
2 1/2-in.	
3-in.	
3 1/2-in.	97.6

Liquid Limit: 6

Plasticity Index: 1

Is layer compacted?

Maximum dry unit weight (pcf): 127.2

Saturated hydraulic conductivity (ft/hr): 5.054e-02

Specific gravity of solids: 2.7

Optimum gravimetric water content (%): 7.4

User-defined Soil Water Characteristic Curve (SWCC)

af	7.25549682996034
bf	1.33282181654764
cf	0.824220751940721
hr	117.4

Gradation, Atterberg limits, hydraulic properties-good defaults or insensitive

Typical unbound materials are provided in groups; the only user inputs are thickness and resilient modulus.

# PAVEMENT ME ALSO ACCOUNT FOR MANY DESIGN FEATURES

The screenshot shows the AASHTOWare Pavement ME Design software interface. The main window displays design parameters for a project named 'AL\_north\_granular'. The 'General Information' section includes: Design type: New Pavement; Pavement type: Jointed Plain Conc; Design life (years): 80; Pavement construction: Se 2015; Traffic opening: Oc 2015. The 'Performance Criteria' table is as follows:

Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	63	
Terminal IRI (in./mile)	172	95
JPCP transverse cracking (percent slabs)	15	95
Mean joint faulting (in.)	0.12	95

The 'JPCP Design Properties' section includes: JPCP Design; PCC surface shortwave absorptivity: 0; PCC joint spacing (ft): 15; Sealant type: Other; Doweled joints: Spec; Widened slab: Wide; Tied shoulders: Tied; Erodibility index: Erosi; PCC-base contact friction: No fr; Permanent curl/warp effective temp: -1. The 'Identifiers' section includes: Display name/identifier: Defa; Description of object: Defa; Approver; Date approved; Author.

