Illinois Tollway's Experience Implementing Performance Specifications for Concrete Pavement Construction

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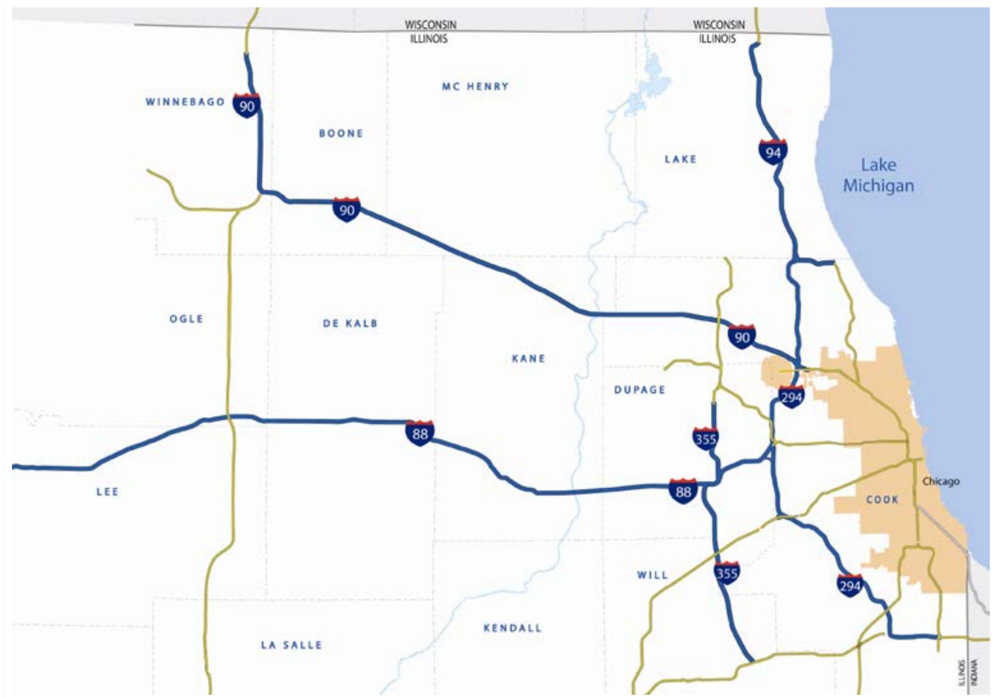
November 5, 2015

Illinois Tollway – Key Statistics

- **286-mile system comprised of four tollways:**
  - Tri-State (I-94/I-294/I-80)
  - Jane Addams Memorial (I-90)
  - Reagan Memorial (I-88)
  - Elgin O'Hare (IL-390)
  - Veterans Memorial (I-355)
- **Opened in 1958 as a bypass around Chicago to connect Indiana and Wisconsin**
- **Carries more than 1.4 M vehicles per day**
- **User-fee system – no state or federal gas tax dollars used for maintenance and operations**



Congestion-Relief Program work in 2009 alone

Nearly $6 Billion Committed

99.9% complete

- **Completed Rebuild & Widen Projects systemwide**
- **Built 12.5-mile I-355 South Extension**
- **Converted 20 barrier toll plazas to Open Road Tolling**

Move Illinois Capital Program

TAKE CARE OF EXISTING SYSTEM NEEDS

JANE ADDAMS MEMORIAL TOLLWAY $2.5 billion

ELGIN O'HARE WESTERN ACCESS $3.4 billion

I-294/I-57 INTERCHANGE $719 million

ILLINOIS ROUTE 53/120 PROJECT

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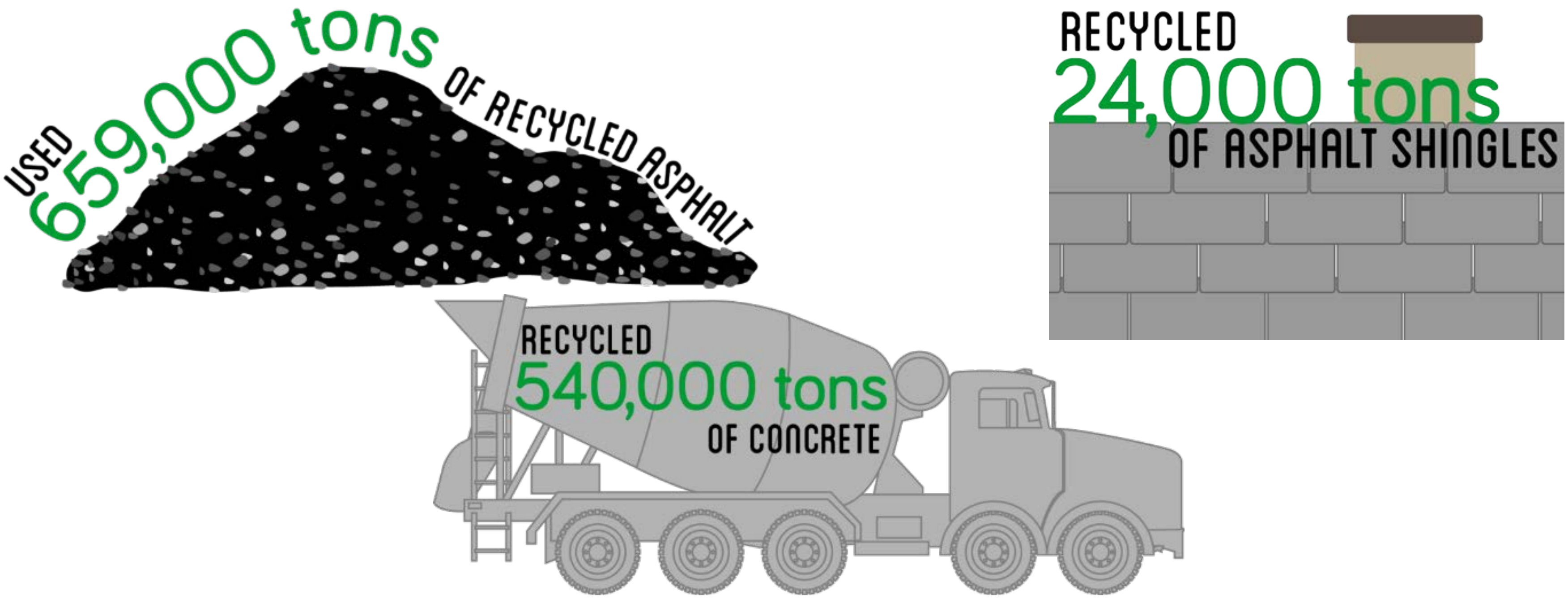
Illinois Tollway

Move Illinois and Sustainability

- ***Move Illinois*** **will be the "cleanest and greenest" program in the Tollway's history.**
  - Minimizes the environmental impact of new roadway construction by reducing, recycling and reusing materials.
  - Commits to incorporating renewable energy products including solar panels, wind turbines and geothermal systems
  - New and existing infrastructure projects including maintenance site reconstruction will seek a recognized green project standards and certification for Leadership in Energy and Environmental Design (LEED)

Sustainability Means a Lot at the Tollway



Nearly 1.4 million tons of recycled concrete, asphalt and aggregate in the construction of new roads – enough to build a nearly 2,700-mile bike path from Boston to San Francisco

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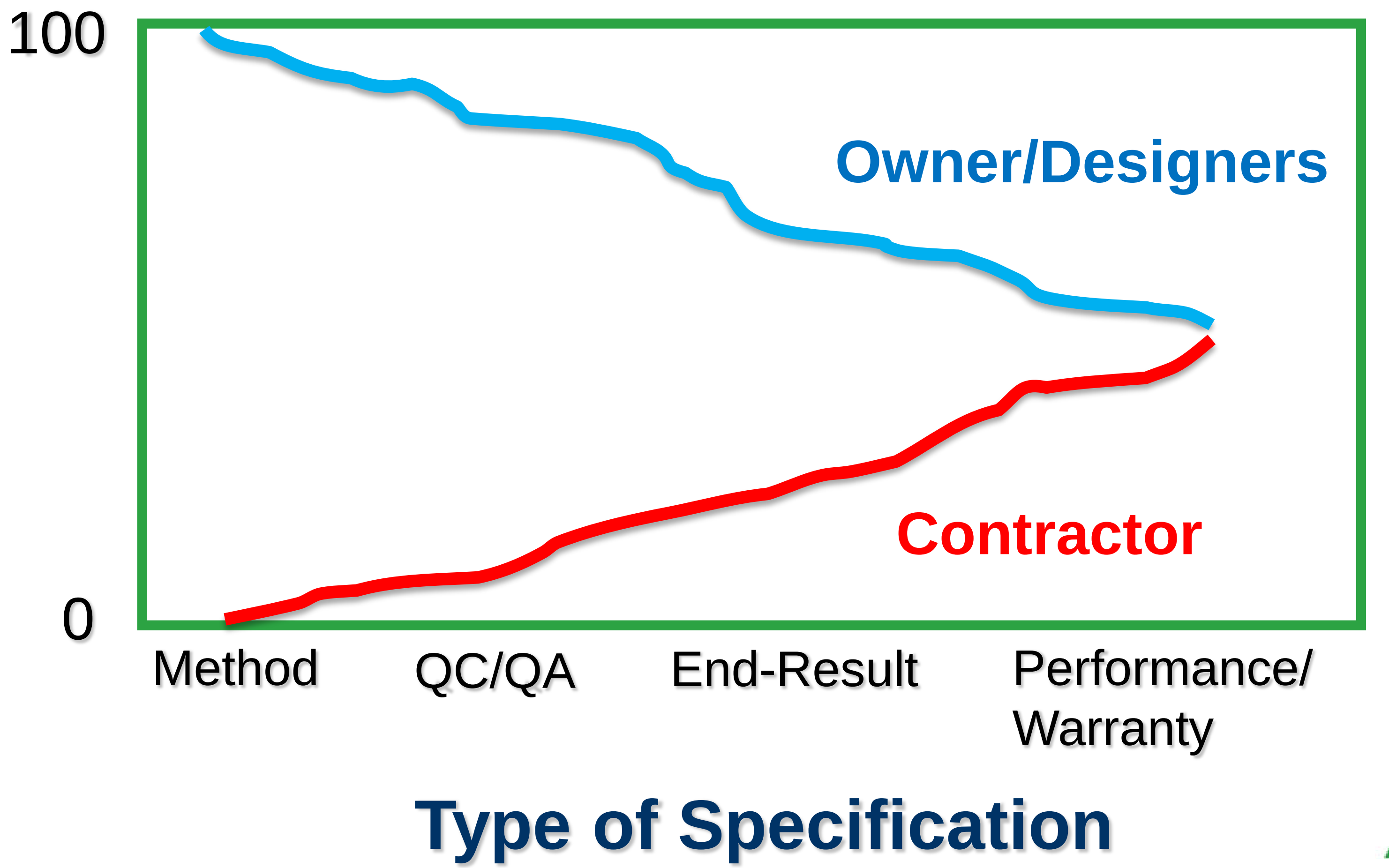
Three Legs of Sustainability to be Equal

Specifications Have Different Risk Profiles



Implementation of Performance Specifications

- **Summer to Fall 2013 – Shadow Implementation**
- **March 2014 – meeting with Tollway Engineering Management to get approval to move forward**
- **March to May 2014 – Development of specification framework**
- **July 2014 – 1st Meeting with Industry to provide overview of PRS & present concept/ideas**
- **July 2014 – First draft of SP**
- **Fall to Winter 2014 – Multiple meetings revising and changing SP**
- **April 2015 – Training on testing and procedures**
- **May 2015 to Current – Performance specifications in effect**

