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미국의 아스팔트 공용성 시방 연구현황

김영수

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North Carolina State University

한국도로학회 아스팔트콘크리트 분과 위원회 세미나

2019년 6월 5일

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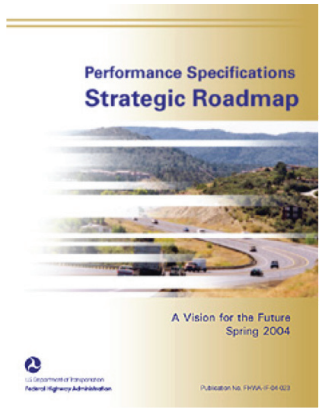
Challenges

- "D" Rating of Roads by the 2017 ASCE Report Card
- Proliferation of new materials
  - RAP, RAS, WMA, REOB, Bio-binders, etc.
- Increase in material costs and reduction in available funds – Need 'better' engineering
- Limitations of volumetric design
- Limitations of empirical index tests
- Integration of mix design-structural design-quality assurance specifications

Performance Specifications Strategic Roadmap: A Vision for the Future

Federal Highway Administration (2004)

- Vision: The performance of highway facilities will improve through better **translation of design intent and performance requirements into construction specifications.**
- Mission: To establish performance specifications as a viable contract option.
- *"**Freedom to innovate with accountability to deliver** is the driving force behind the performance specification movement."* - Ted Ferragut, TDC Partners, Ltd



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Performance Specifications

Words of Wisdom

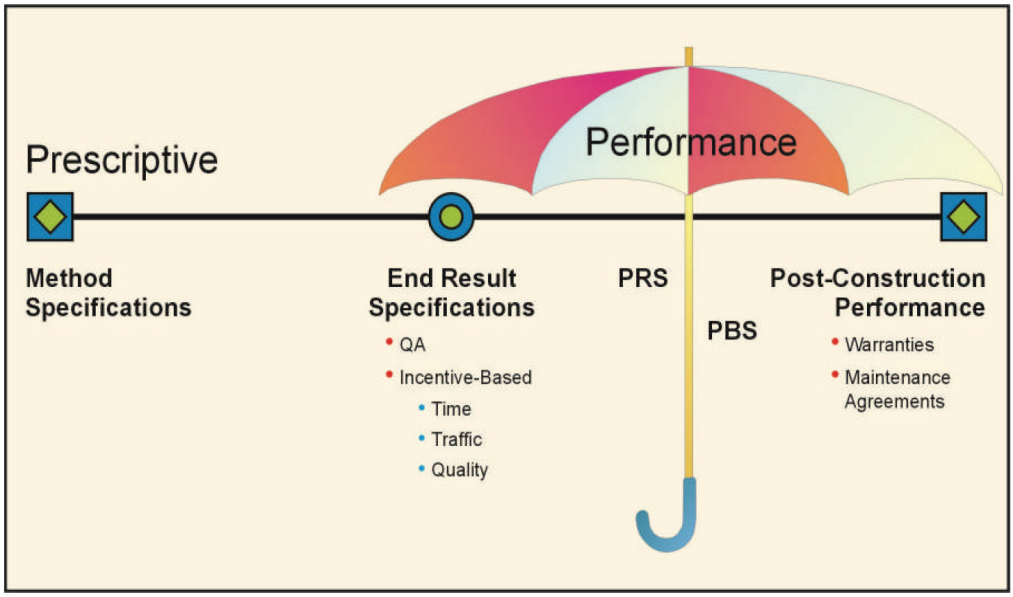
If you want a good tasting food,

Don't tell the cook how to make it!

They may surprise you with how good it can taste!

Type of Specifications

SHRP2 R07



Scott et al. 2013. Performance Specifications for Rapid Highway Renewal. SHRP2 R07.

Performance-Based Specifications

Transportation Research Circular E-C137

- QA specifications that describe the desired levels of **fundamental engineering properties** that are predictors of performance and appear in primary prediction relationships (i.e., pavement performance prediction models). **Because most fundamental engineering properties associated with pavements are currently not amenable to timely acceptance testing, PBS have not found application in highway construction.**

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Performance-Related Specifications

Transportation Research Circular E-C137

- QA specifications that describe the desired levels of key **materials and construction quality characteristics** (e.g., volumetric, density, thickness) that have been found to **correlate with fundamental engineering properties that predict performance. These characteristics are amenable to acceptance testing at the time of construction.** They provide the basis for rational acceptance/pay adjustment decisions.