**Design features:**

- Joint spacing
- Dowels
- Widen lanes
- Shoulder type
- Sealant type

**These are not design features, but inherent property of the material or construction:**

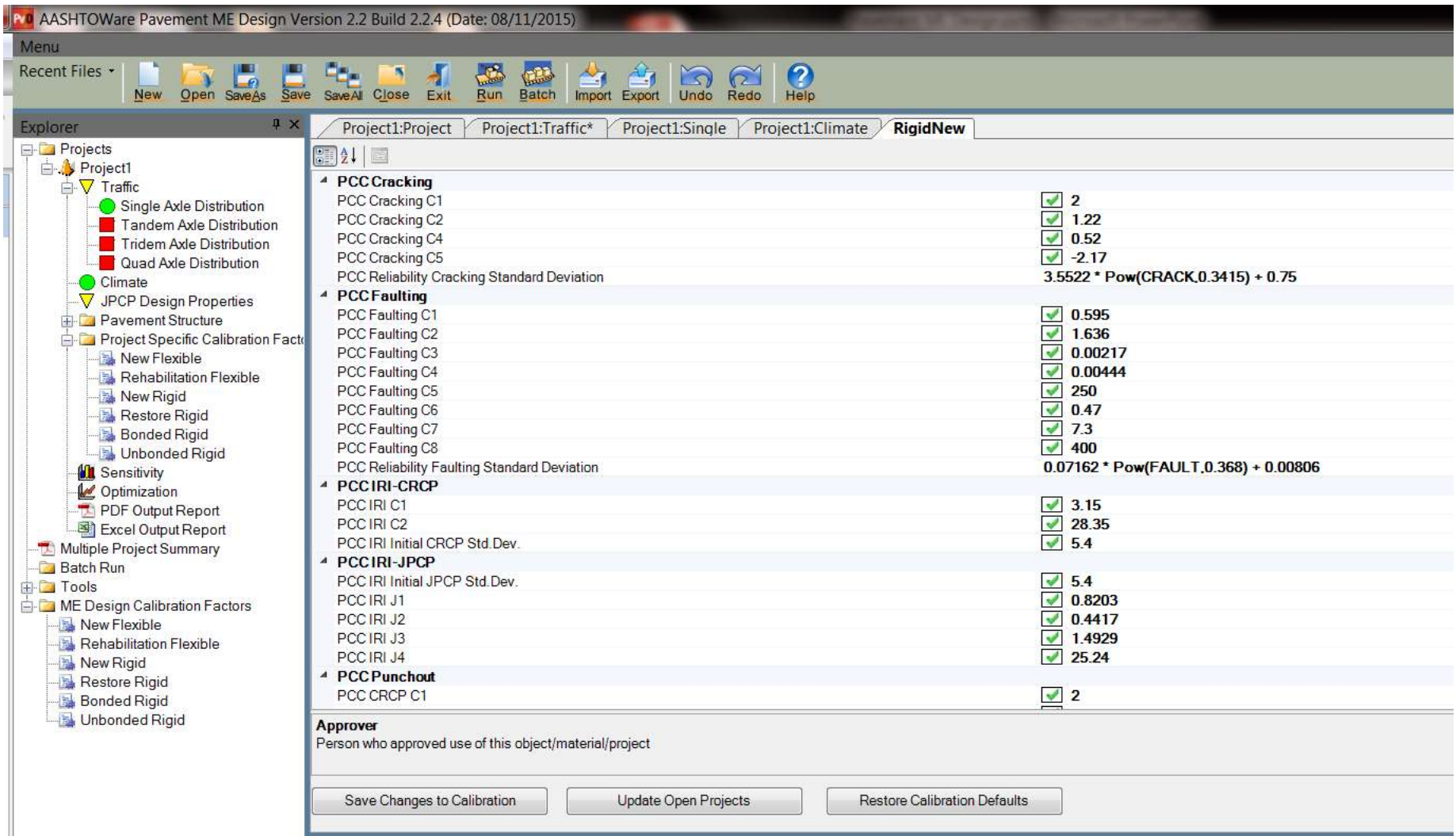
- Base friction
- Base erodibility

**Semi-constants:**

- Built-in gradient
- Surface shortwave absorptivity

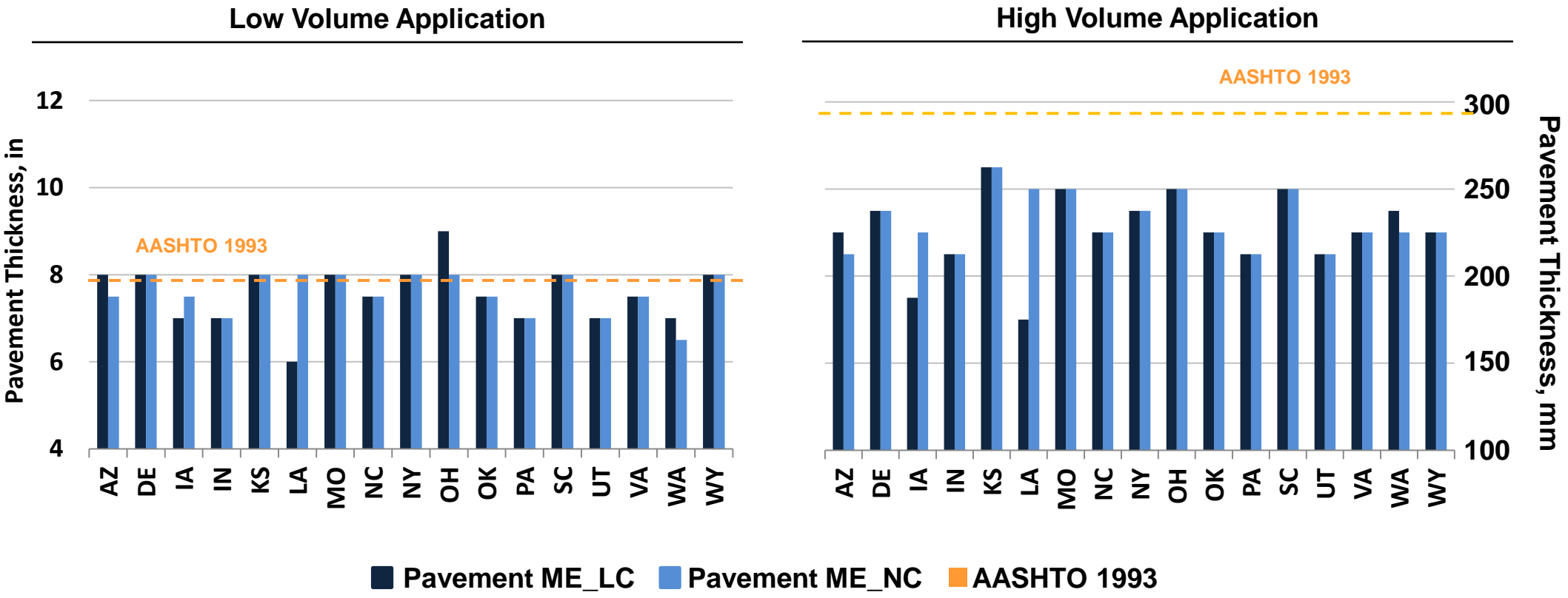
**There is no such thing as one-size-fits-all design. Each project is unique.**

# PAVEMENT ME ALLOWS AGENCIES TO DEVELOP AND USE LOCAL CALIBRATION COEFFICIENTS



You can save your local calibration coefficients as default or restore the national as default at one click

# LOCAL CALIBRATION RESULT IN 1/2-IN OR LESS DIFFERENCE IN REQUIRED THICKNESS vs. NATIONAL CALIBRATION



However, using Pavement ME result in ~2-3 in thinner JPCPs when compared to the AASHTO 93 guide.

# THREE NATIONAL CALIBRATIONS FOR NEW JPCP SO FAR

Most JPCP designs have been done using the 2<sup>nd</sup> Calibration

Cal. 1  
(NCHRP 1-37)

Cal. 2 (NCHRP 1-40D)  
• Models updated  
• Cal. database expanded

Cal. 2.5 (NCHRP 20-07 Task 288)  
• To correct CTE testing

Cal. 3 (NCHRP 20-07 Task 327)  
• To validate Task 288



MEPDG 0.7  
2004

MEPDG 1.0 - Pavement ME 2.1  
2007

2011

Pavement ME 2.2  
August, 2015



# CAL. 2 AND CAL.3 NOT SUPPOSED TO CHANGE DESIGNS ON AVERAGE



AASHTOWare: Pavement ME Design  
FY15 Enhancements

## Impact of New Global Calibration

- Version 2.2 new global calibration for JPCP and CRCP should not result in significantly different designs on average since the same field sections with the same performance trends were used.
- Of course, some designs will be a little thicker and some thinner due to variations involved.

# 15-25 PAGES OF REPORT SUMMERIZES ALL THE INPUTS AND OUTPUTS

Many more intermediate outputs are also available for in-depth analysis

**DARWIN** **ME** **Project1**  
 File Name: C:\Users\rodman.apal\Documents\My Darwin\ME\Projects\Project1.dgn

**Design Inputs**

Design Life:	20 years	Existing construction:	-	Climate Data:	41.986, -87.914
Design Type:	Jointed Plain Concrete Pavement (JPCP)	Pavement construction:	June, 2013	Sources (Lat/Lon):	
		Traffic opening:	September, 2013		

**Design Structure**

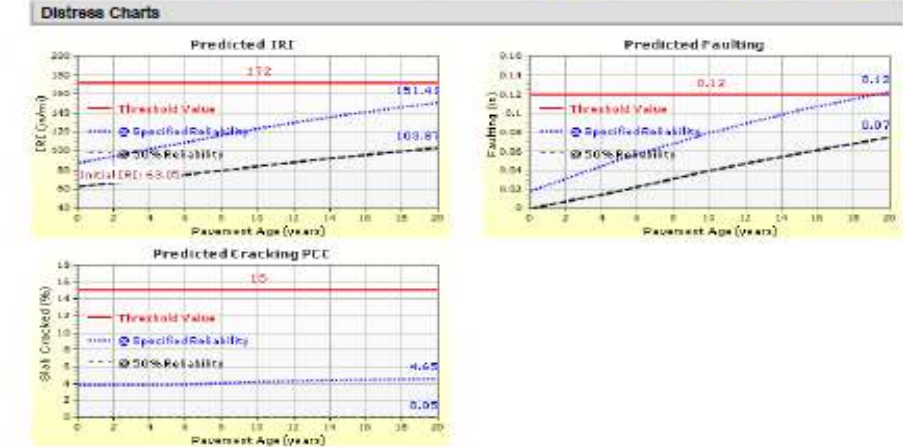
Layer type	Material Type	Thickness (in.)	Joint Design:	Age (year)	Heavy Trucks (cumulative)
PCC	JPCP Default	10.0	Joint spacing (ft)	2013 (initial)	4,000
Non-Stabilized	Permeable aggregate	10.0	Dowel diameter (in.)	2023 (10 years)	7,876,620
Subgrade	A-6	Semi-Infinite	Slab width (ft)	2033 (20 years)	17,935,200

**Design Outputs**

**Distress Prediction Summary**

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	172.00	151.41	90.00	95.69	Pass
Mean joint faulting (in.)	0.12	0.12	90.00	88.42	Fail
JPCP transverse cracking (percent slabs)	15.00	4.65	90.00	100.00	Pass