Shadow Performance Specifications

- **Develop and evaluate like FULL implementation**
- **Does not impact contractor pay for the shadow project**
- **Learning and pre-implementation tool**

Performance Specifications Applied to Larger Concrete Paving Projects Starting in 2015

- **Project would have at least 10 sublots**
- **Will be evaluated and determined by Tollway**
- **Pay factors will be different by corridor**

Steps for Implementation of Performance Specifications

1. **Conduct project coordination meetings**
   select location, gather information, develop sampling & testing plan
2. **Collect and analyze historical data**
   AQCs, M & R criteria, costs, discount rate, etc.
3. **Develop and evaluate pay factors**
   PaveSpec, historical evaluation

Steps for Implementation of Performance Specifications

4. **Prepare for implementation on project**
   layout of lots & sublots, sampling & testing details
5. **Develop Special Provisions**
   followed by meetings, presentations, revisions
6. **Conduct field sampling and testing**
   database management, dispute resolution
7. **Evaluate PRS results**
   Incentives/disincentives for each lot

Develop Pay Factors

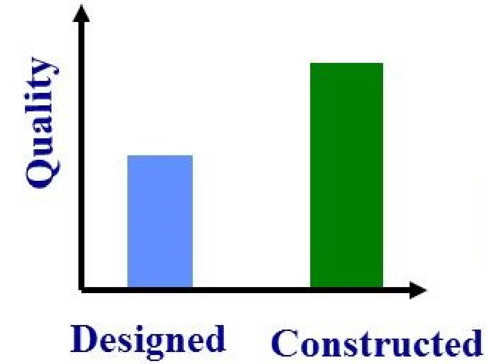
Pavement Design

Planning

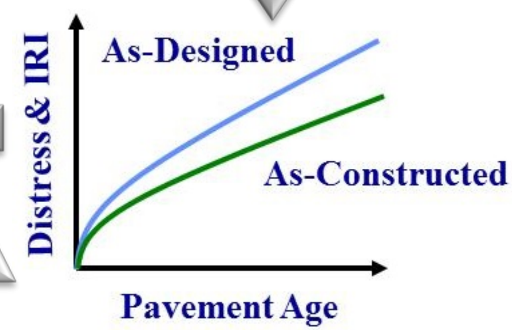
Establish Performance Criteria

Identify AQCs and Target Values

PAVESPEC

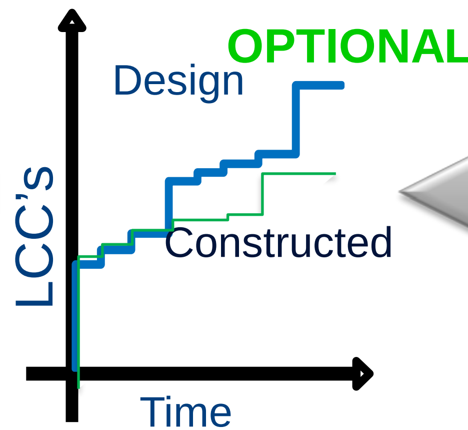


Design AQC vs. As-Constructed AQC

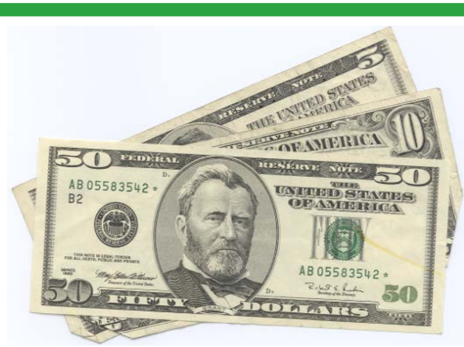


Model ME Performance

M&R Plan

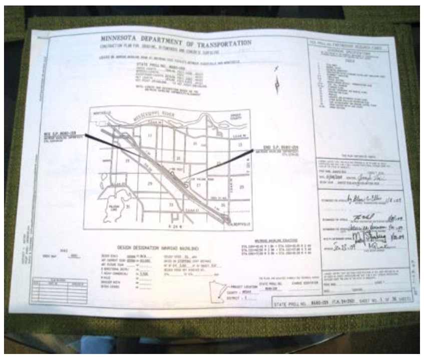


Compare As-Built and As-Designed



Pay Factor f(ΔLCC)

Use Pay Factors



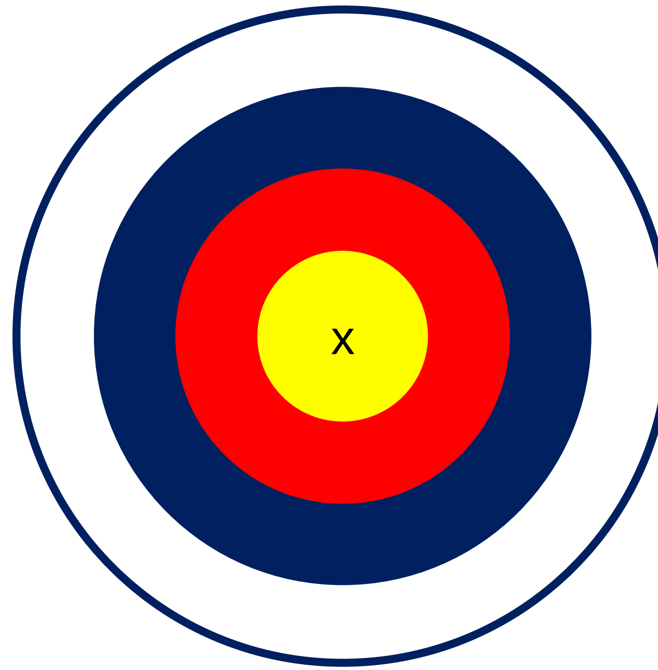
Incorporate Pay Tables Into Specifications & Project Letting

Pavement Construction, Sampling, and Testing

Incentive and Disincentive Pay

First Define Acceptance Quality Characteristics (AQC's)

- **Measureable**
  - More rapid the better
- **Correlate with performance**
  - Prediction models
- **Are under contractor's control**
  - Can be varied on the project



Acceptance Quality Characteristics (AQCs)

- **Five AQCs**
  - Compressive strength
  - Air
  - Thickness
  - Smoothness
  - Dowel Alignment
- **Each has**
  - Target
  - Rejectable level
  - Maximum level

All AQC tests MUST be tested with random sampling

Levels of Pavement Quality

- **Target Quality Level (TQL)**
  - At target 100% pay
  - Near target pay adjustment (incentive/disincentive)
- **Rejectable Quality Level (RQL)**
  - Corrective measures required
- **Maximum Quality Level (MQL)**
  - No further incentive

Lots and Sublots

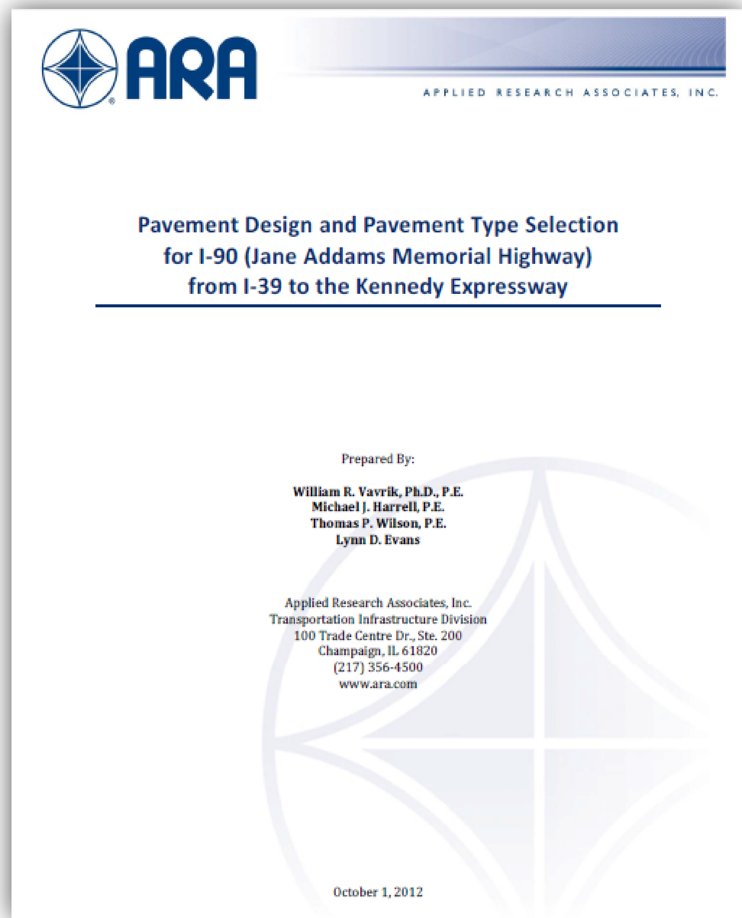
- **Lot: All mainline concrete**
- **Sublot: Division of a lot for testing and sampling**
  - One lane wide and ~1,000 ft. long (Generally 700 – 1,300 ft.)
  - Provisions for pavement blockout
    - Access areas, bridge approach, ramp transition, etc.
- **Sublot limits marked on plans (by lane)**
- **Payment is made on lot basis**
- **Rejection is made on sublot basis**

Non-Conforming Materials

- **If RQL not met, contractor to develop Corrective Action Plan**
- **No incentive/disincentive for a sublot with non-conforming materials.**
- **Accept or reject concrete on a sublot basis.**

Pavement Type Selection Report (LCCA) is the Construction PRS Basis

- Traffic
- Design
- Reliability & Performance Criteria
- Support conditions
- M & R strategies
- Costs & other miscellaneous data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APPLIED RESEARCH ASSOCIATES, INC.

Pavement Design and Pavement Type Selection
for I-90 (Jane Addams Memorial Highway)
from I-39 to the Kennedy Expressway

Prepared By:

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October 1, 2012

Maintenance and Rehabilitation Strategy

Year	Activity
0	Construct new JPCP with HMA shoulders
11	Mainline—Reseal 100% transverse joints (TJ) and 100% longitudinal joints (LJ)
	Shoulder—Rout and seal all cracks; Apply microsurface
18	Mainline—Concrete full-depth patching (3.5% of area); Reseal 100% TJ and 100% LJ
	Shoulder—Rout and seal all cracks; Apply microsurface
25	Mainline—Concrete full-depth patching (5.0% of area); Diamond grind; Reseal 100% TJ and 100% LJ
	Shoulder—Rout and seal all cracks; Apply microsurface
30	Mainline—Concrete full-depth patching (6.0% of area); Apply 4.0-in SMA overlay
	Shoulder—Apply 4.0-in HMA overlay
38	Mainline—Rout and seal all cracks
	Shoulder—Rout and seal all cracks
44	Mainline—Remove 4.0-in SMA; Concrete full-depth patching (7.0%); Apply 4.0-in SMA overlay
	Shoulder—Rout and seal all cracks; Apply microsurface