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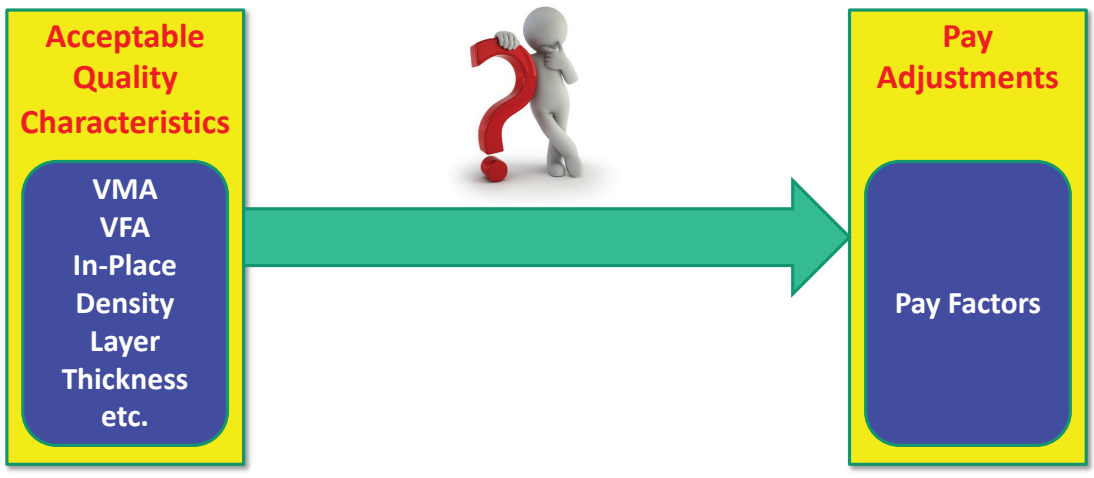
Current QA Specification



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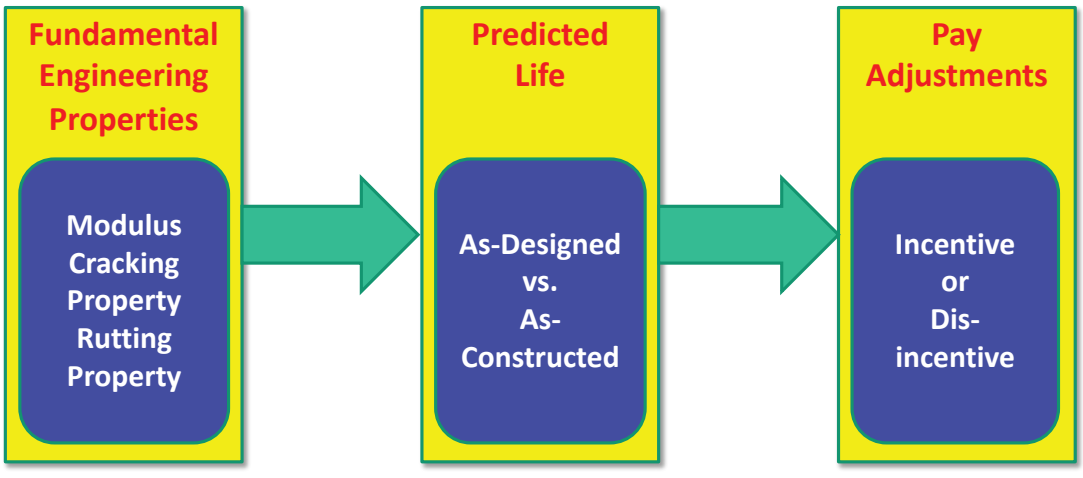
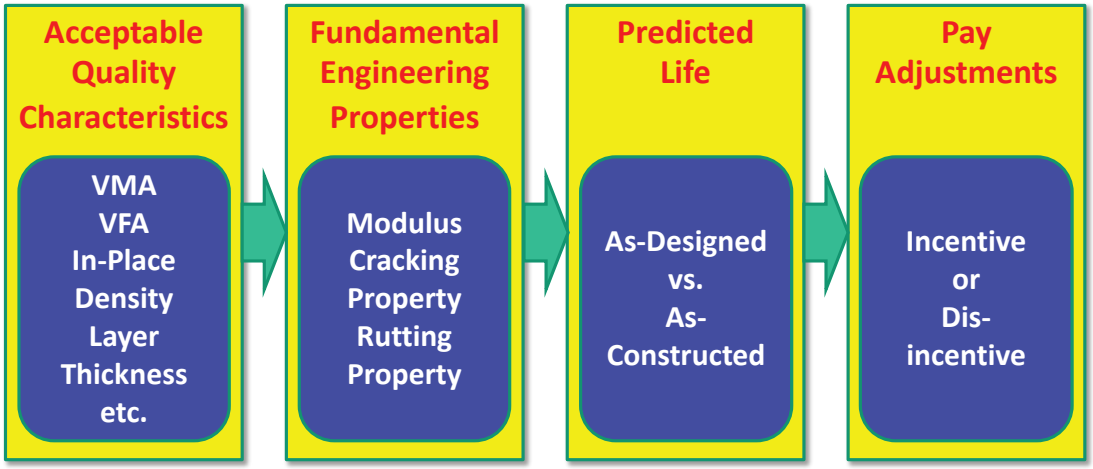
Performance-Based Specification



Performance-Related Specification



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Vision of FHWA

"Performance-Related Specifications (PRS) is the future of pavement specification type."

