Performance and Life-Cycle Cost Benefits of Stone Matrix Asphalt

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National Center for Asphalt Technology

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Presentation Outline

- Background
- Research Objective
- Market Analysis
- Performance Analysis
- Life-cycle Cost Analysis (LCCA) Case Studies
- Conclusions

Background

- SMA: durable and rut-resistant gap-graded asphalt mix
    - Stone-on-stone contact to offer strength
    - Rich mortar binder to provide durability
- First introduced into the United States in early 1990s
- Commonly used as a premium asphalt mix to enhance field performance and extend life span of asphalt pavements and overlays
- Generally more expensive than dense-graded mixes containing polymer-modified asphalt binders
- Higher cost offset by the increase in life expectancy

Laboratory Evaluation of SMA mixes

- Comparing the test results of SMA versus a control dense-graded mix, not necessarily using polymer modified asphalt binder
- Better rutting resistance due to stone-on-stone aggregate structure
- Better resistance to moisture damage due to thicker asphalt film between aggregate particles
- No consistent trends on stiffness and cracking resistance comparisons
- Reduced susceptibility to oxidative aging

Field Evaluation of SMA Pavements

- NCHRP Project D9-8, Performance of SMA Mixes in the United States
  - 85 SMA pavement sections
  - 2 to 6 years old
  - Outstanding rutting and cracking performance
- Similar performance benefits reported by other studies
- Functional benefits
  - Improved visibility
  - Reduced splash and spray
  - Increased friction resistance
  - Noise reduction

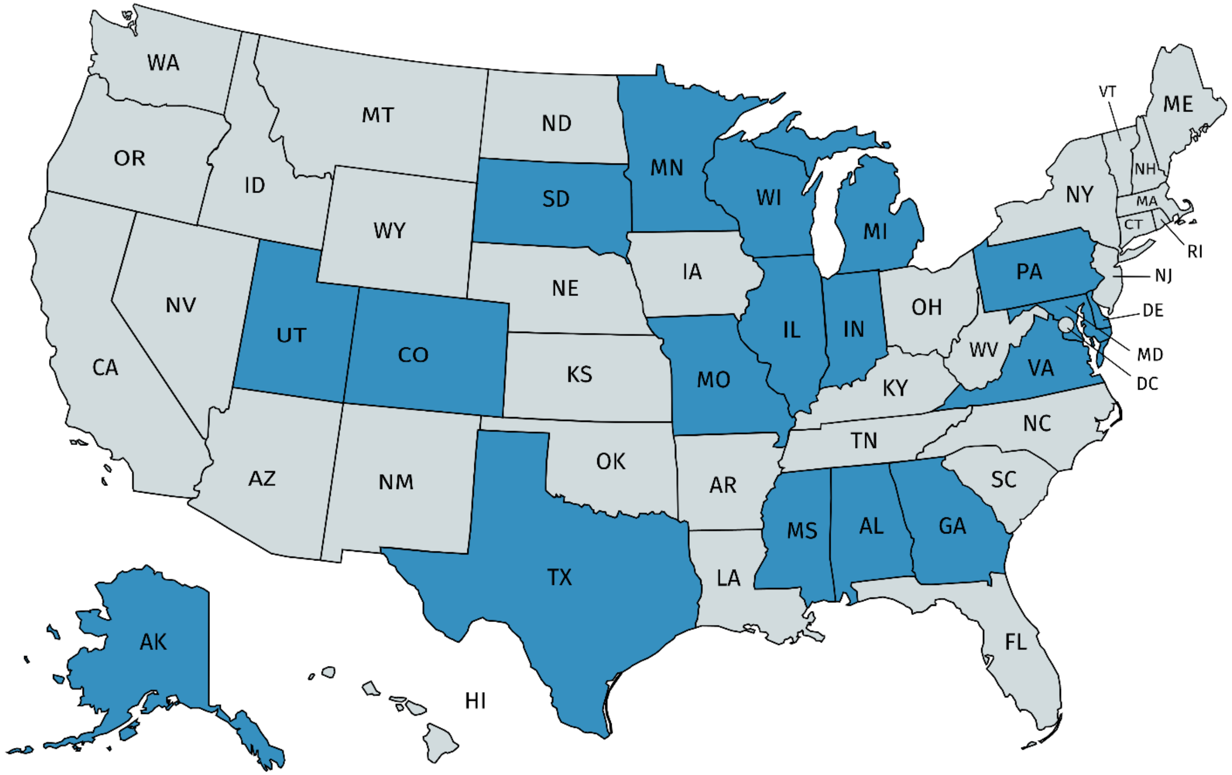
Research Objective

- Quantify and compare the performance and life-cycle cost benefits of SMA versus polymer-modified Superpave dense-graded mixes used on similar trafficked highways