Varies
as-constructed vs. as-designed

Historical AQC Data

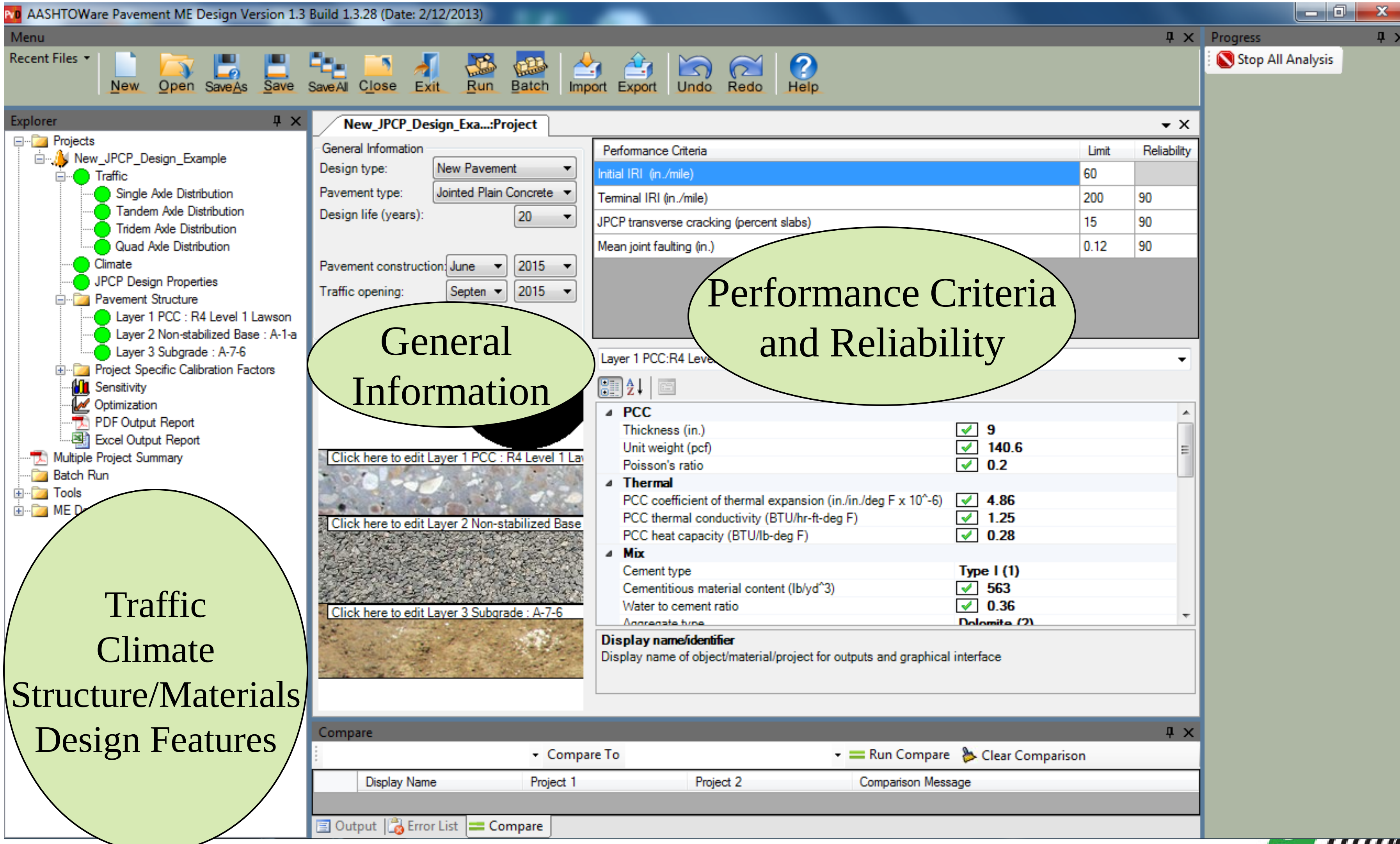
- **Means and Standard Deviations**
- **IMIRS (Illinois Materials Inspection and Reporting System) database**
  - Compressive strength, air content
- **Historical QC/QA data over last 2-5 years**
  - Smoothness, thickness
- **Other sources**
  - National historical dowel alignment data

PaveSpec 4.0
Mechanistic-Empirical Models and AQCs

Input	Significantly Impact Distress			
	Transverse "Slab" Cracking	Transverse Joint Faulting	Transverse Joint Spalling	Smoothness
Initial Smoothness	X	X	X	X
PCC Strength	X			X
PCC Thickness	X	X	X	X
PCC CTE	X	X		X
Effective Dowel Diameter*		X		X
PCC air content			X	X
PCC mix w/c ratio	X	X	X	X

*Computed by measuring dowel alignment & NCHRP 10-69 procedure

Pavement ME (MEPDG)

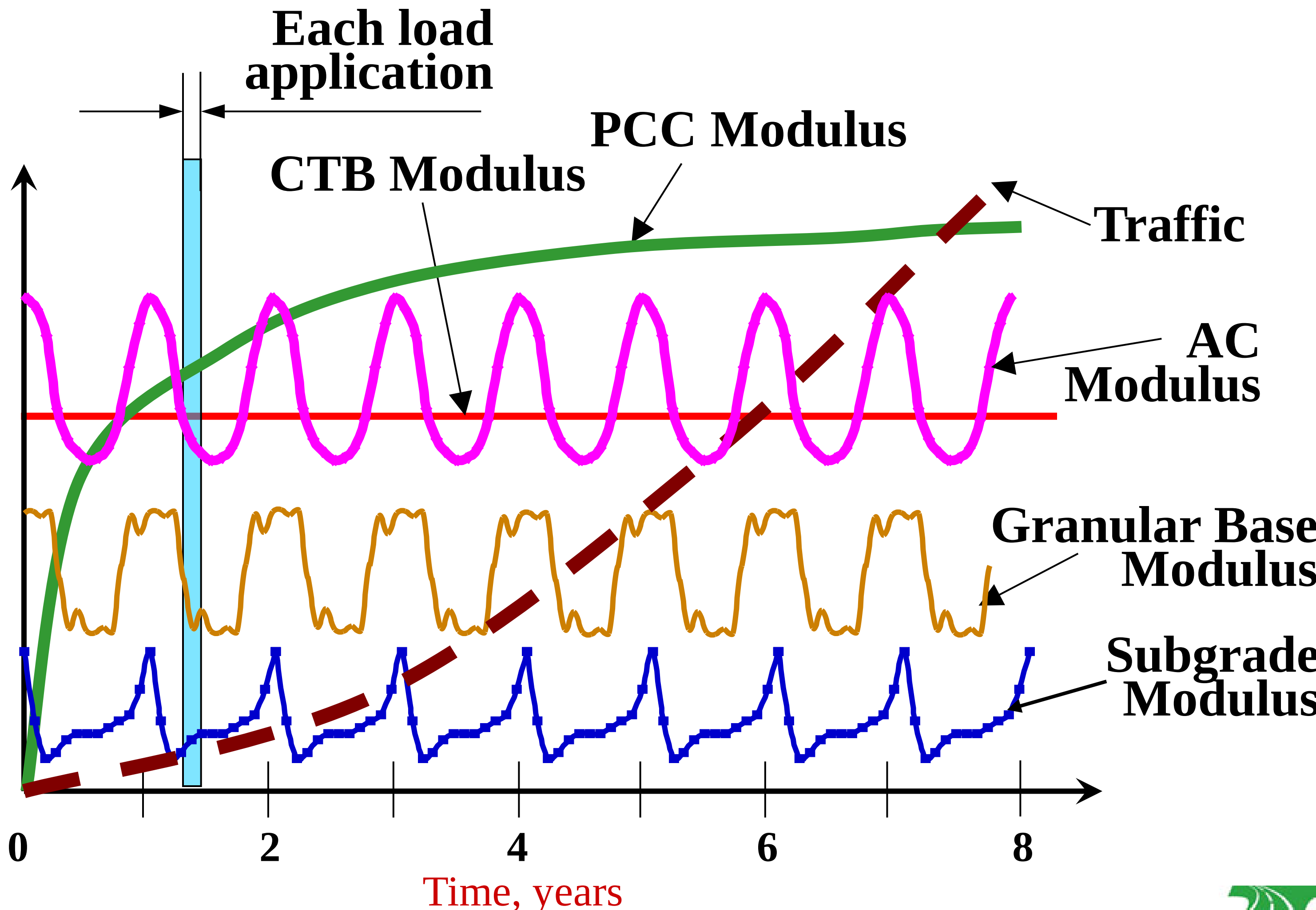


Pavement ME Structural Response Model

- **ISLAB2000—enhanced 2.5D Finite Element Method**
- **Rapid solution method required to make millions of calculations rapidly**
  - Neural network with dimensional analysis and equivalent system
  - Modified MC-HARP and traditional back-propagation neural networks

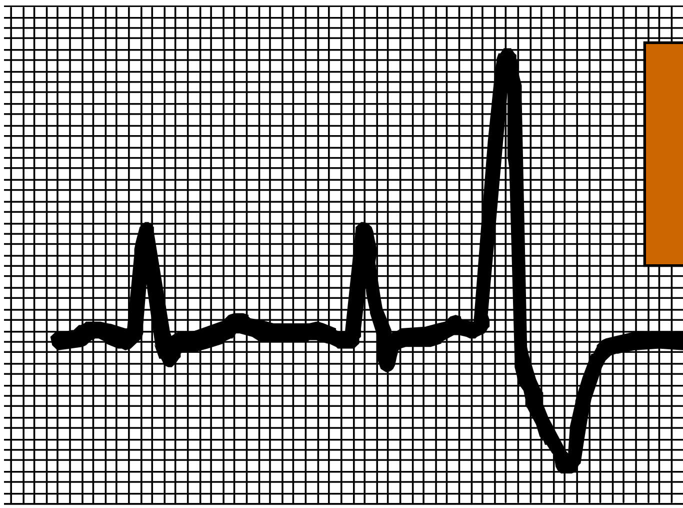
Illinois Tollway

Pavement ME Seasonal Variation of Inputs



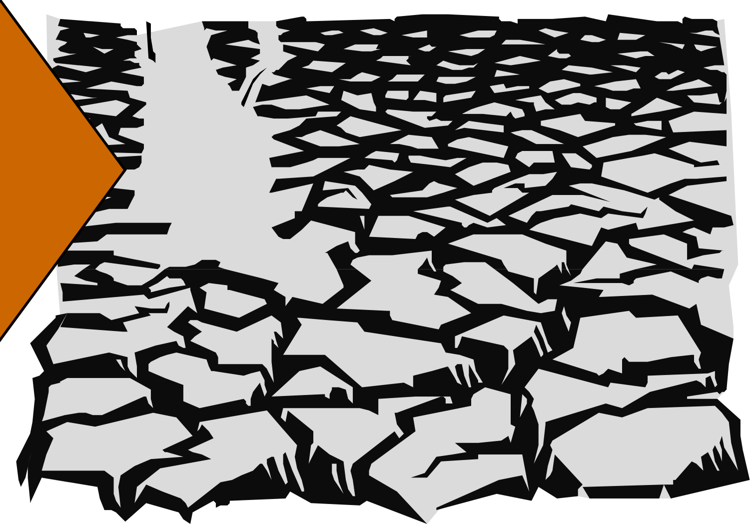
Relating Structural Responses to Distresses