PRS

- PRS contains two types of models:
  - Performance prediction models
  - Maintenance cost models
- Pay adjustments are determined by comparing:
  - As-designed LCC
  - As-constructed LCC

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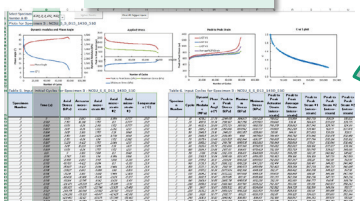
Challenges in PRS Acceptance

- Principles underlying performance prediction models are **complex**.
- Testing **efficiency** and **simplicity**
- **Standardization** of test methods
- **Field validated** performance prediction models
- **Same principles and test methods** from material specifications, mix design, pavement design, and PRS

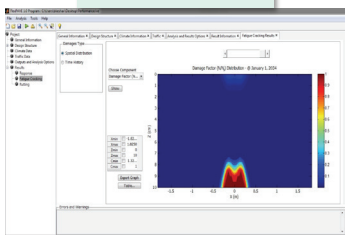
FlexPAVE™ System

AMPT

FlexMAT™



FlexPAVE™



FlexPAVE™ System allows the integration of:

- Performance engineered mix design
- Mechanistic-empirical pavement design
- Performance-related specification

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AMPT Performance Test Methods

AMPT Performance Test Methods

- **Modulus**
  - Axial compression dynamic modulus test (AASHTO T 378 or TP 132)
  - Dynamic modulus mastercurve and time-temperature shift function
- **Cracking Resistance**
  - AMPT cyclic fatigue test (AASHTO TP 107 or TP 133)
  - C vs. S (damage characteristic curve)
  - Energy-based failure criterion
- **Rutting Resistance**
  - Stress Sweep Rutting (SSR) test (AASHTO TP 134)
  - Reduced load time and stress shift factors
  - Shift model coefficients

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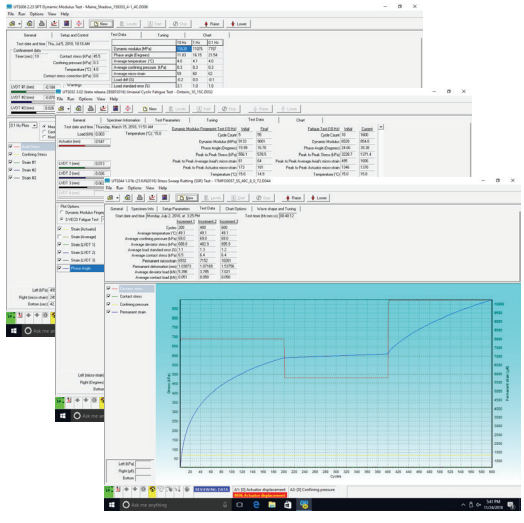
Asphalt Mixture Performance Tester

AMPT



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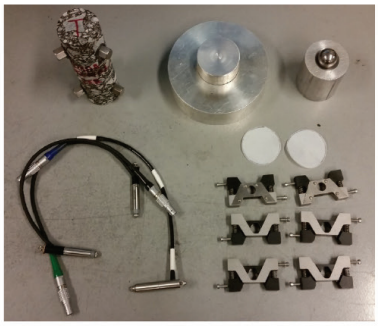
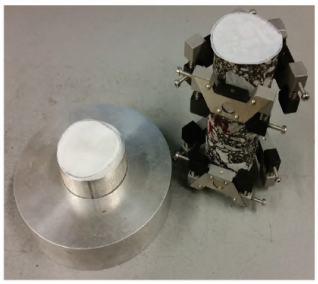
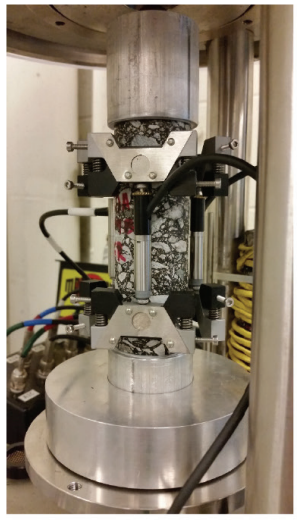
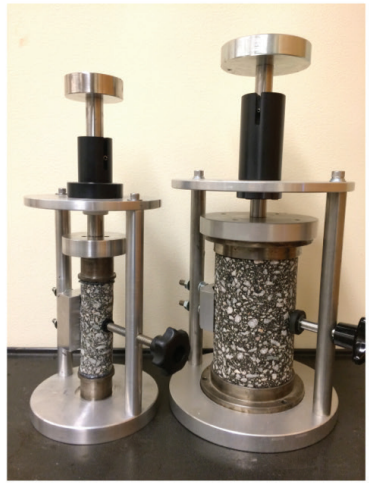
Hardware