**Distress Charts**

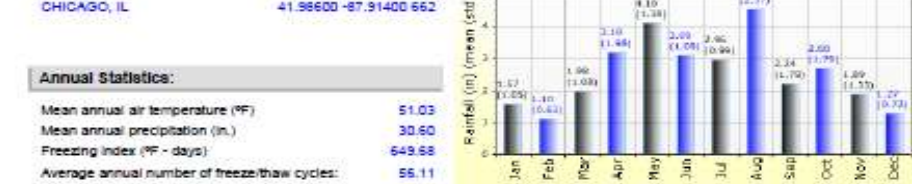


**DARWIN** **ME** **Project1**  
 File Name: C:\Users\rodman.apal\Documents\My Darwin\ME\Projects\Project1.dgn

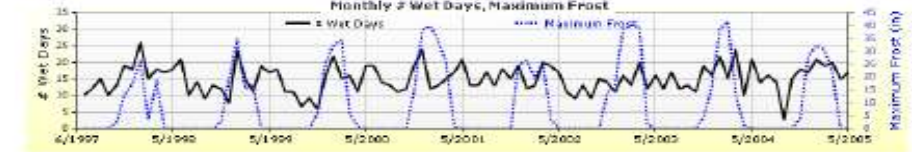
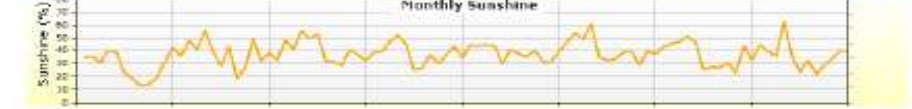
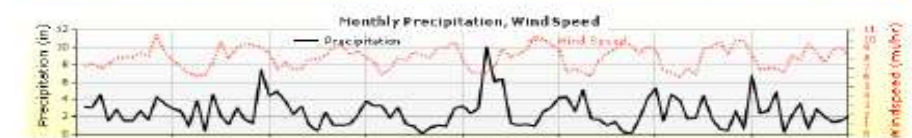
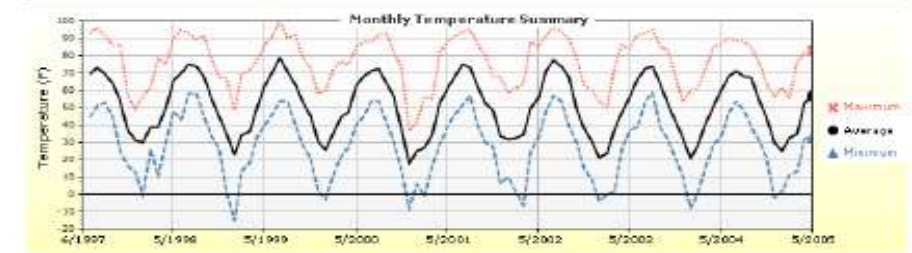
**Climate Inputs**

**Climate Data Sources:**

Climate Station Cities:	Location (lat lon elevation(ft))
CHICAGO, IL	41.98600 -87.91400 662



**Monthly Climate Summary:**



# OUTLINE

1. AASHTO Pavement ME

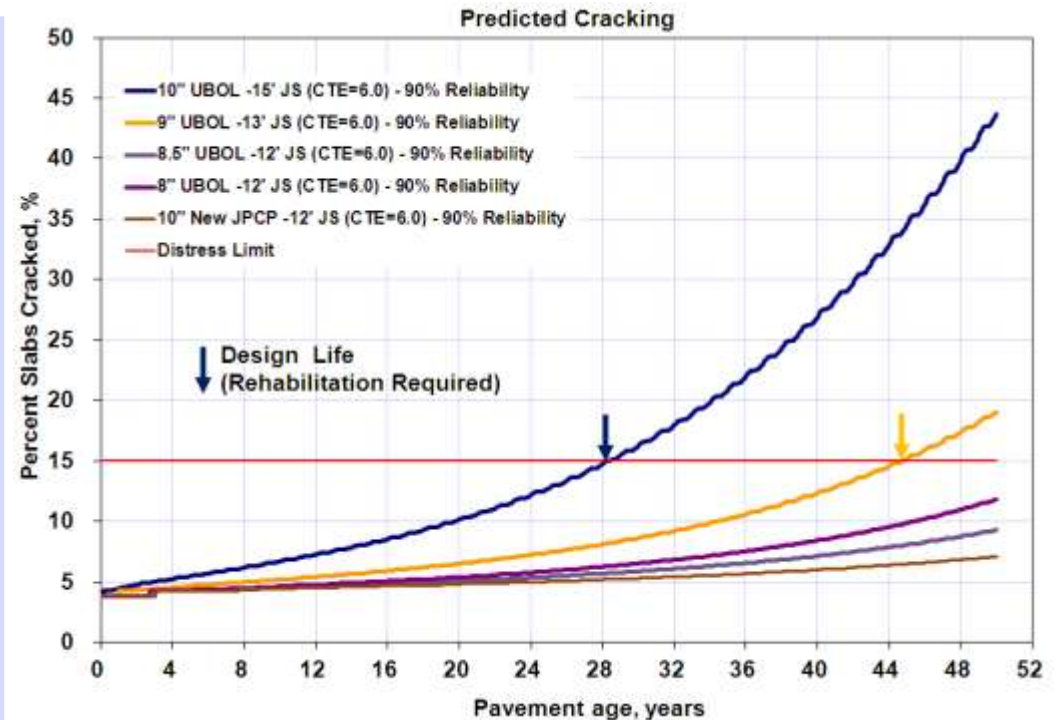
2. How to Establish Inputs

3. Optimize the Design

# PAVEMENT-ME ALLOWS FOR COMPARISONS OF DIFFERENT DESIGNS

## Predicted Performance Curves & Pavement Designs

- Many pavement designs will meet the design criteria
  - Pavement-ME predicts what the actual performance could be
  - Allows for comparisons and evaluation of different design features / thickness
- Performance estimates help determine the “when” and “what” rehabilitation activities to perform



## Comparing Designs

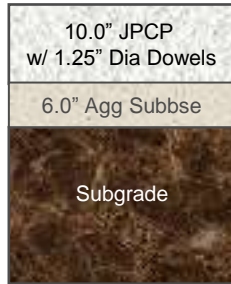
- Pavement-ME is for 50 years to give long term performance for each design
- Pavement design must meet the “design criteria” (eg less than 10% cracking at year 30)

Combining Performance Results with the LCCA finds the design that best balances the initial costs, life cycle costs and performance

# COMBINING PAVEMENT ME AND LCCA INTO THE DESIGN PROCESS

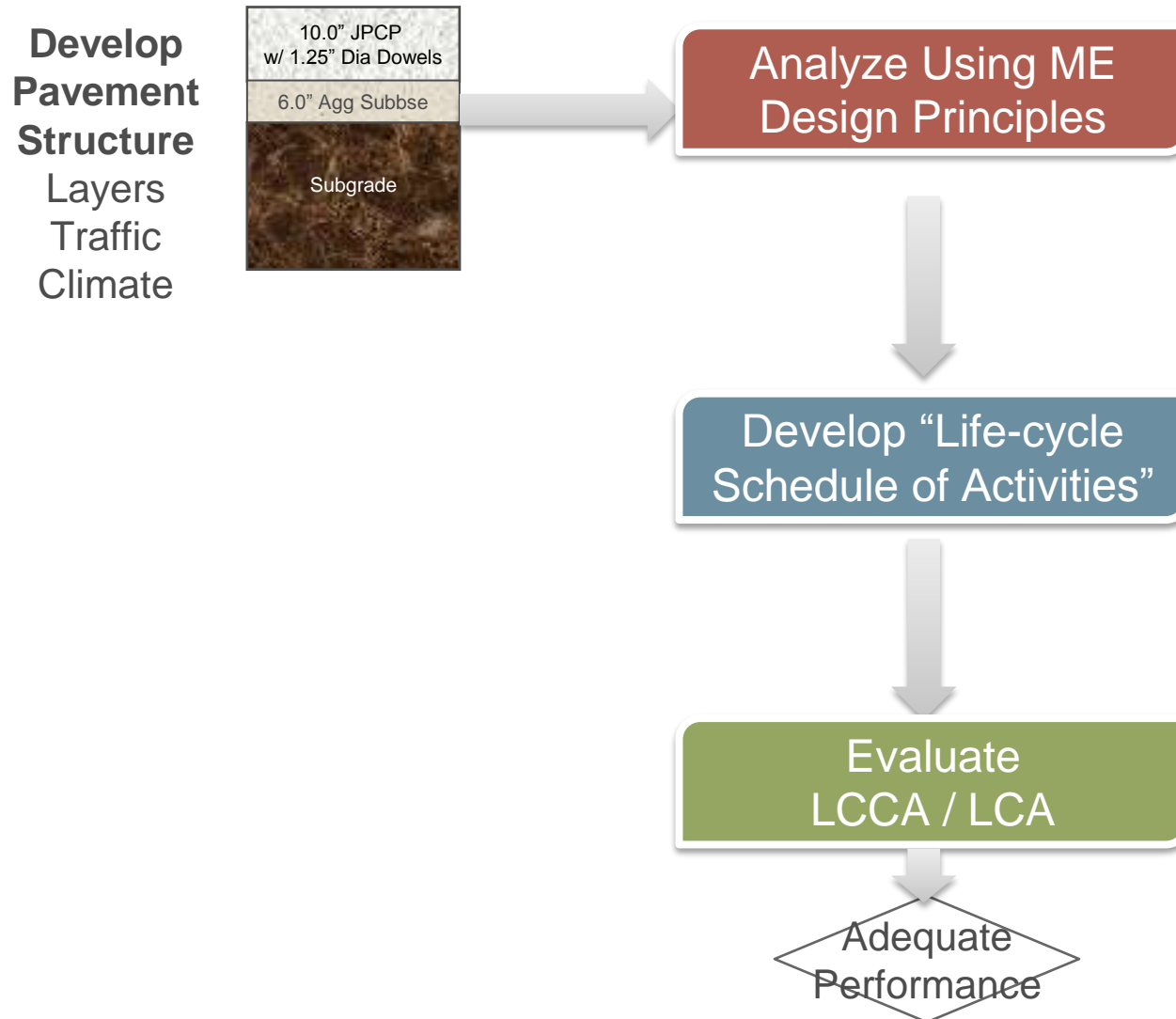
finds the optimum design in terms of initial, long-term cost and performance