Pavement Response



TRANSFER FUNCTION

Pavement Distress



- Stresses
- Deflections

Transfer Function Nationally Calibrated Coefficients

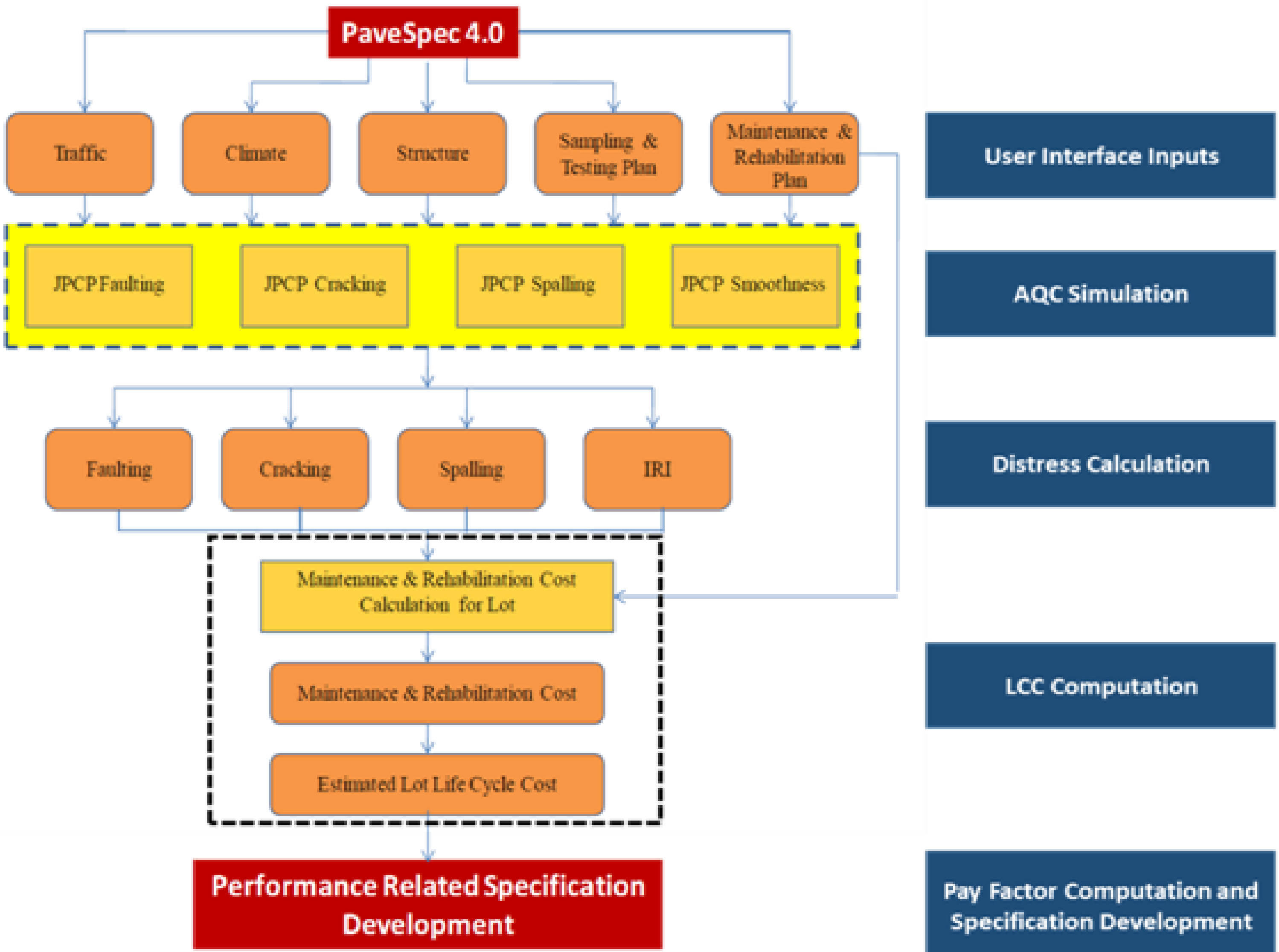
- Cracking
- Faulting

PaveSpec 4.0
Mechanistic-Empirical Models and AQCs

Input	Significantly Impact Distress			
	Transverse “Slab” Cracking	Transverse Joint Faulting	Transverse Joint Spalling	Smoothness
Initial Smoothness	X	X	X	X
PCC Strength	X			X
PCC Thickness	X	X	X	X
PCC CTE	X	X		X
Effective Dowel Diameter*		X		X
PCC air content			X	X
PCC mix w/c ratio	X	X	X	X

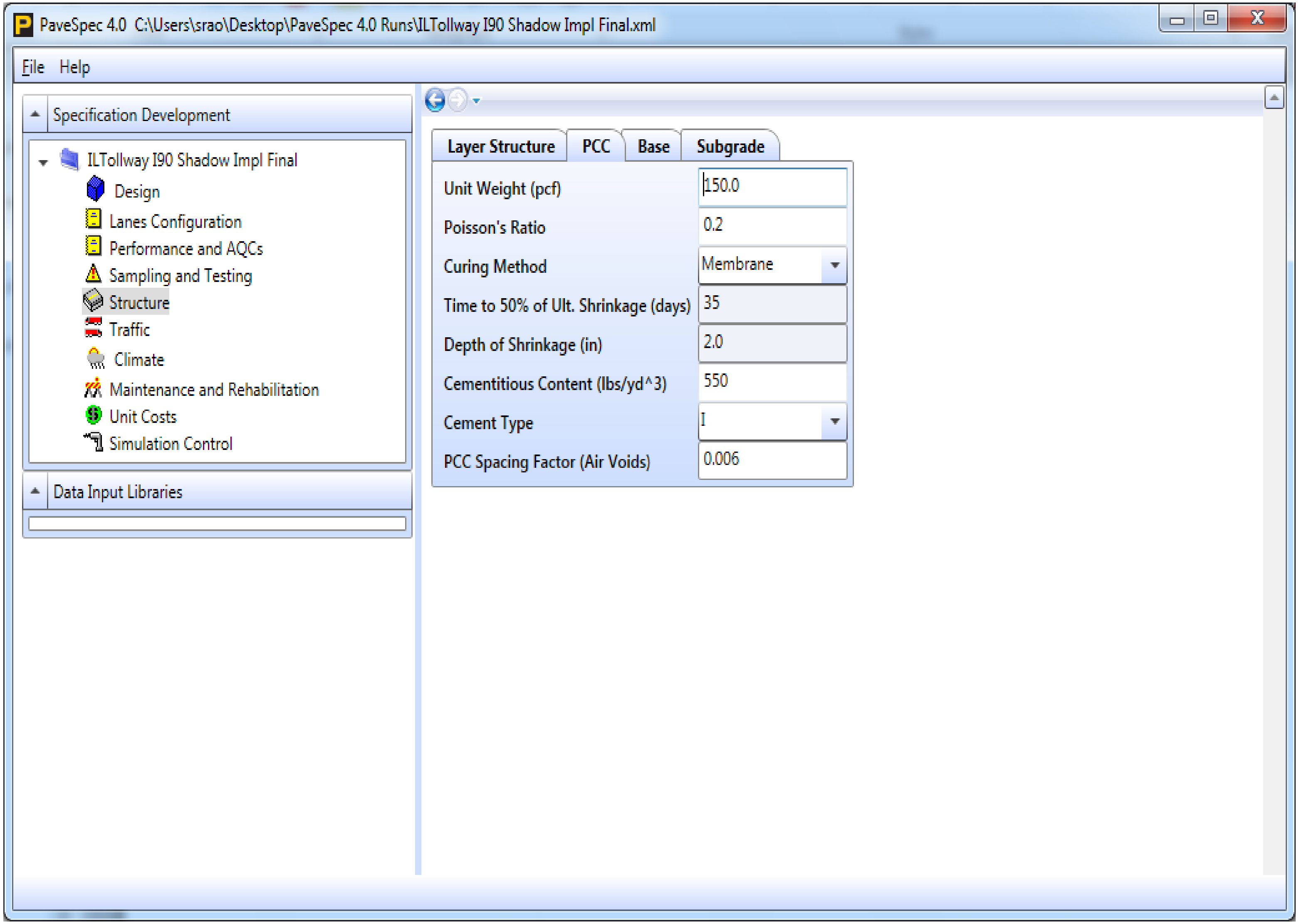
*Computed by measuring dowel alignment & NCHRP 10-69 procedure

PaveSpec 4.0

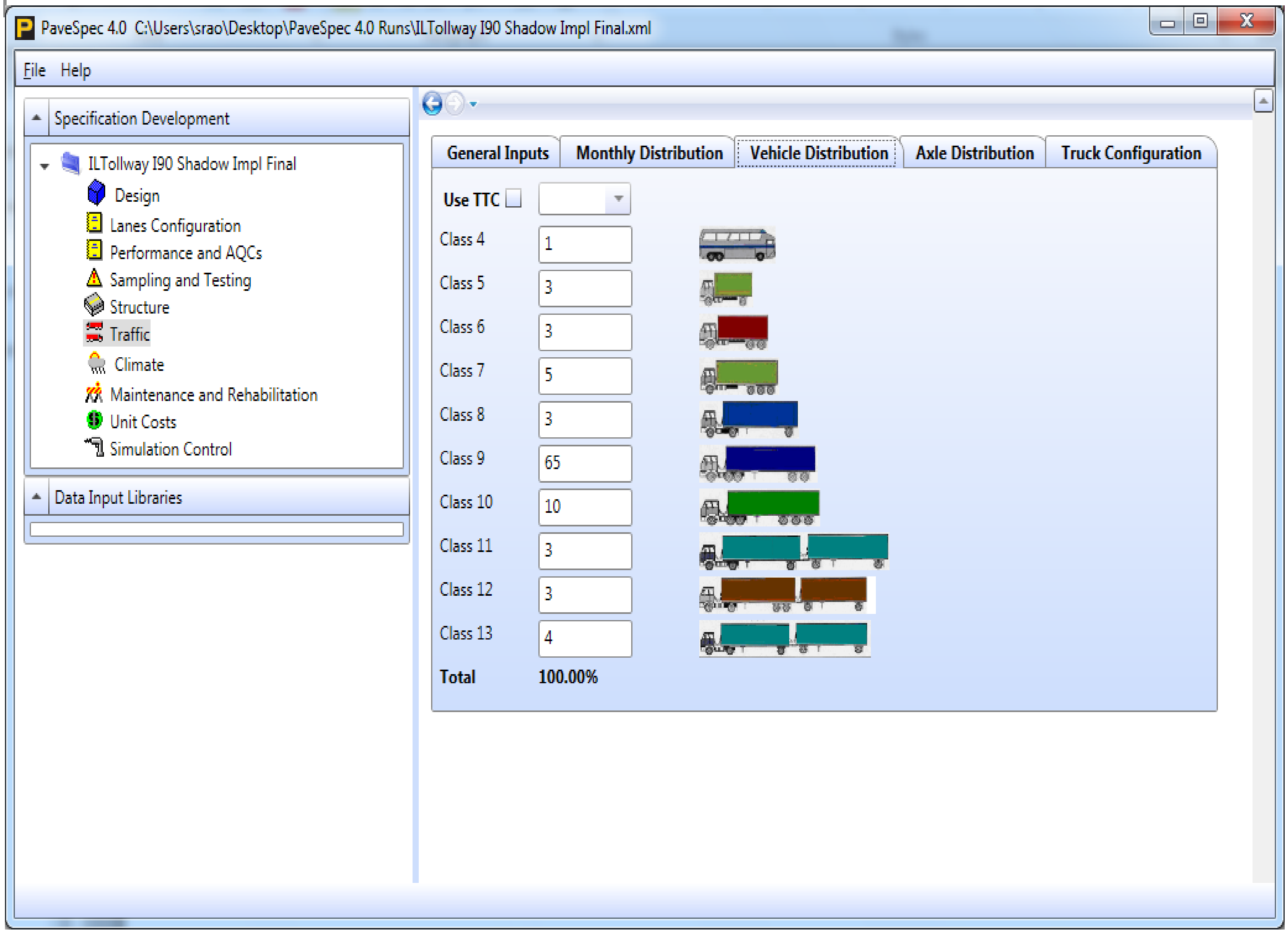


PaveSpec 4.0
Traffic
Climate
Structure
Sampling & Testing Plan
Maintenance & Rehabilitation Plan
JPCP Faulting
JPCP Cracking
JPCP Spalling
JPCP Smoothness
Faulting
Cracking
Spalling
IRI
Maintenance & Rehabilitation Cost Calculation for Lot
Maintenance & Rehabilitation Cost
Estimated Lot Life Cycle Cost
Performance Related Specification Development
User Interface Inputs
AQC Simulation
Distress Calculation
LCC Computation
Pay Factor Computation and Specification Development