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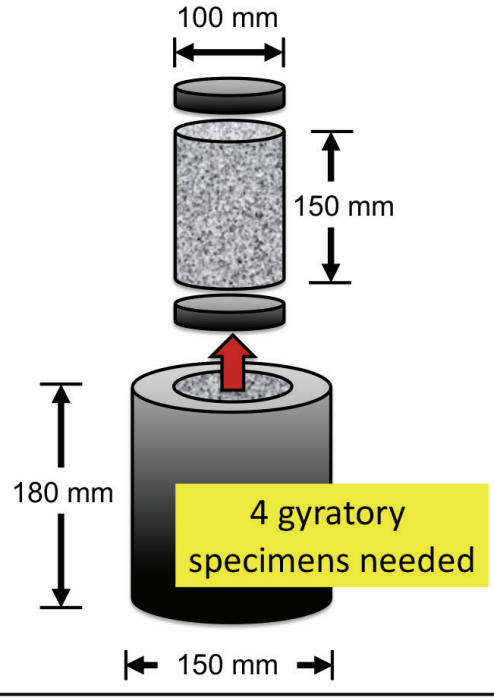
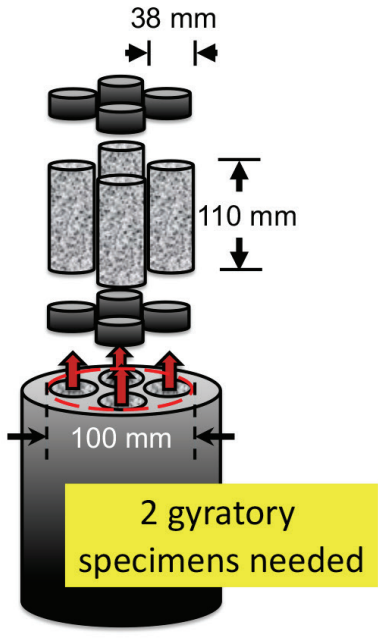
Rutting Test Specimen



E* and Fatigue Test Specimen



AMPT Performance Testing Efficiency

Test Method	Number of Tests	Testing Time
Dynamic Modulus Test	3	1 day
Cyclic Fatigue Test	3	1 day
Stress Sweep Rutting Test	4	1 day
Total	10	3 days

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FlexMAT™ for Material Level Analysis

FlexMAT™

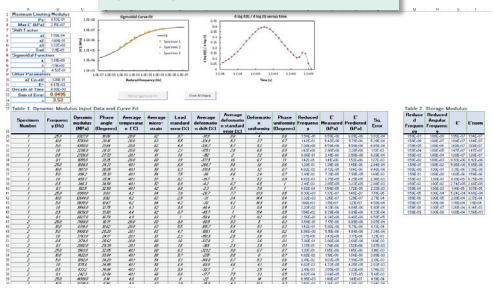
Import Data from AMPT

	A	B
1	**FlexMAT Input**	
2	Number of Specimens	
3	Dynamic Modulus Test	3
4	Fatigue Test	3
5	AC Mix Properties	
6	VMA (%)	18.9
7	VFA (%)	64.1
8	Optional Analysis	
9	Nf Prediction	
10	Temperature (°C)	
11	Strain Amplitude (με)	
12	Frequency (Hz)	
13	Nf	
14	Damage Capacity, Sapp	
15	Temperature (°C)	
16	Sapp	

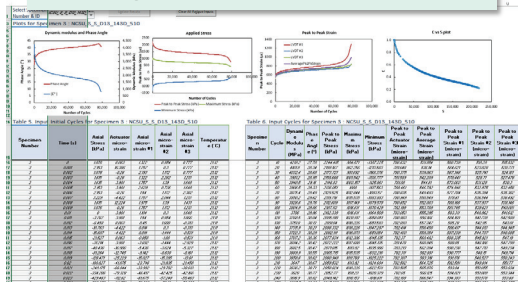
Load Dynamic Modulus Data | Load Fatigue Data | Clear All Inputs