Develop  
Pavement  
Structure  
Layers  
Traffic  
Climate



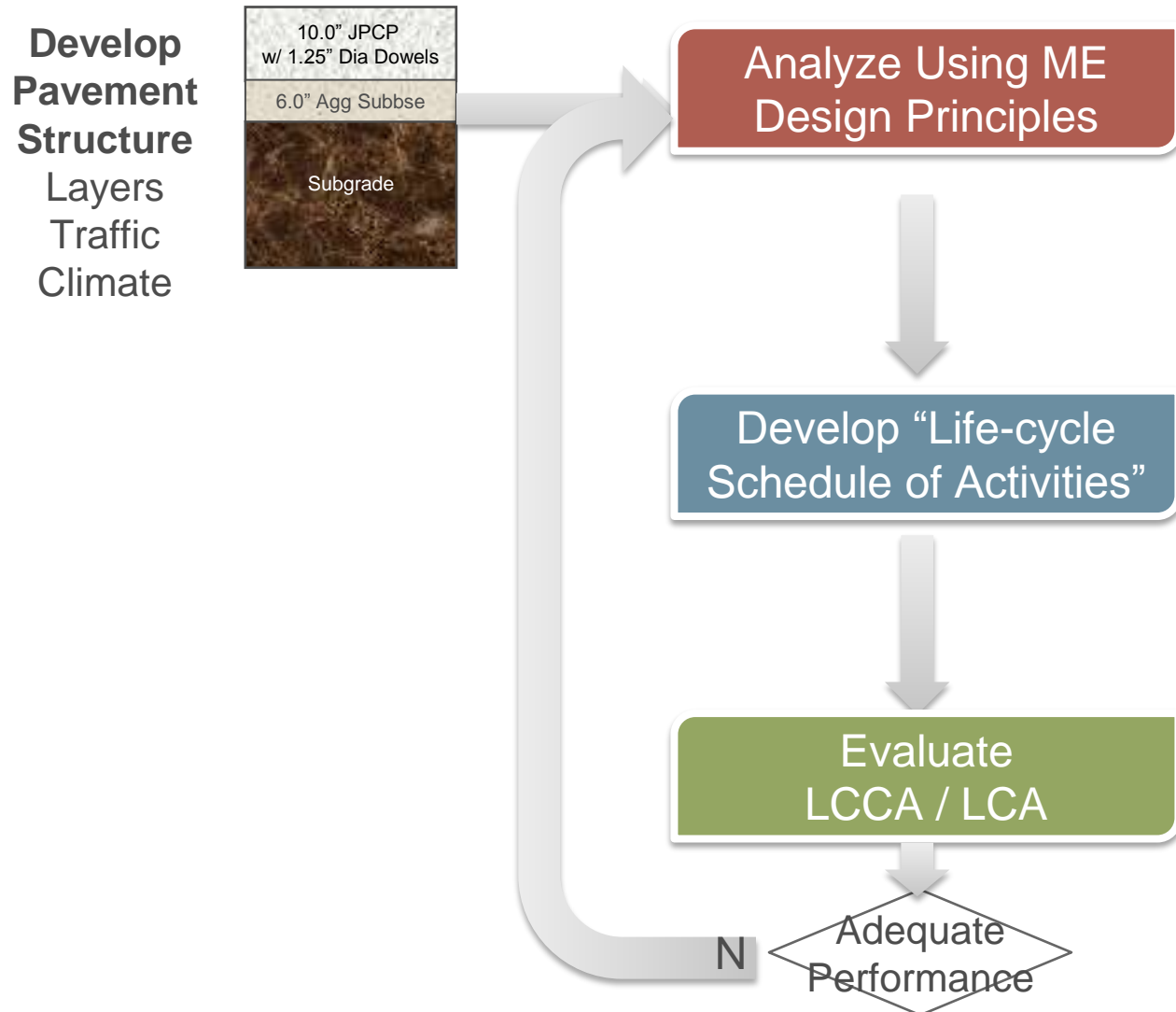
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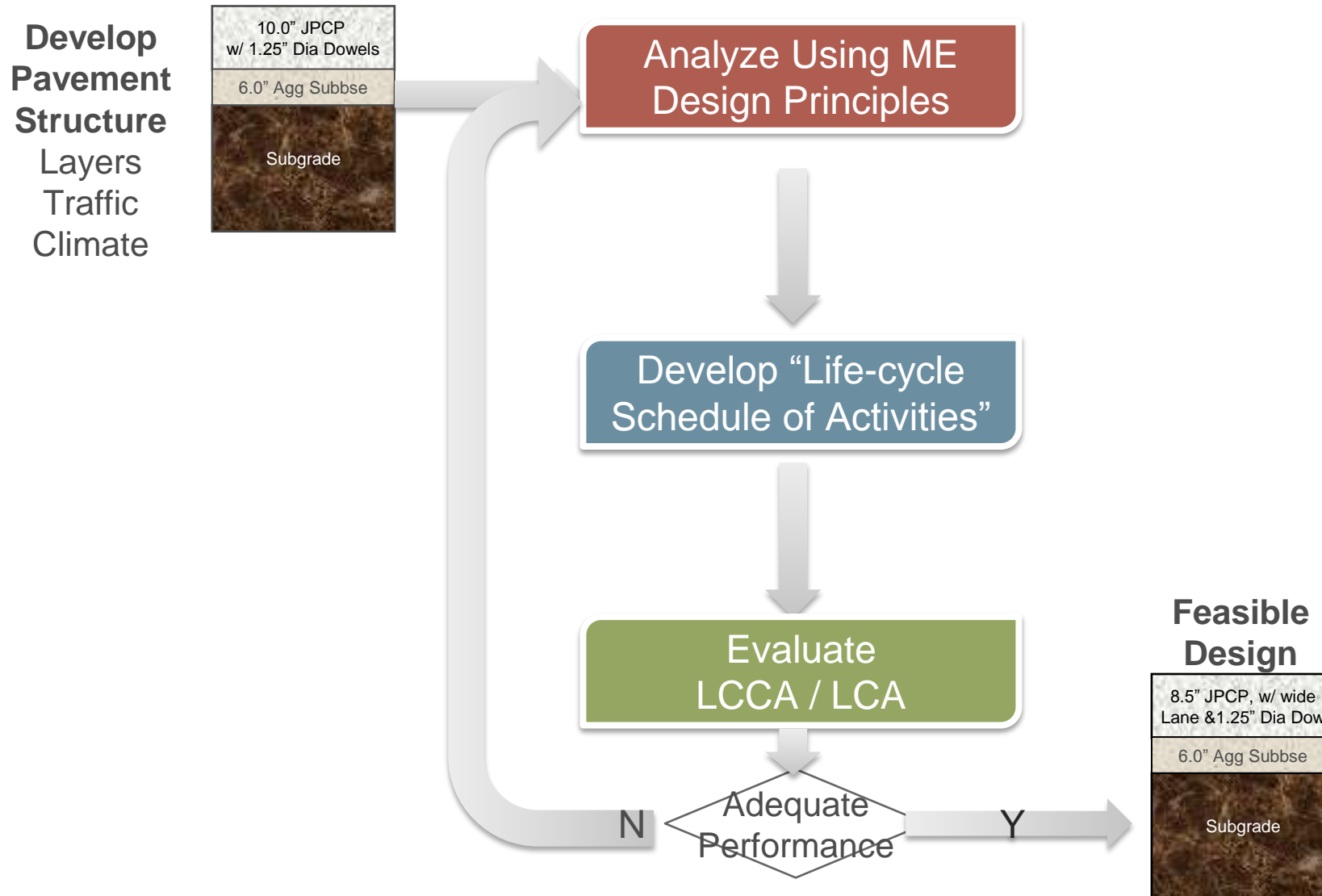