Market Analysis → Performance Analysis → Life-cycle Cost Analysis

Market Analysis

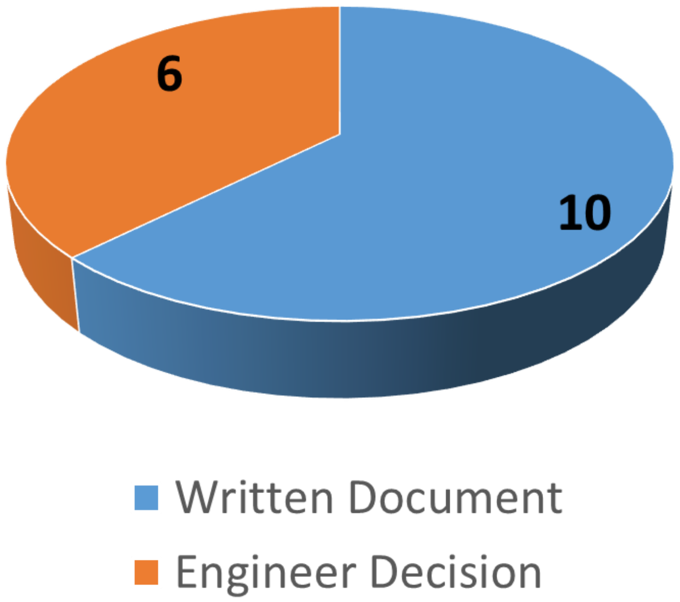
- Survey of state asphalt pavement associations (SAPAs) identified at least 18 states that use SMA on a routine basis



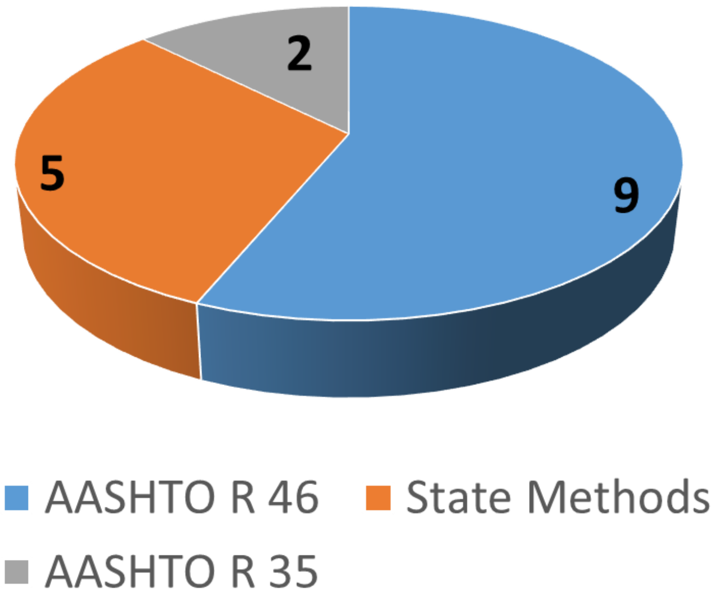
Market Analysis

- Follow-up survey of SHAs
- Survey questions
  - Mix selection policy
  - Mix design specification
  - Bid item numbers
  - Cost and tonnage from 2011 to 2015
  - Field performance data

Mix Selection Policy



Mix Design Method



2011-2015 Tonnage

68,000 Tons

Highest tonnage

1. Maryland
2. Alabama
3. Utah

1,872,000 Tons

Weighted Bid Price (2011-2015)