FlexMAT™ Analysis

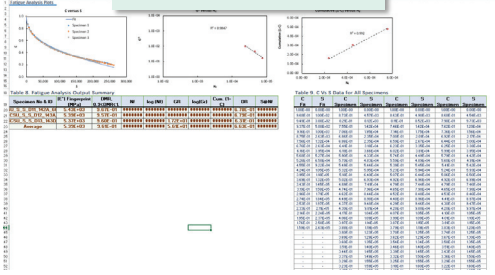
|E*| Mastercurve



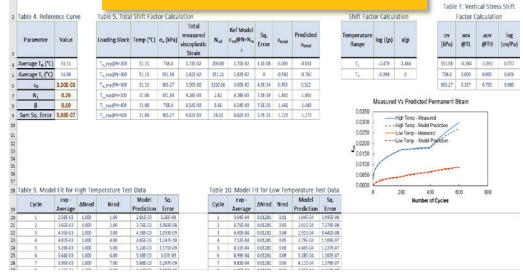
Damage Characteristic Curve



Failure Criterion



Rutting Shift Model



FlexPAVE™ for Pavement Performance Prediction

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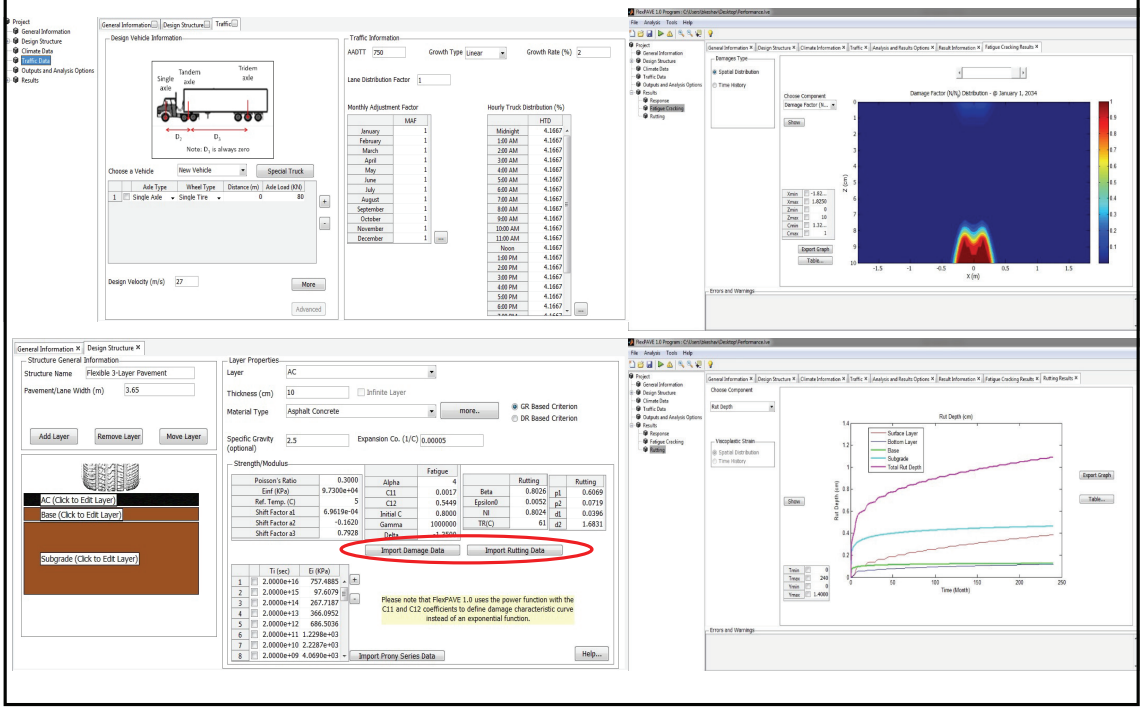
FlexPAVE™



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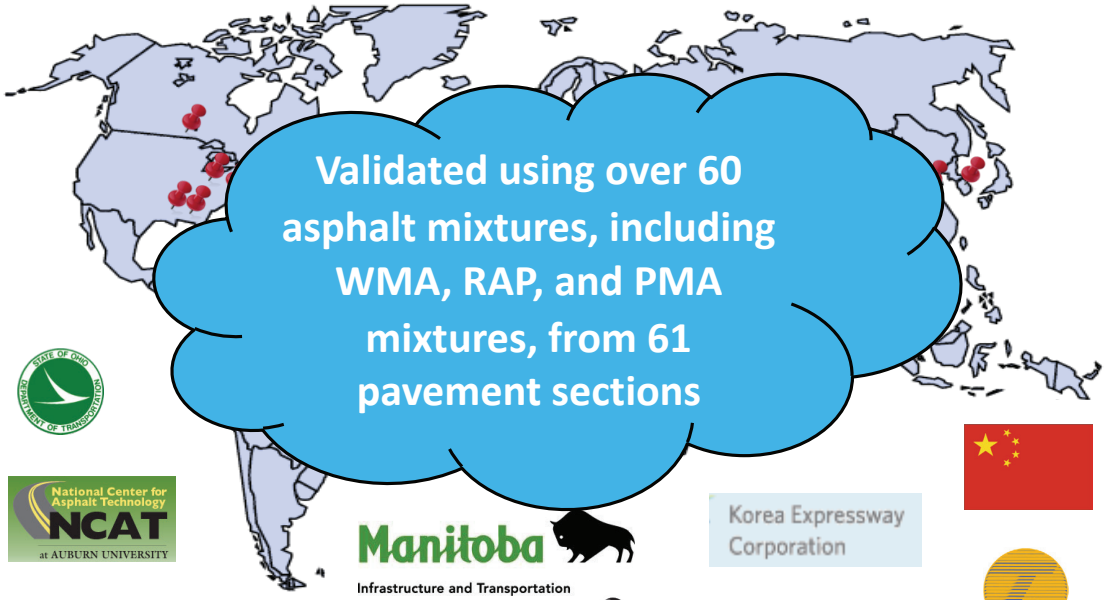
Validation Sections