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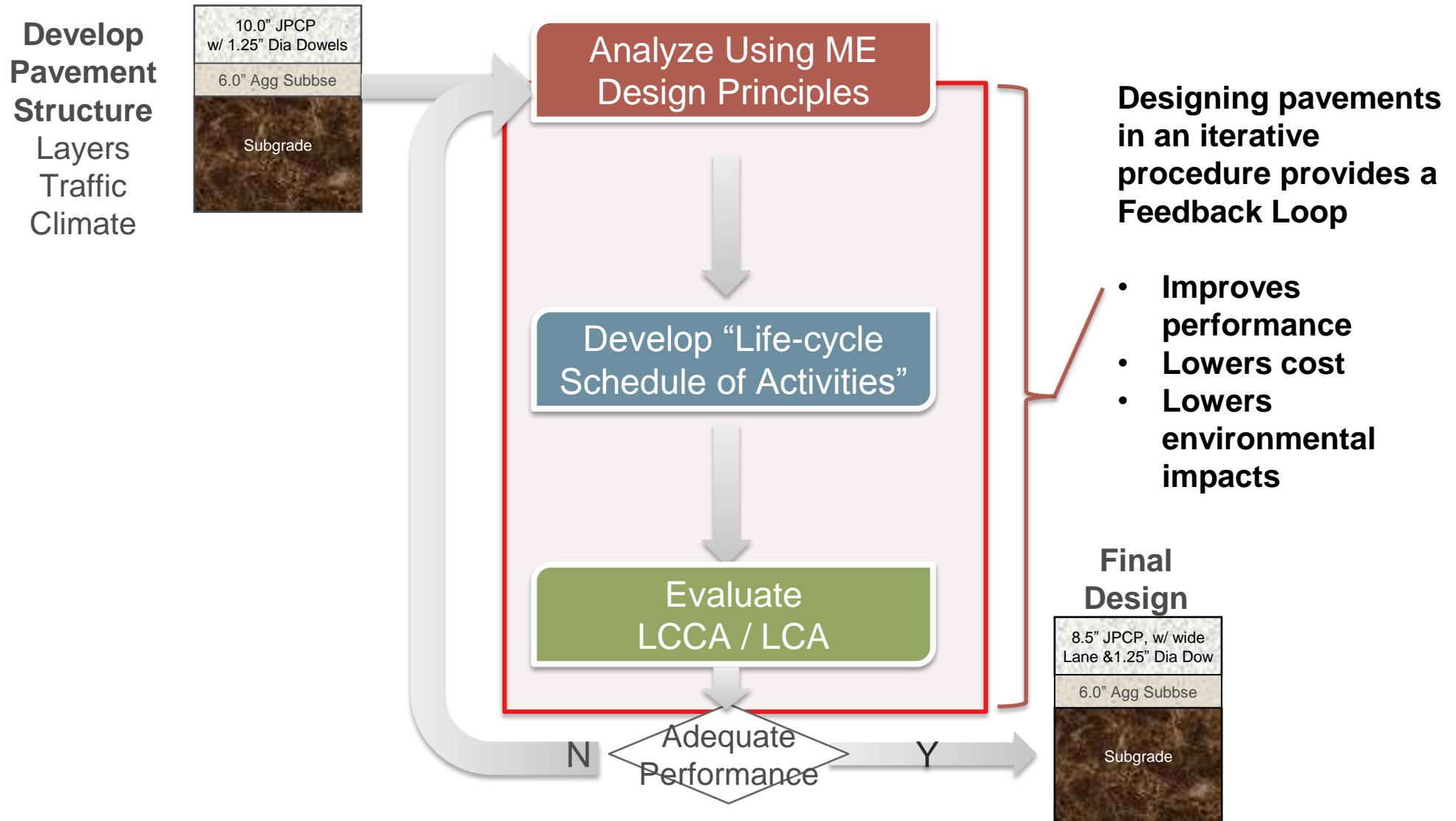
finds the optimum design in terms of initial, long-term cost and performance