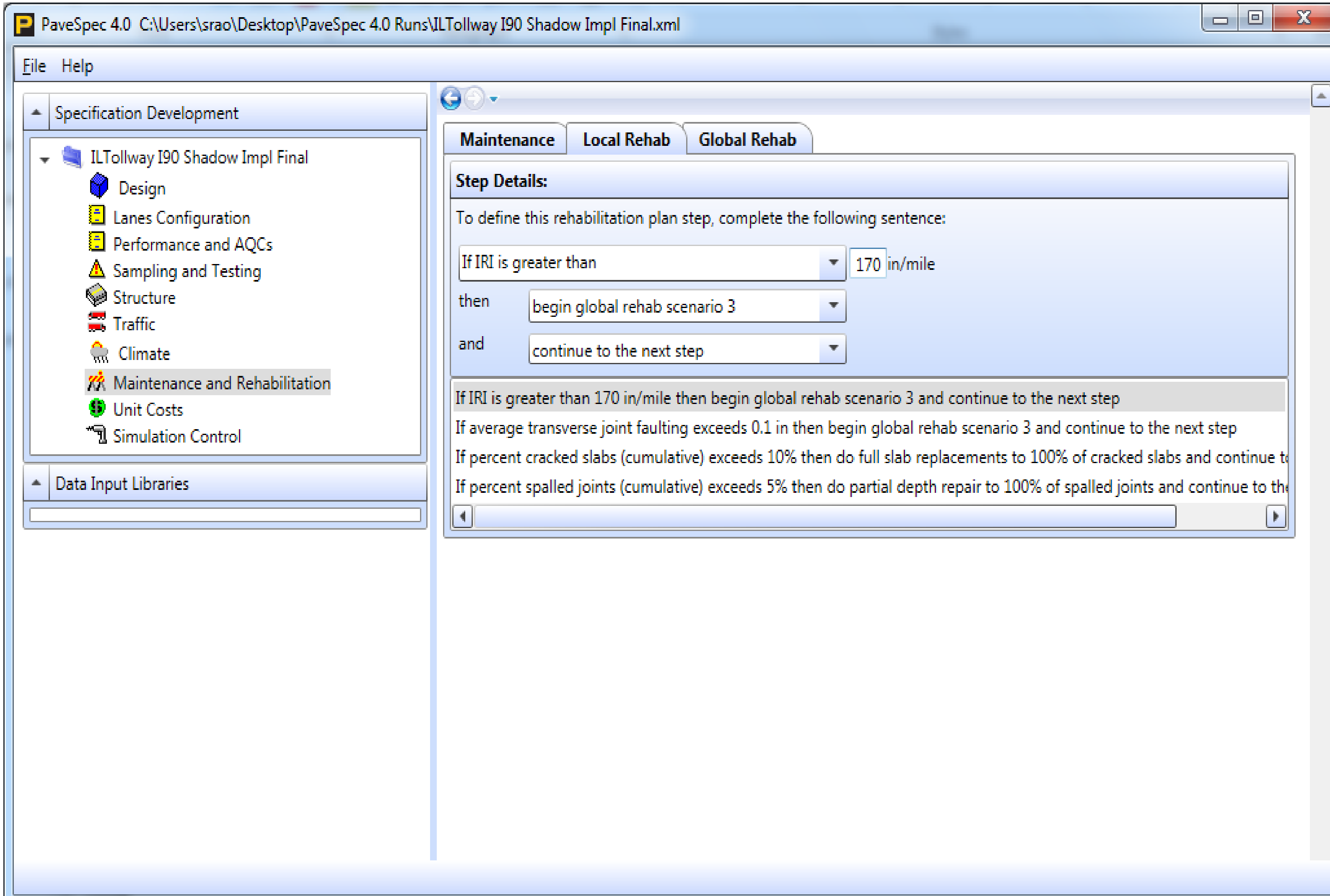
PCC Layer Inputs



Vehicle Classification Distribution

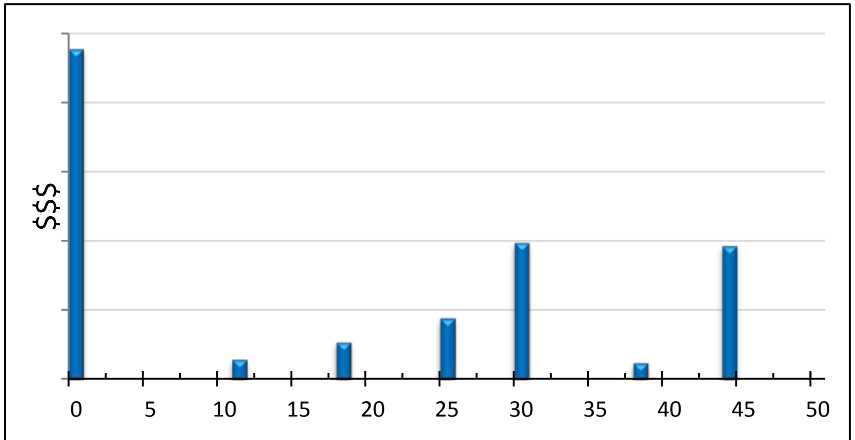


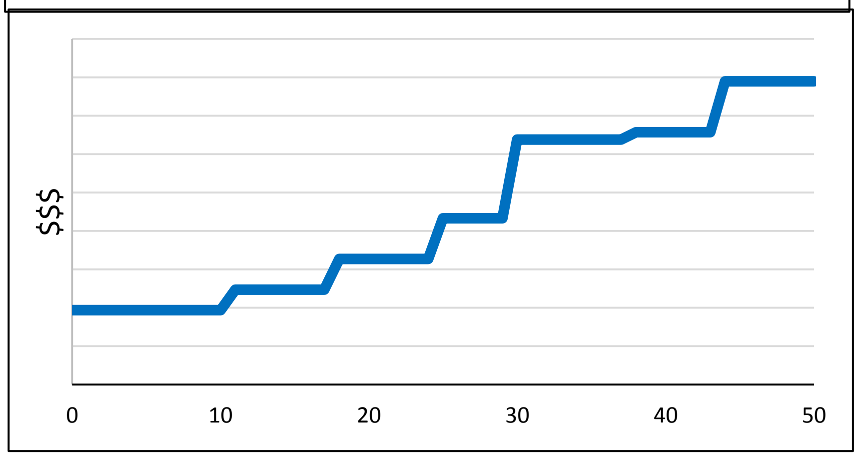
8 Maintenance & Rehab Inputs



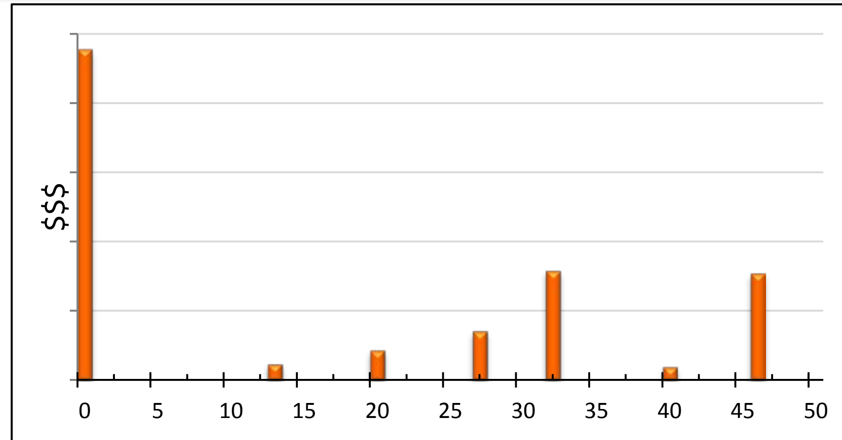
Why Use Performance Modeling for PF?

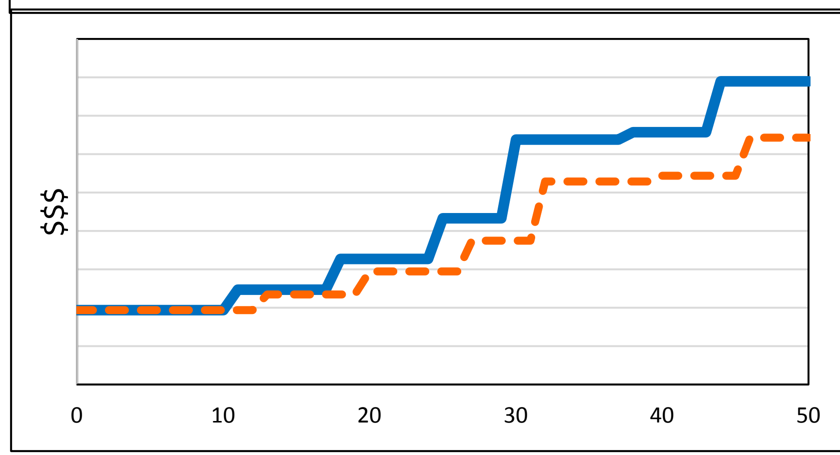
Design





As-Built





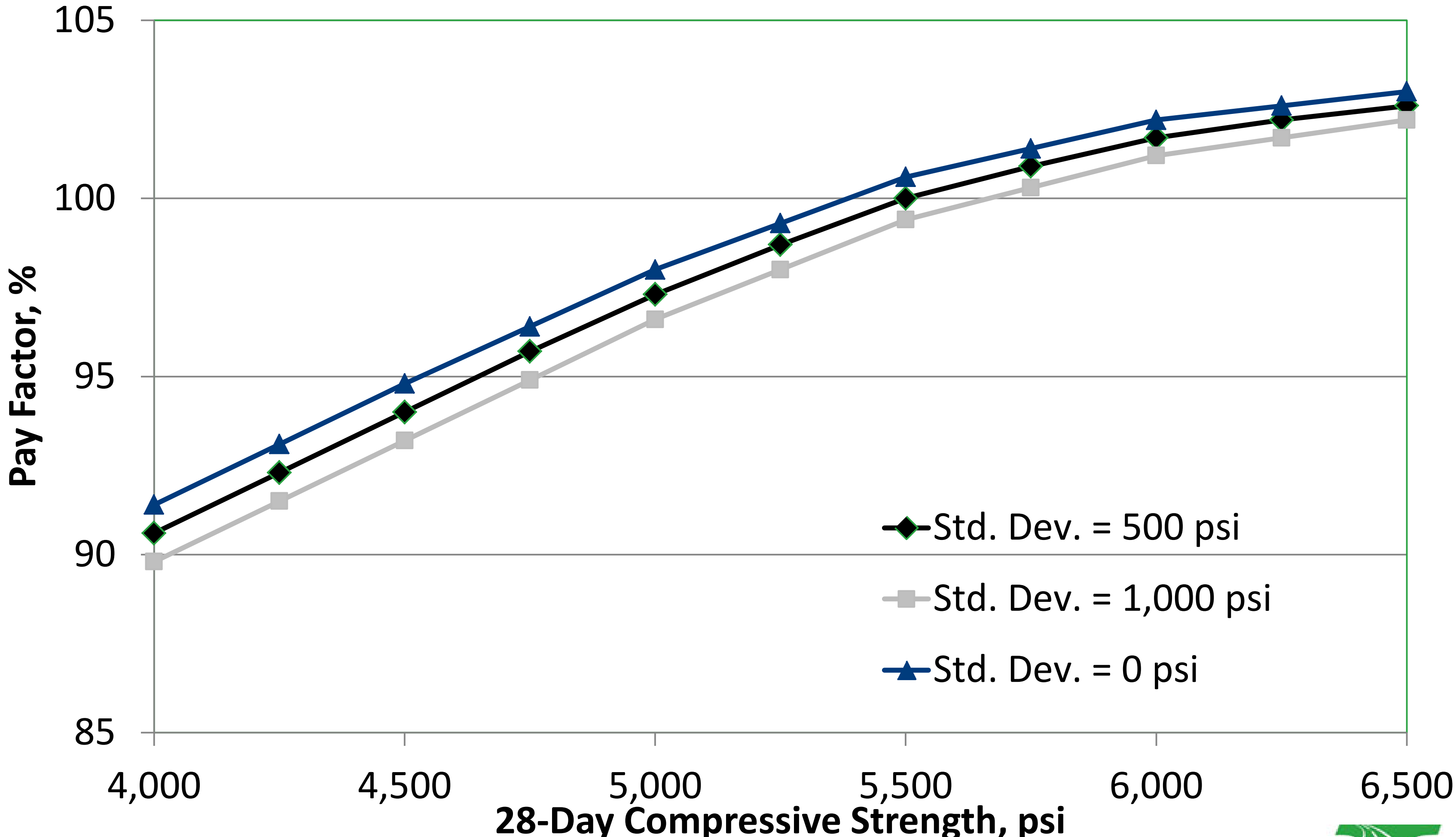
Rational and defensible pay factors to provide a measure of the value of quality that is directly related to performance