Validated using over 60 asphalt mixtures, including WMA, RAP, and PMA mixtures, from 61 pavement sections

National Center for Asphalt Technology NCAT at AUBURN UNIVERSITY

Manitoba Infrastructure and Transportation

Korea Expressway Corporation

WesternResearch INSTITUTE

U.S. Department of Transportation Federal Highway Administration

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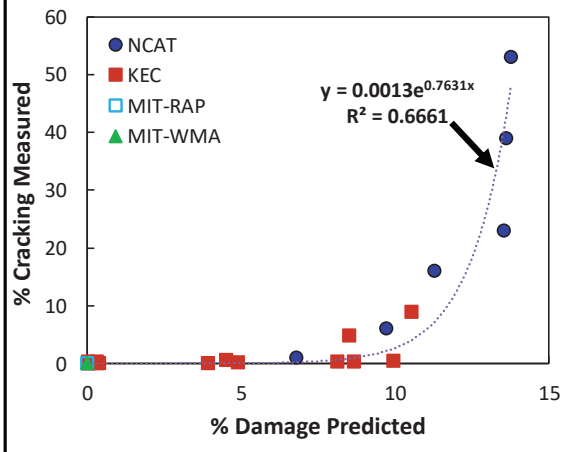
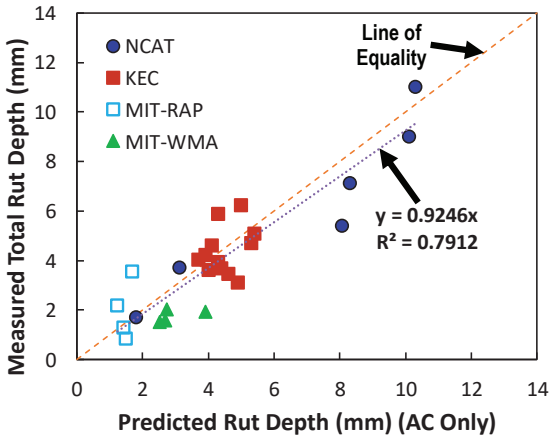
Field Validation





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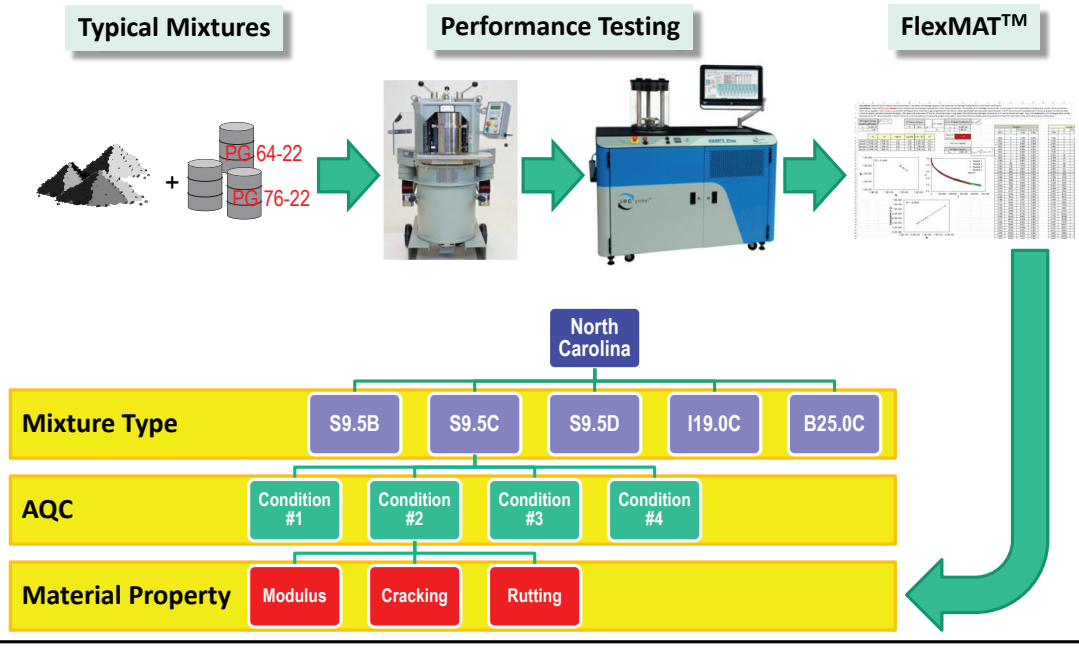
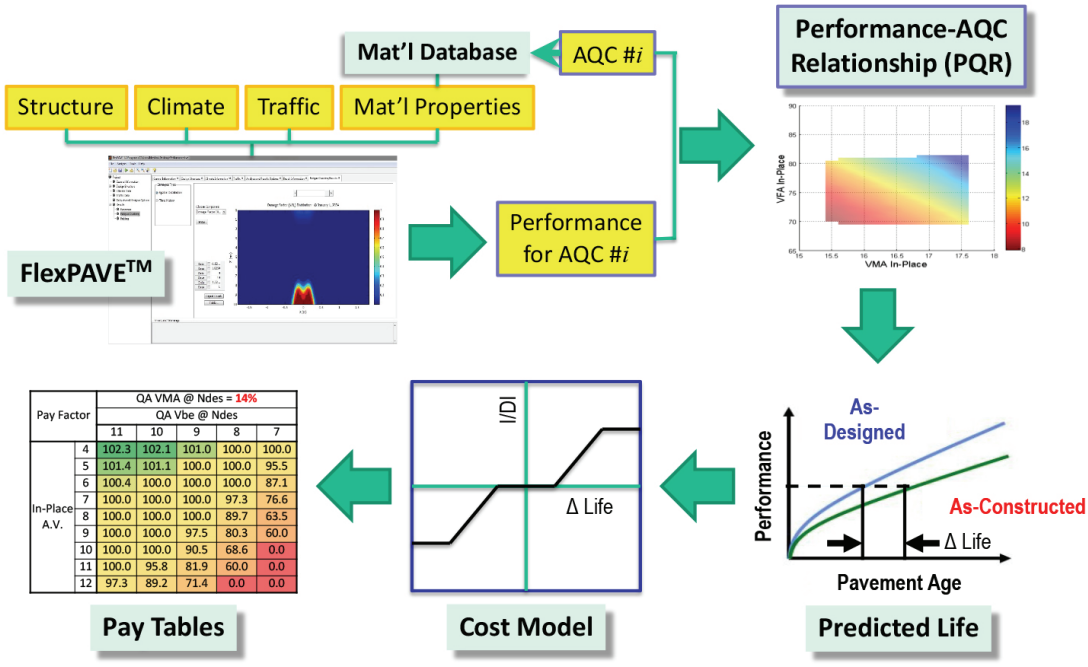
Asphalt Mixture Performance-Related Specifications (AM-PRS)