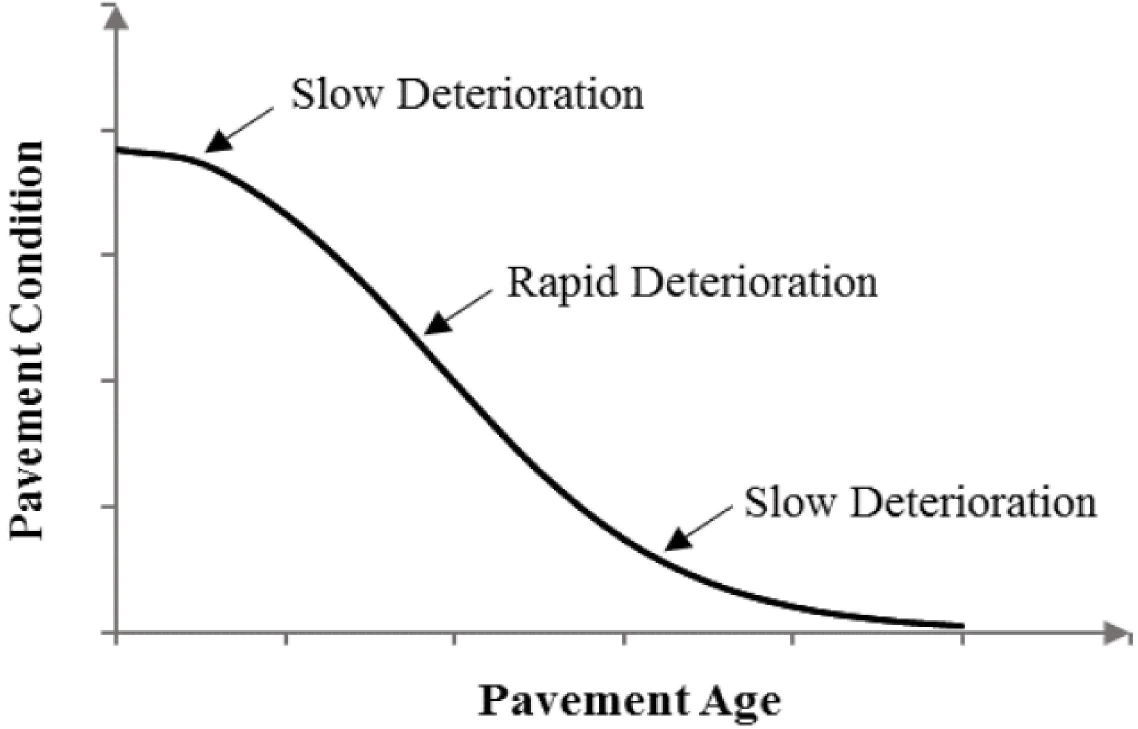
- SMA consistently more expensive than dense-graded mixes
- Difference in weighted bid price varied from $6 to $31 per ton
- SMA higher bid price possibly due to
  - Higher asphalt contents
  - Requirement for more cubical and durable aggregates
  - Inclusion of fibers as stabilizers
  - No/reduced use of RAP and RAS
  - Reduced plant versatility

Performance Analysis

- To compare the long-term field performance of SMA versus comparable Superpave dense-graded mixes
  - Equivalent roadway category
  - Equivalent pavement type
- Pavement management system (PMS) data of 407 SMA and 807 Superpave pavement sections
  - 2 states evaluate individual pavement distresses (rutting, cracking, etc.)
  - 7 states use composite condition indexes (distress index, surface rating, etc.)

Performance Analysis

- Network-level analysis approach
- S-shaped logistic performance prediction model used in most cases