28-Day Compressive Strength

- **Test with cylinders (Illinois Modified AASHTO T22, T23)**
  - Process described in IDOT Article 1020.09 Strength Tests
  - 6”x12” cylinders only
- **Two cylinders per sublot**

Level	Mean (psi)	Std. Dev. (psi)
Target	5,500	500
Rejectable	4,000	-
Maximum	6,500	-

Strength Pay Factor Curve

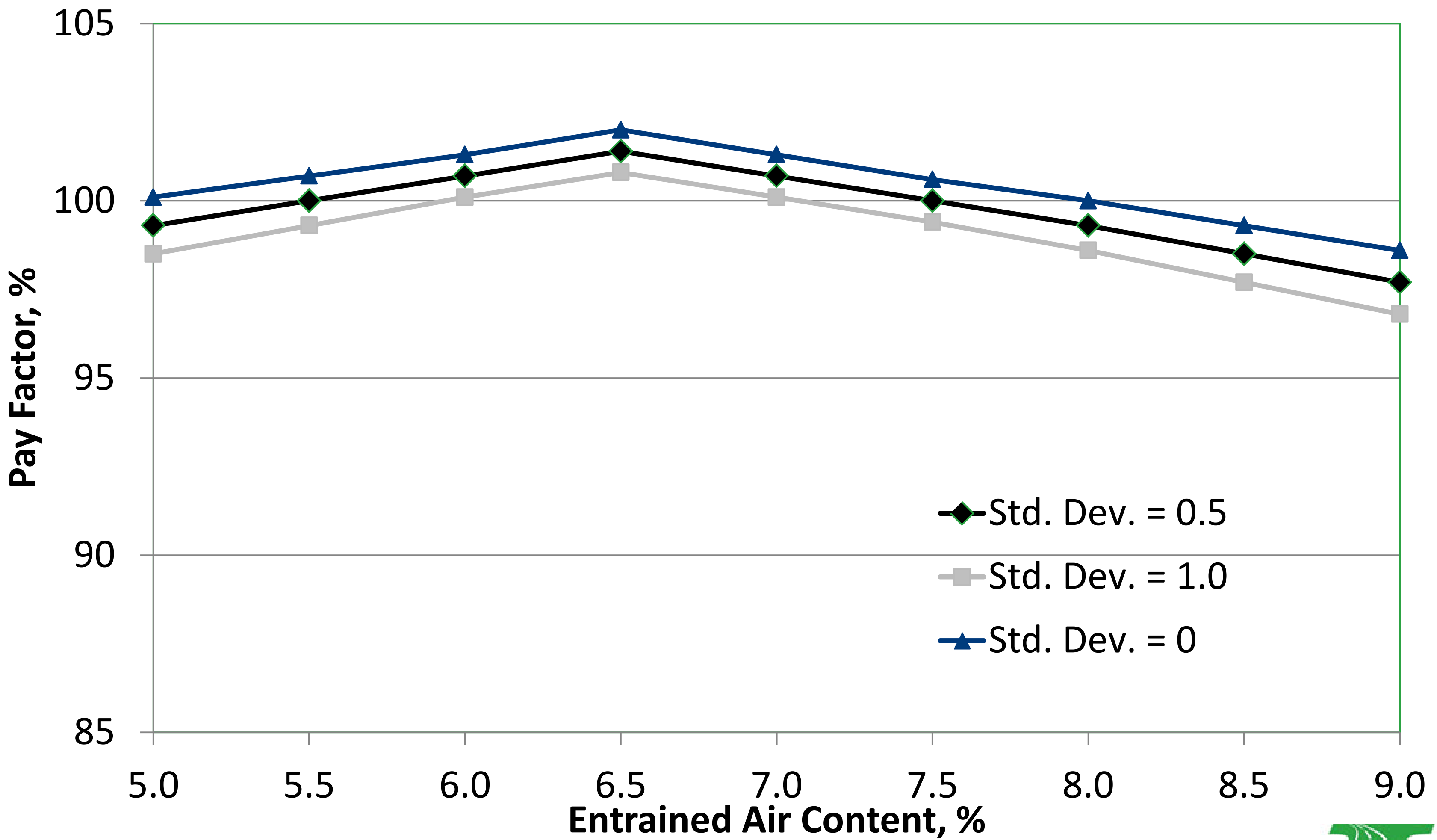


Air Content

- **Test with pressure meter according to IDOT Article 1020.08 Air Content**
- **Computed from average of four tests per sublot**
  - Same samples used for strength cylinders + 3 others

Level	Mean Content (%)	Std. Dev. (%)
Target	6.5	0.5
Rejectable	5.0	-
Maximum	9.0	-

Air Content Pay Factor Curve

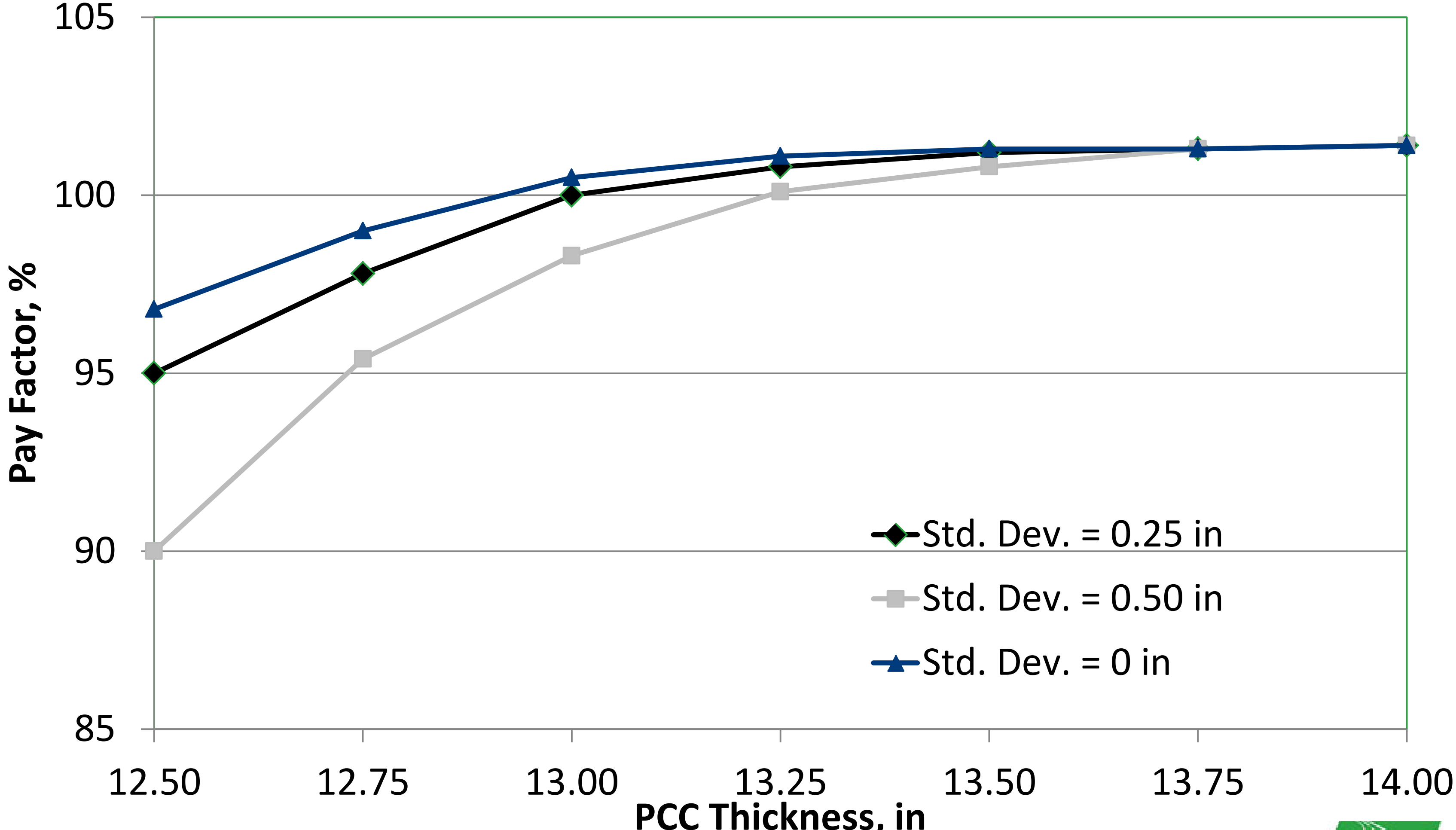


Slab Thickness

- **Test with MIT-Scan T2 meter as described by user manual**
  - Random pre-determined locations
- **Computed from average of four measurements per sublot**

Level	Mean (in)	Std. Dev. (in)
Target	Plan thickness	0.25
Rejectable	Plan thickness - 0.5	-
Maximum	Plan thickness + 1.0	-