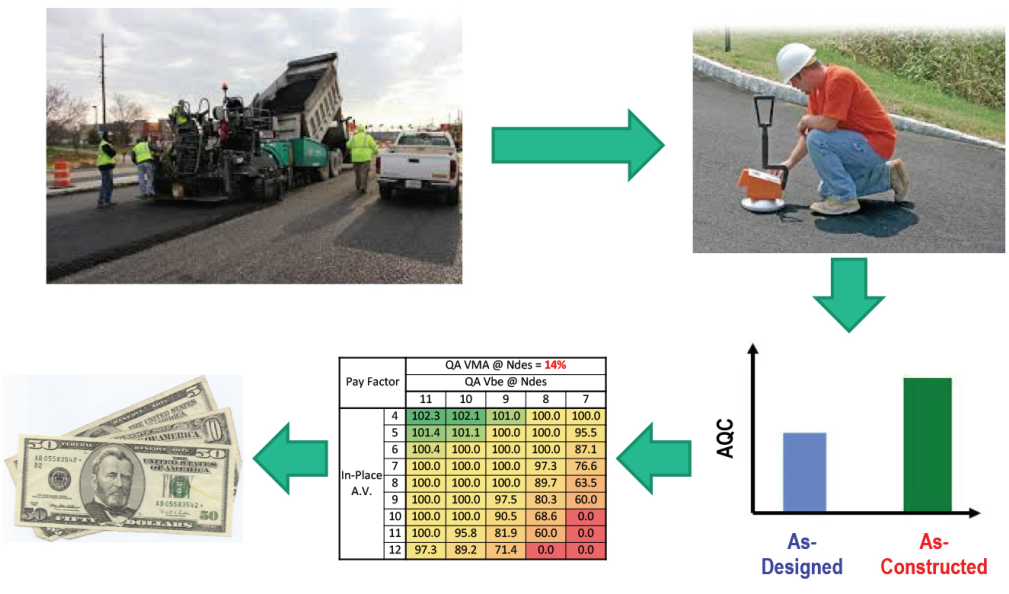
Building Material Database



Developing Pay Tables and PRS



AQC Data Collection and Pay Adjustment



Example Pay Tables

Pay Factor		QA VMA @ Ndes = 13%				
		QA Vbe @ Ndes				
		11	10	9	8	7
In-Place A.V.	4	101.5	100.0	100.0	93.9	67.3
	5	100.3	100.0	100.0	84.9	60.0
	6	100.0	100.0	96.3	73.7	0.0
	7	100.0	100.0	88.2	60.0	0.0
	8	100.0	97.1	78.3	0.0	0.0
	9	100.0	89.8	65.9	0.0	0.0
	10	96.1	80.8	60.0	0.0	0.0
	11	89.3	69.7	0.0	0.0	0.0
	12	81.1	60.0	0.0	0.0	0.0