# COMBINING PAVMENT ME AND LCCA INTO THE DESIGN PROCESS

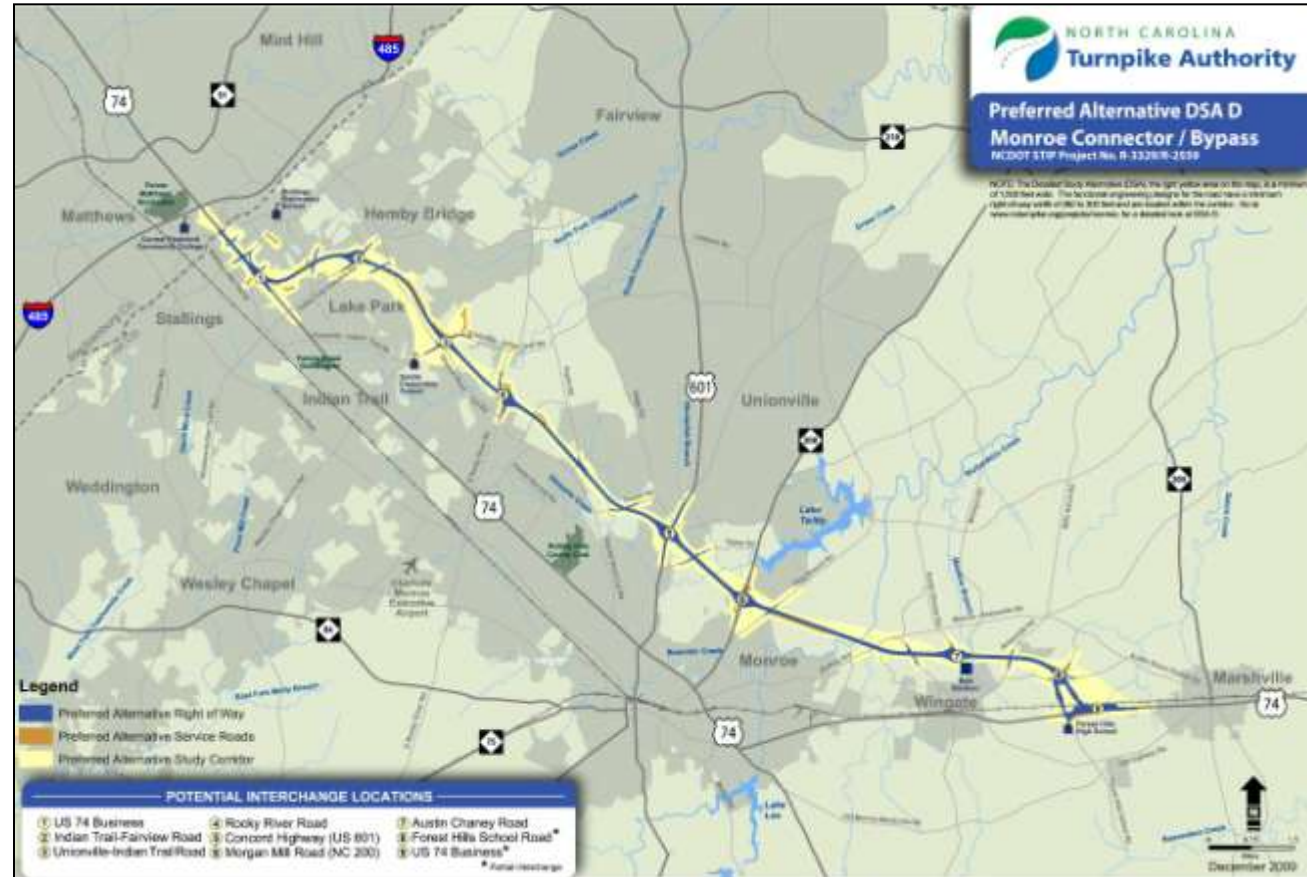
finds the optimum design in terms of initial, long-term cost and performance



# MONROE PARKWAY IS NEW ROAD NEAR CHARLOTTE NC

From US 74 at I-485 in eastern Mecklenburg County to US 74 near the Town of Marshville

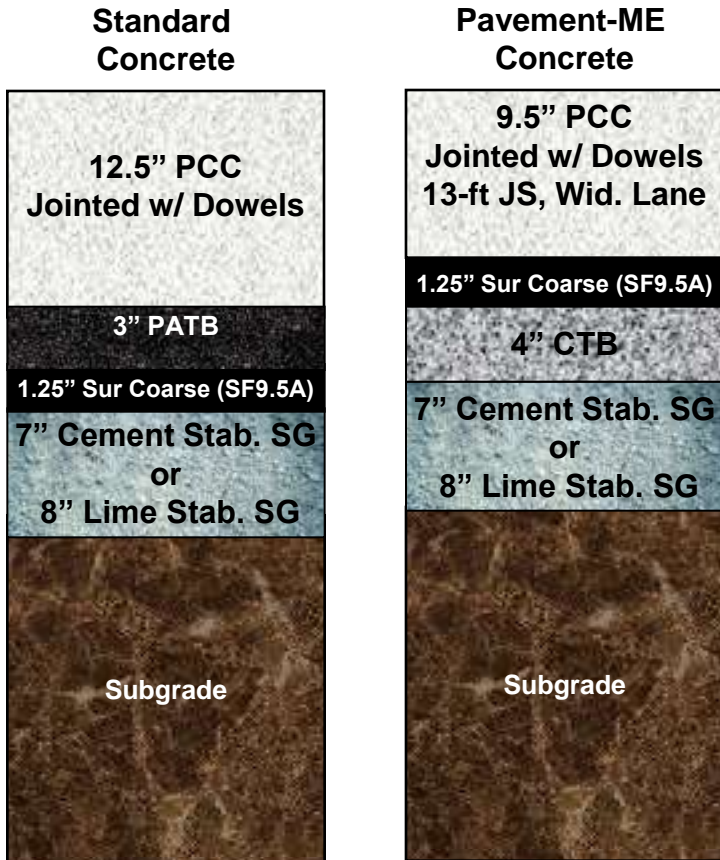
- Project owner: North Carolina Turnpike Authority (NCTA)
- Preliminary cost estimate ~ \$520 M  
Project was let as Design-Build with alternate pavement designs (asphalt or concrete)
- Length is approximately 21 miles
- Estimated Traffic:<sup>1</sup>
  - Yr 2015 – ADT = 35,600
  - Yr 2030 – ADT = 56,600
    - % Duals = 1 % TTST = 2%
    - Growth = 3.14%
  - 20-yr F-ESALS<sup>2</sup> = 7.74 M
  - 30-yr R-ESALS<sup>2</sup> = 18.0 M



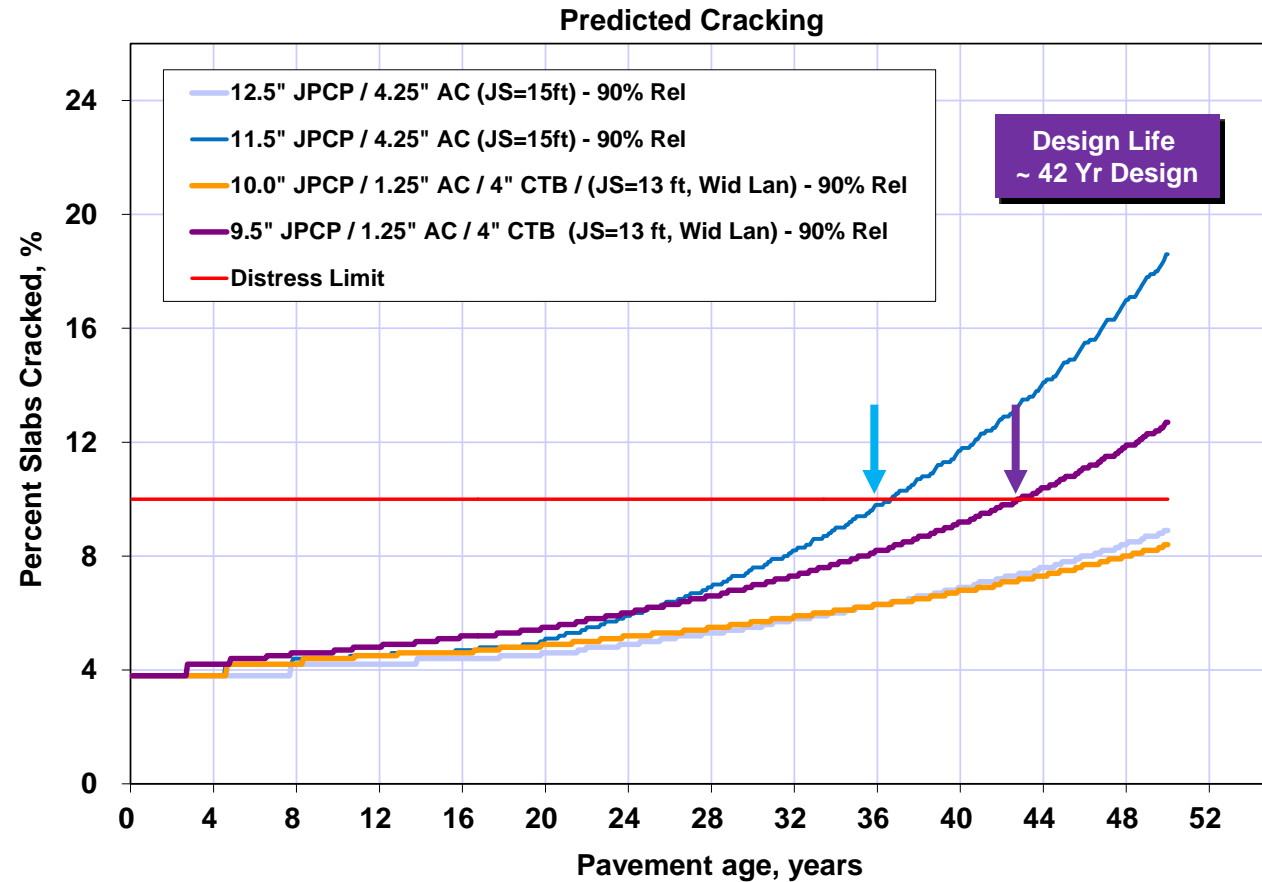
1. NCTA – Proposed Monroe Connector/Bypass Preliminary Traffic and Revenue Study – 2009 Update  
2. F-ESALS based on Dual TF = 0.35, TTST TF = 1.15, Lane Distribution Factor = 0.8 (3 lanes / direction)  
R-ESALS based on Dual TF = 0.3, TTST TF = 1.6, Lane Distribution Factor = 0.8 (3 lanes / direction)