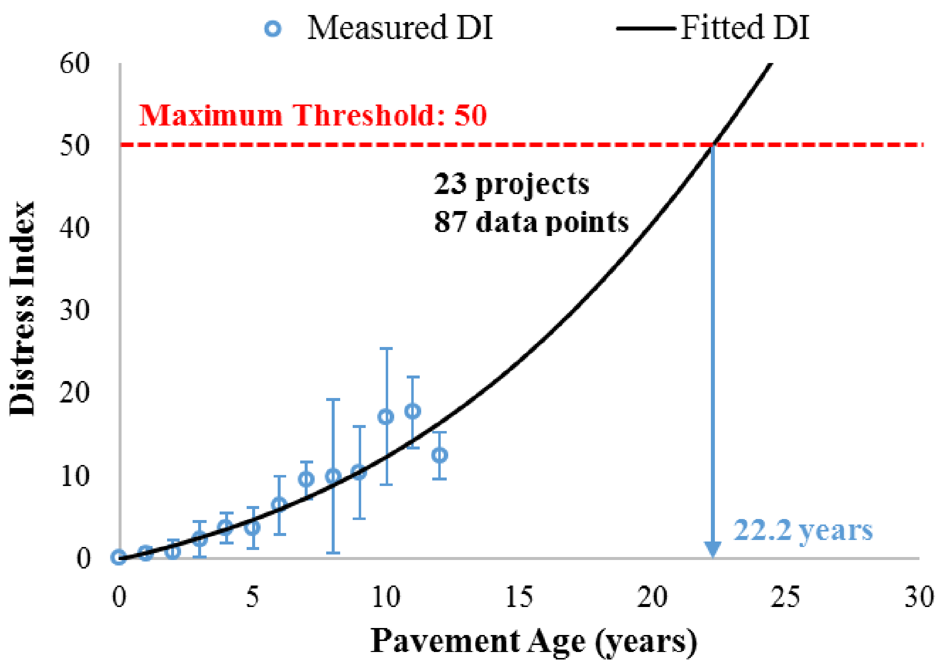


Example: Michigan DOT Data

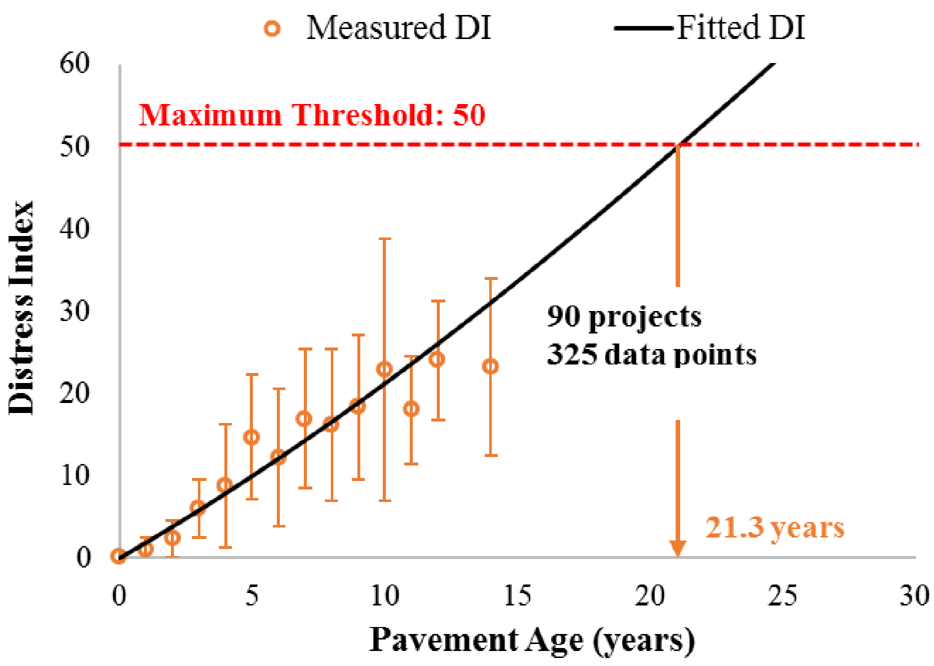
- Conduct distress survey by videotaping pavement surface
- Assign distress points based on distress type, extent, and severity
- Calculate distress index (DI) by combining all distress points
  - A “snapshot” of pavement distress condition
  - DI = 0: distress-free condition
  - **DI = 50: remaining service life of zero**
  - DI develops following a logistic growth model