Pay Factor		QA VMA @ Ndes = 14%				
		QA Vbe @ Ndes				
		11	10	9	8	7
In-Place A.V.	4	102.3	102.1	101.0	100.0	100.0
	5	101.4	101.1	100.0	100.0	95.5
	6	100.4	100.0	100.0	100.0	87.1
	7	100.0	100.0	100.0	97.3	76.6
	8	100.0	100.0	100.0	89.7	63.5
	9	100.0	100.0	97.5	80.3	60.0
	10	100.0	100.0	90.5	68.6	0.0
	11	100.0	95.8	81.9	60.0	0.0
	12	97.3	89.2	71.4	0.0	0.0

Pay Factor		QA VMA @ Ndes = 15%				
		QA Vbe @ Ndes				
		11	10	9	8	7
In-Place A.V.	4	101.6	102.4	102.6	102.0	100.2
	5	100.8	101.6	101.7	100.8	100.0
	6	100.0	100.7	100.6	100.0	100.0
	7	100.0	100.0	100.0	100.0	100.0
	8	100.0	100.0	100.0	100.0	98.1
	9	100.0	100.0	100.0	100.0	90.9
	10	100.0	100.0	100.0	97.6	82.0
	11	100.0	100.0	100.0	90.9	70.9
	12	100.0	100.0	95.1	82.7	60.0

Pay Factor		QA VMA @ Ndes = 16%				
		QA Vbe @ Ndes				
		11	10	9	8	7
In-Place A.V.	4	100.0	101.4	102.4	102.9	102.6
	5	100.0	100.6	101.6	102.0	101.6
	6	100.0	100.0	100.8	101.1	100.5
	7	100.0	100.0	100.0	100.0	100.0
	8	100.0	100.0	100.0	100.0	100.0
	9	100.0	100.0	100.0	100.0	100.0
	10	100.0	100.0	100.0	100.0	100.0
	11	100.0	100.0	100.0	100.0	97.4
	12	98.0	100.0	100.0	99.3	90.9

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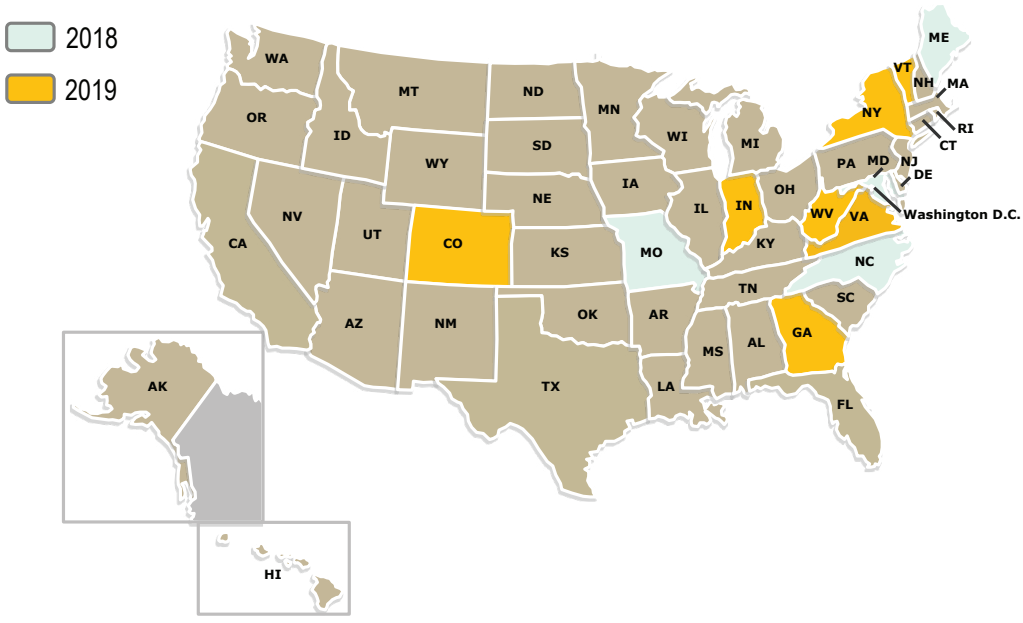
PRS Shadow Projects - USA



Puerto Rico Infrastructure Restoration Project

- $900 million investment by FEMA in the next five years
- Performance-Engineered Mix Design and PRS based on test methods and models developed at NCSU
- First project in late summer or early fall of 2019

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PRS Software

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AM-PRS Benefits

- Long term pavement performance predicted from **fundamental engineering properties**
- AQC data collection procedures **do not change**
- **Incentives and disincentives** that are justified through reduction or increase in pavement life
- Allow contractors to be **more innovative and more competitive**
- Result in **better performing** pavements
- Provide an opportunity to **integrate** mixture design, pavement design, and construction QA specifications **using the same test methods and performance models**

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Thank you!