# PAVEMENT-ME SHOWS OTHER CONCRETE SECTIONS MEET THE 30-YEAR DESIGN CRITERIA

Changing designs also changed the controlling distress



Pavement-ME Predicted Performance

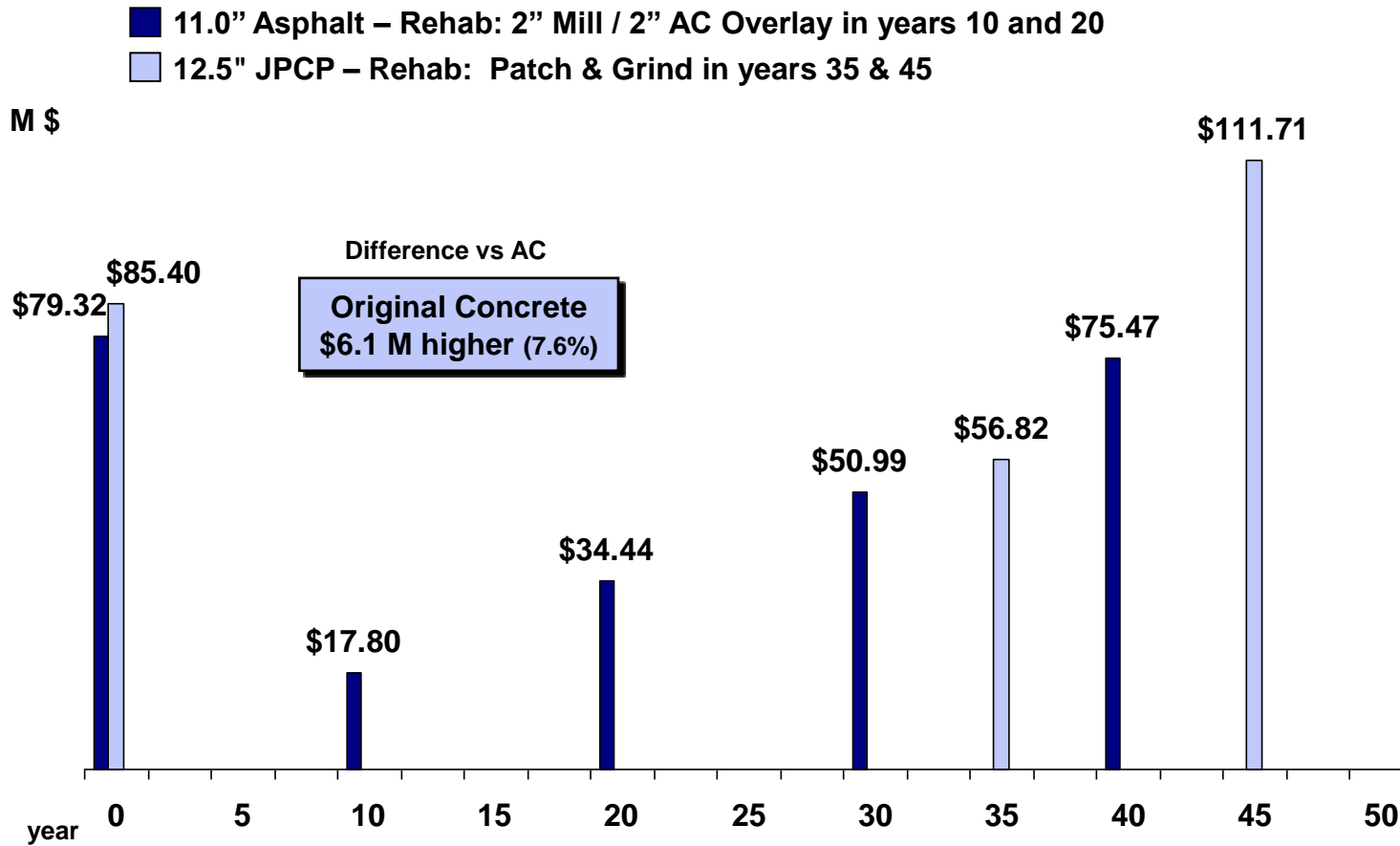


9.5" Jointed Pavement with Widened Lanes & 13-ft joint spacing is a 42-Year design

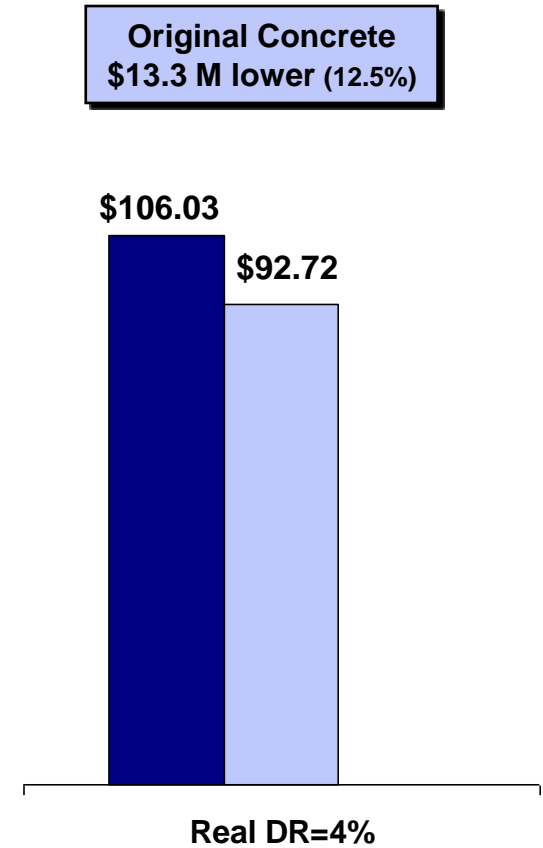
# THE ORIGINAL CONCRETE PAVEMENT HAS HIGHER INITIAL COST BUT LOWER LIFE CYCLE COST