Slab Thickness Pay Factor Curve

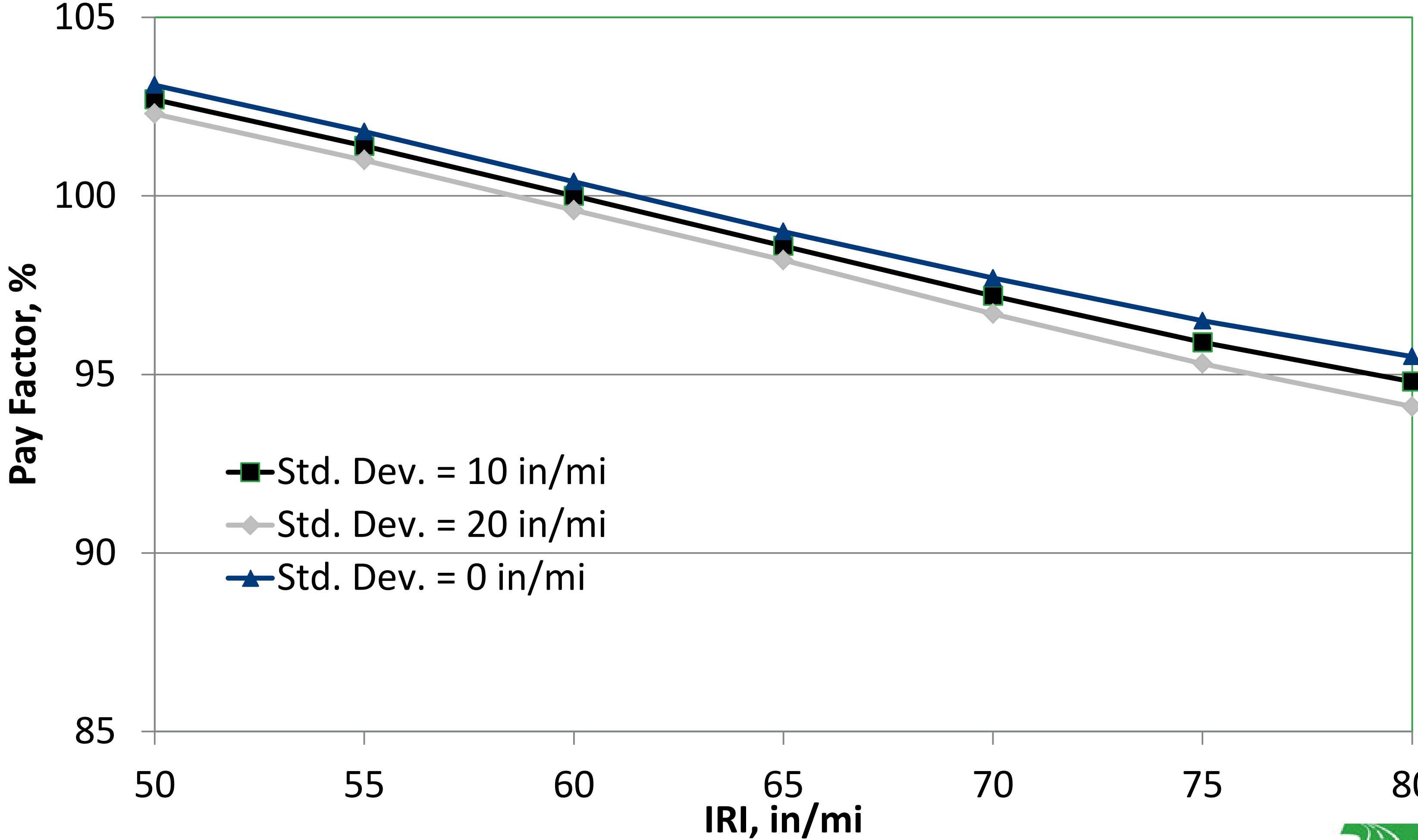


Smoothness (IRI)

- **Test in accordance with ASTM E950**
  - Class I inertial profiler
- **Test and report each wheel path**
- **Computed from average of wheel paths**

Level	Mean (in/mile)	Std. Dev. (in/mile)
Target	60.0	10.0
Rejectable	80.0	-
Maximum	50.0	-

Smoothness Pay Factor Curve

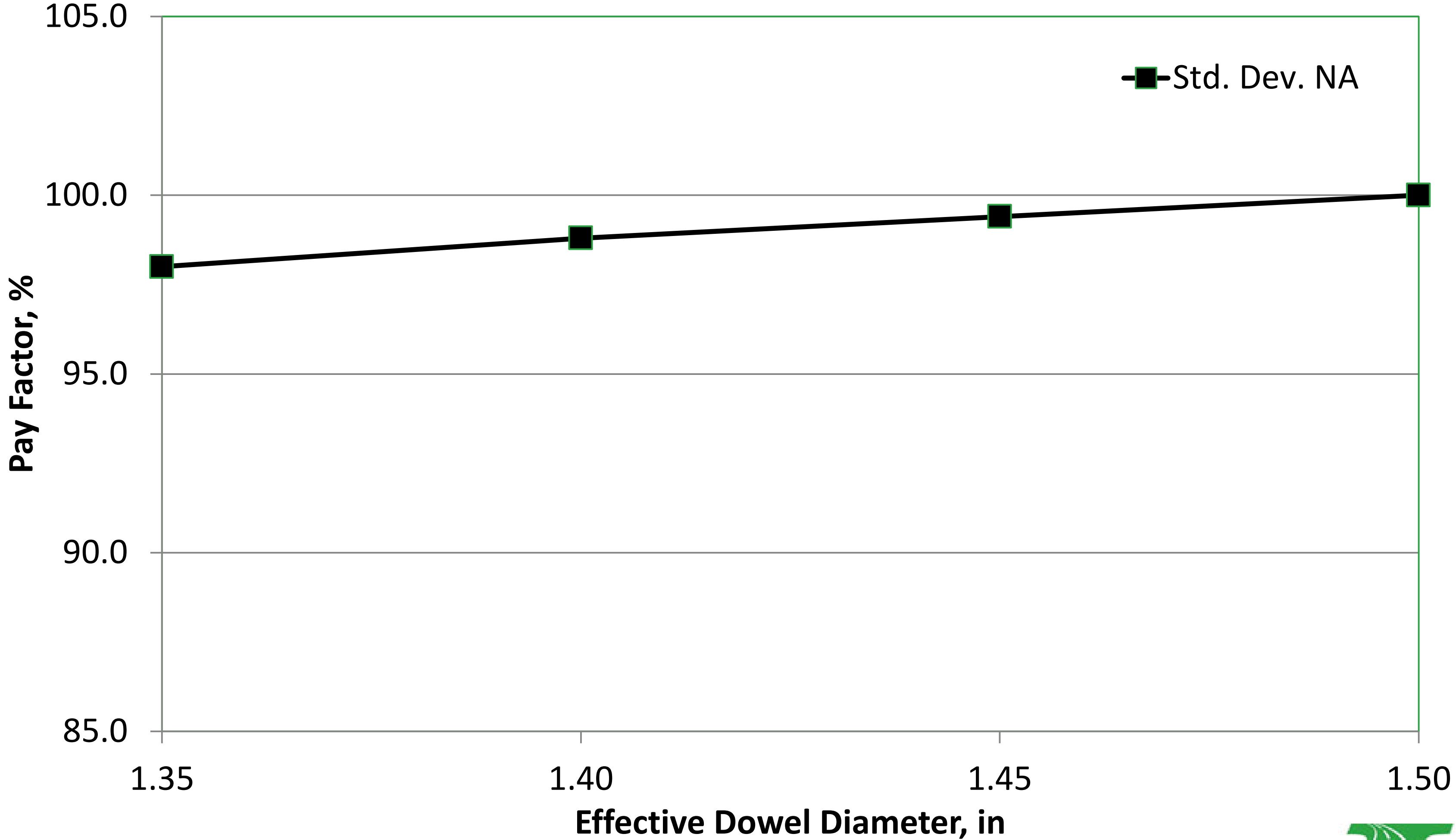


Effective Dowel Diameter (EDD)

- **Test with MIT-Scan 2**
- **Calculate EDD as described in NCHRP Report 637**
- **Averages of five consecutive joints**
- **Rejection on individual alignment criteria**
- **Process control separate of PRS**

Level	Mean (in.)	Std. Dev. (in.)
Target	1.50	N/A

Effective Dowel Diameter Pay Factor Curve



Lot Composite Pay Factors

$$PF_{lot} = \left(\frac{PF_{str}}{100}\right)\cdot\left(\frac{PF_{air}}{100}\right)\cdot\left(\frac{PF_{thk}}{100}\right)\cdot\left(\frac{PF_{smth}}{100}\right)\cdot\left(\frac{PF_{dowel}}{100}\right)100$$

Maximum Composite PF: 105%

*Minimum Composite PF: 85%**

*Provided AQCs meet the RQL standards

Spreadsheet to Track Construction Quality Data

This draft spreadsheet was developed by Applied Research Associates, Inc. for the Illinois Tollway.

It is used for computing the pay adjustment according to the performance-related specifications for rigid pavements as specified in:

PERFORMANCE-RELATED PORTLAND CEMENT CONCRETE PAVEMENT, JOINTED – 13 INCH (Tollway) Effective: September 1, 2014

Please go to tabs Strength PF, Thickness PF, Effective Dowel Diameter PF, Air Content PF, Smoothness PF and enter information as requested.
Once information is entered on those tabs, enter bid price and conforming area below for total pay adjustment.

DO NOT ENTER anything else or change anything else on this sheet.

Strength Pay Factor:	na
Thickness Pay Factor:	na
Dowel Diameter Pay Factor:	na
Air Content Pay Factor:	na
Smoothness Pay Factor:	na
Calculated Composite Pay Factor:	na
Adjusted Composite Pay Factor:	na

Enter Bid Price and Conforming Area below:

BID PRICE ($/sq. yd.):

CONFORMING AREA (sq. yd.):

Total Pay Adjustment ($): na

Data distributed to all through Ebuilder

Performance Specifications Started With Tollway Concrete Material Specs for Patching

- **Back in 2008, hundreds of long life full depth PCC patches were required on a Chicago area Tollway expressway**
- **CTL Group was hired to come of with a solution to make them fast but long life**
- **Performance Engineered Mixes (PEM's) and the specifications for them resulted**

Current Tollway Applications for PEM Specs

- **Accelerated (HES) weekend patching mixes**
- **Rapid Ca Al cement overnight patching mixes**
- **Mass concrete PCC mixes for structures**
- **HPC bridge deck / approach slab PCC mixes**
- **Ternary black rock PCC mixes for composite pavements**
- **Ternary optimized PCC mixes for single lift pavements**

Performance Requirements for HPC Deck Mixes

Test Method	Performance Requirement	Time
AASHTO T 22-10	$4000 \leq f'_{cr} \leq [f'_{cr} + 1500]$ psi at 14 days	14 days
AASHTO T 119	Slump greater than 3" for 45 minutes after water added to cement	0
ASTM C1581-09a (Ring Test)	Minimum 28 days with no cracking ***(Exempt if < than 600 lb/yd^3 cementitious & > of 1.5 gal/yd^3 SRA is used)***	28 days
AASHTO T 160-09 (Length Change)	Maximum 0.03 percent after 7 days curing and 21 days drying, zeroed at the start of drying	28 days
AASHTO T 161(A)-08 (Freeze/Thaw Mod.)	Minimum RDM of 80 percent after 300 cycles ***Exempt if ASTM C457 requirements are met and aggregate is IDOT Class A+***	74 days typ.
AASHTO T 303 (Alkali Reactivity)	Expansion less than 0.10% at 16 days ***Exempt if total alkali content from cement is < than 4 lb/yd^3***	16 days
ASTM C457-11 (Hardened Air)	Spacing factor not exceeding 0.008-in Specific surface not less than 600 in^2/in^3 Total air content not less than 4.0%	7 days
AASHTO T 277-07 (Cl Penetration)	Max 1250 Coulombs after 28 day accelerated curing	28 days

Success to Date with PEM for HPC Decks

- **Since 2012, 28 HPC bridge decks placed along I-90. Many more coming this year.**
- **Isolated shrinkage cracks found on only one of the bridges.**
- **Isolated restraint cracks found on only 12 of the 28 decks.**
- **Can we make the specs more strict?**

ARA Illinois Tollway

Recommendations to Agencies on Developing PEM Specifications

- **Reach out to the experts for ideas**
- **Collaborate with your local roadbuilders**
  - Road and bridge builders associations
  - Local ACPA chapters
- **Train the field staff (for new testing)**
- **Most importantly, develop the specs through the local concrete suppliers and chapter ACI group or NRMCA!**
- **<u>Don't wait for the Professors!</u>**

All Future Pavement Construction to Use Only Performance Related Optimized Ternary Mixes

- **Between 2014 and 2026, more than a million cu. yds. of performance related ternary pavement mixes to be produced for new Chicago expressways.**
- **Mixes will require a minimum of 35% SCM's except with cold weather placements.**
- **Blended cements allowed.**
- **Feed of washed chips to optimize gradation is mandatory.**
- **More than 500,000 cu yds to be placed on I-90 in 2015 & 2016.**

Summary of 2015 implementation of Performance Specifications at Tollway

- **Applied to nine I-90 reconstruction and widening projects with 13” JPCP**
- **No. of sublots ranged from 20 to 120 per contract**
- **Approx. 1,443,512 sq. yds. of JPCP to be built under Performance Specifications in 2015 & 2016**
- **Approx. 300k sq. yds. placed to this date.**

Results to Date as of: *11/02/2015*

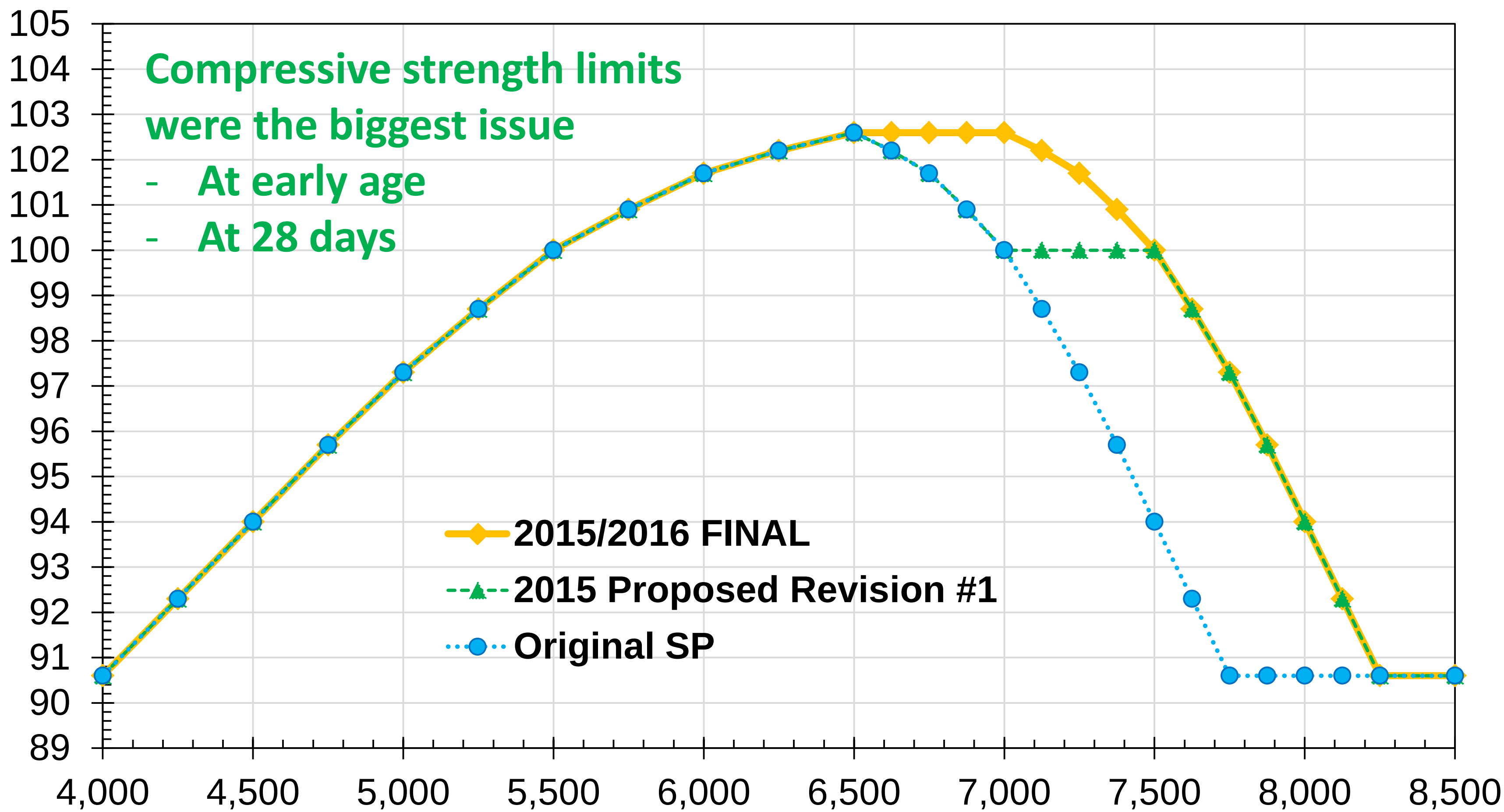
	Percent of Sublots with data (by Contract)								
	G	W	J	Z	A	Q	X	M	C
Air	90.0	84.1	64.2	20.0	38.2	20.5	58.8	57.1	60.9
Strength	75.0	66.0	34.2	18.8	8.8	17.8	14.7	35.7	34.8
Thickness	100.0	75.7	56.7	17.5	29.4	20.5	55.9	71.4	52.2
Dowel Diam.	95.0	67.3	60.0	17.5	33.8	17.8	55.9	67.9	43.5
Smoothness	55.0	0.0	1.7	13.8	0.0	8.2	23.5	0.0	4.3

Overall: 37.8 Percent of sublot/data for the pay factor types have some data

	Quality Pay Factors by Type and Contract								
	G	W	J	Z	A	Q	X	M	C
Air	100.7	101.1	101.2	101.1	101.5	101.3	101.1	101.0	101.0
Strength	98.9	100.4	100.9	95.4	102.4	99.5	101.8	100.3	98.5
Thickness	101.2	101.3	101.0	101.0	100.7	98.7	101.1	100.9	101.0
Dowel Diam.	99.9	99.9	100.0	99.9	99.9	100.0	99.9	99.8	99.2
Smoothness	99.4	100	100.6	96.9	100	94.4	94.7	100	100
Composite PF	**100.08**	**102.72**	**103.75**	**94.30**	**104.56**	**93.91**	**98.44**	**102.01**	**99.68**

100	Values have no or insufficient sublot data and are only used for the Composite PF calculation

Issues Encountered or Lessons Learned



Issues Encountered or Lessons Learned

Mix Designs More Important	Good Measurement Critical

- **Allow for slight mix design adjustments to be quickly approved (7 days)**
- **Be prepared for many trial batches**
- **Make the Contractor responsible for preparing and delivering compressive strength cylinders**
- **Make sure agency's labs cure and test properly**

Issues Encountered or Lessons Learned

- Plan for the hand pours or manual placements
  - Allow for sublot boundaries to be adjusted
  - Locations of manual placement paid for at bid price with no adjustment potential
  - Minimum properties required to be obtained as measured using QC/QA, not PRS
- Smoothness measurements delayed when new pavement is used as a haul road in narrow work zones
- Don't let the contractor sneak in his own QC data

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Issues Encountered or Lessons Learned

- **Possibly account for cold weather placements**
  - **Reduce SCM content in mixes after the need for cold weather protection arrives**
  - **Create second lot with compressive strengths and smoothness pay factors eliminated from composite pay factor for all placements afterwards**

2015 PRS Construction Revision

- **Mix Designs**
  - **3-day Strength – reduced to 2500 psi**
  - **Mix Design adjustments – faster approval (7 days)**
- **Pavement PRS**
  - **Strength Testing Calculation (Third Cylinder)**
  - **Strength Pay Factor adjusted**
  - **Dispute response time: revised from 3 to 14 days**
  - **Blockouts / Handpours defined and preapproved**
  - **Late Season Paving accounted for**

Benefits to Performance Specifications

- **Improved design-to-construction communication**
- **Develop more rational pay factors**
- **Improved and focused testing by all parties**
- **Improved understanding of performance by all**
- **Improved quality focus**
- **Clearer distinction in roles and responsibilities**
- **Creates a more innovative environment**
- **Most importantly – overall cost savings!**

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Recommendations to Agencies on Developing PRS Specifications for JPCP

- **Specify most objective procedures for measurement of quality characteristics to minimize dispute resolution battles with the contractors.**
- **Be prepared for agency to be totally responsible for taking measurements.**
- **Allow for 1 to 3 year warranties to still be used with the promise to the industry to reduce them or eliminate them should PRS show improvements down the road.**
- **Shadow current projects to establish database to base future PRS quality characteristic limits on.**

Next Tollway Endeavor with PRS

- Develop PRS for continuously reinforced concrete pavements
- Being re-engineered by the Tollway through ARA, U of I, Texas A & M, and Oregon State to be more dependent on the performance of mix and more economical to build
- Start to develop PRS for asphalt mixes and pavement construction

THANK YOU

U.S. Department of Transportation
Federal Highway Administration

Develop and Deploy Performance-Related Specifications (PRS) for Pavement Construction

FHWA DTFH61-13-C-00025

ARA

NC STATE UNIVERSITY

OSU Oregon State UNIVERSITY

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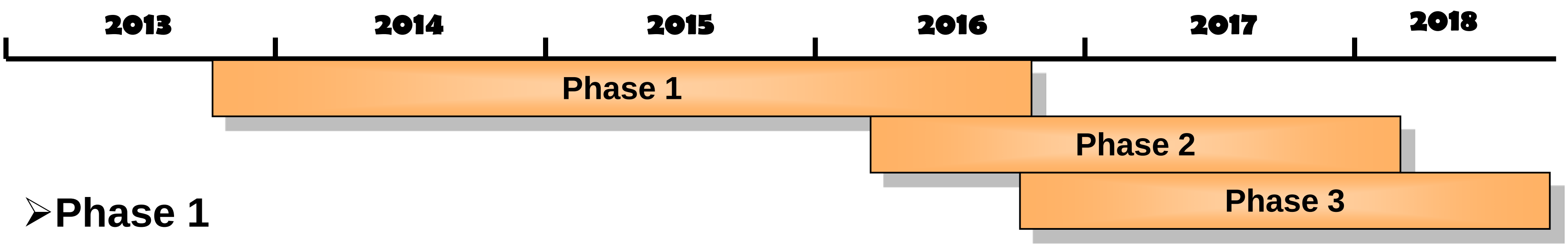

- **Phase 1**
  - **Development of PRS models and software**
    - **Asphalt and Jointed Plain Concrete Pavements**
  - **Guidelines development**
  - **Deployment projects and PRS validation**
- **Phase 2**
  - **Sensitivity analysis**
  - **Software integration**
  - **Inspection and material testing program optimization**
  - **PRS refinements**
- **Phase 3**
  - **Pay factor weighting evaluation**
  - **Risk evaluation**
  - **PRS final refinements**

Develop and Deploy Performance-Related Specifications (PRS) for Pavement Construction

- **WHAT WE ARE WORKING ON RIGHT NOW (PCC)**
    - **Improved durability models for PCC**
    - **Improvement to PaveSpec 4.0**
        - Speed
        - Analysis Engine
        - Life-Cycle Cost Analysis
        - User Costs
        - Sampling/Testing Details and Lot/Sublot Analysis
    - **Incorporation of durability models into PaveSpec**
    - **Guideline documents**

Interested in Shadow Implementation?

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