Makes pavement type selection difficult

Nominal Expenditures by Pavement Type (\$ M)



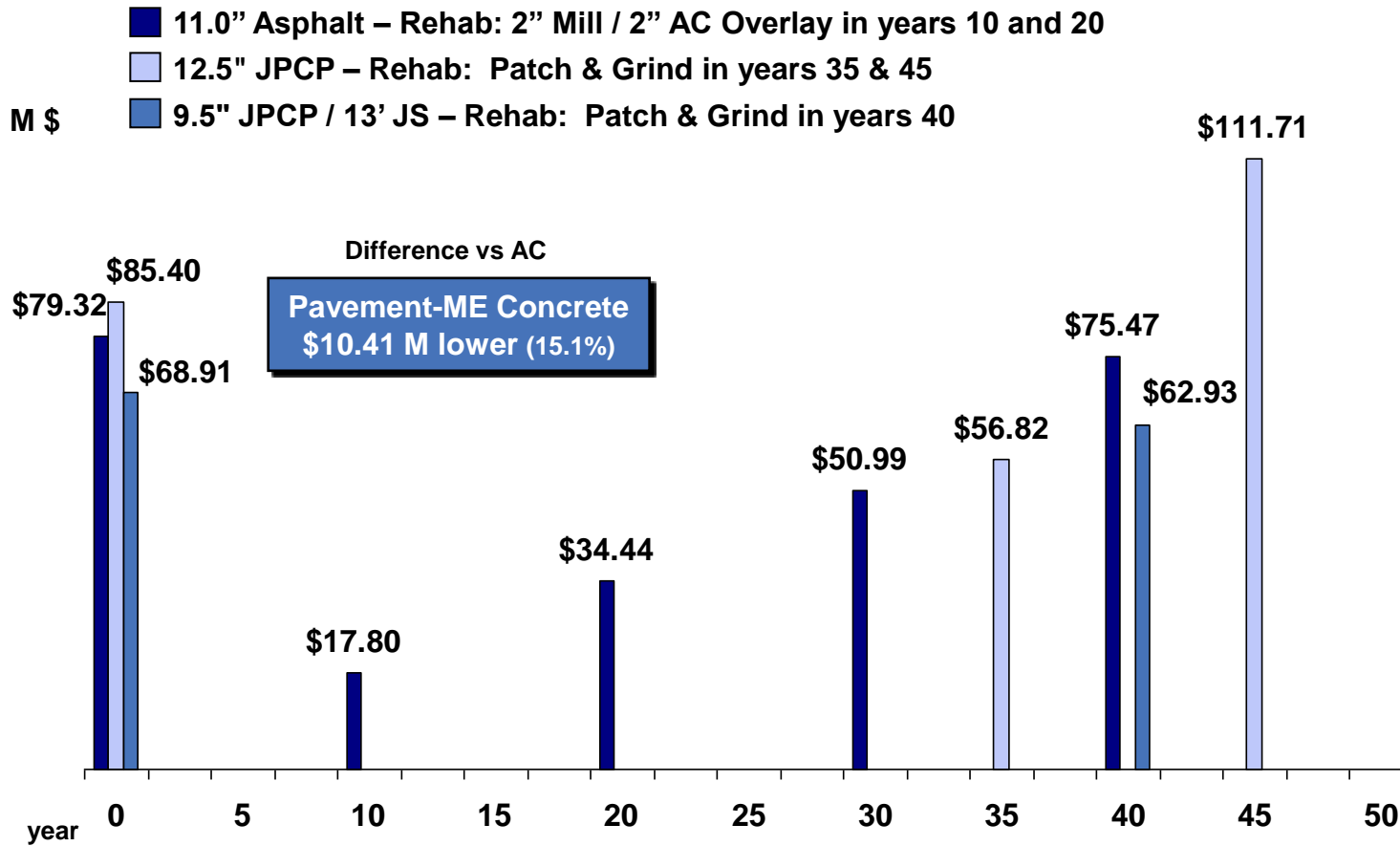
LCC Net Present Value (\$ M)



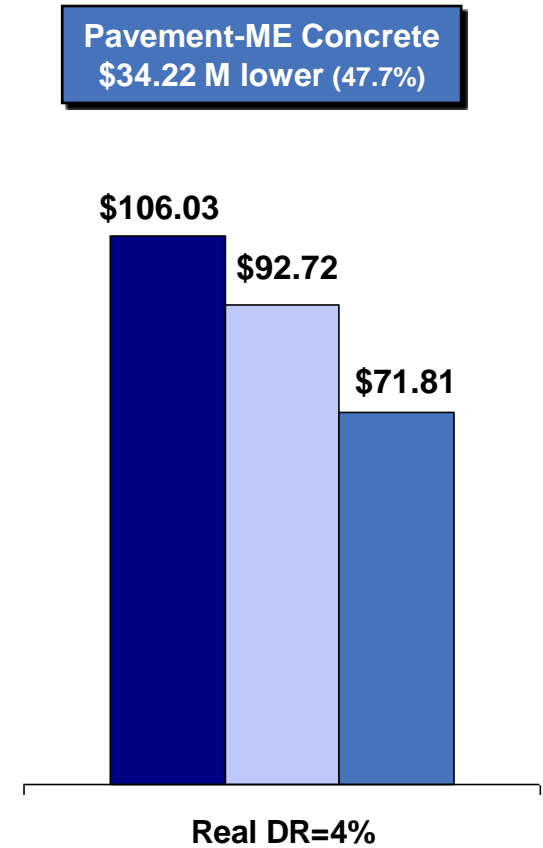
Costs for 21 miles, 3 lanes plus Shoulders. Initial Costs include Pavement, base, and subgrade stabilization materials and labor  
 Rehabilitation costs – AC Activities based on NCDOT Schedules with same activities continued throughout 50 year analysis  
 Concrete activities based on Pavement-ME (no salvage) – 3% Patch & 100% Grind in yr 35, 5% Patch & 100% Grind in yr 35

# THE OPTIMIZED PAVEMENT HAS BOTH LOWEST INITIAL COSTS & FUTURE REHABILITATION COSTS

Nominal Expenditures by Pavement Type (\$ M)



LCC Net Present Value (\$ M)



Costs for 21 miles, 3 lanes plus Shoulders. Initial Costs include Pavement, base, and subgrade stabilization materials and labor  
 Rehabilitation costs – AC Activities based on NCDOT Schedules with same activities continued throughout 50 year analysis  
 Concrete activities based on Pavement-ME (no salvage) – 3% Patch & 100% Grind in yr 35, 5% Patch & 100% Grind in yr 35

# SUMMARY

- 1 Pavement ME is a powerful tool for pavement performance prediction**
  - Covers a wide range of applications
  - Determines when and how the pavement will fail
  - No longer just a thickness design procedure
  
- 2 For design, Pavement ME only needs a handful of important and necessary inputs**
  - Three levels of input determination
  - Many inputs are semi-constants
  - Even more inputs are not sensitive
  - Be aware which are the design variables
  
- 3 Combine Pavement ME and LCCA to find the optimum design**
  - No one-size-fits-all design. Each project is unique.
  - Use Pavement ME to generate many feasible designs
  - Use LCCA to decide the final design