Example: Michigan DOT Data

SMA: 22 years



Superpave: 21 years

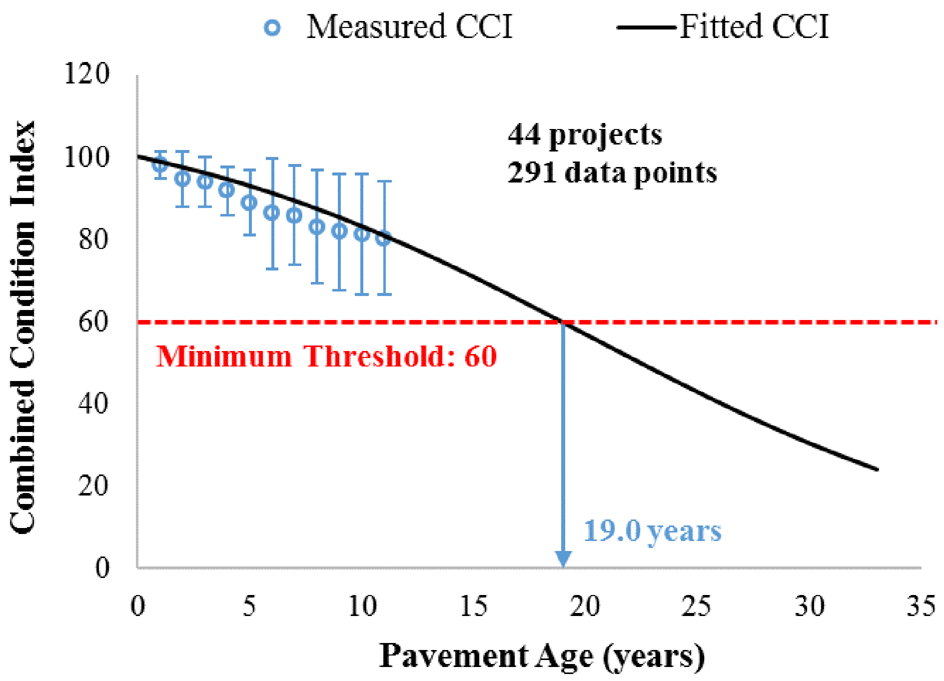


Example: Virginia DOT Data

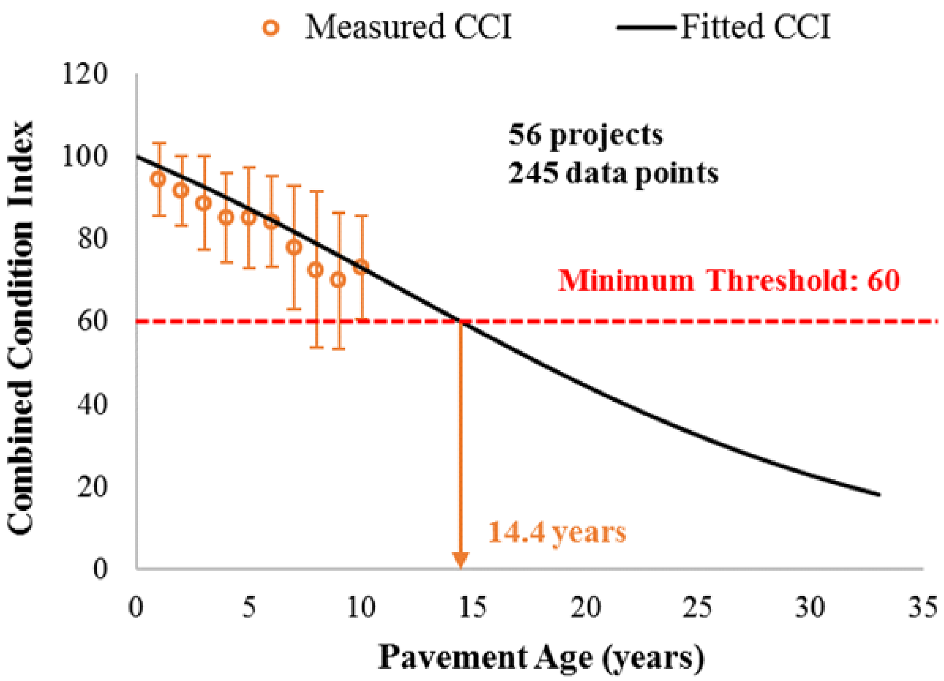
- Conduct distress survey using an Automated Road Analyzer (ARAN)
- Determine load related distress rating (LDR) and non-load related distress rating (NDR) based on distress type, extent, and severity
- Calculate critical conditioning index (CCI) as Min. (LDR, NDR)
    - A “snapshot” of overall pavement condition
    - CCI = 100: distress-free condition
    - CCI = 0: completely failed condition
    - **CCI = 60: remaining service life of zero**
    - CCI develops following a s-shaped logistic performance model

Example: Virginia DOT Data

SMA: 19 years



Superpave: 14 years



Summary – Flexible Pavements

Highway Agency	Performance Measure	Predicted Service Life (Years)		SMA Life Extension (Years)
		SMA	Superpave	
Alabama DOT	Pavement Condition Rating	16.2	16.6	-
Colorado DOT	Rutting Cracking	17.0	17.4	-
Georgia	PACES Rating	16.0*	11.0*	**5.0**
Maryland SHA (Interstate)	Rutting Cracking Index	24.8	26.9	-
Maryland SHA (Principal Arterial)	Rutting Cracking Index	32.2	24.0	**8.2**
Minnesota DOT	Ride Quality Index Surface Rating	16.6*	11.3*	**5.3**
Virginia DOT	Critical Condition Index	19.0	14.4	**4.6**

*Note: * PMS data from a limited number of pavement sections*

Summary – Composite Pavements

Highway Agency	Performance Measure	Predicted Service Life (Years) SMA	Predicted Service Life (Years) Superpave	SMA Life Extension (Years)
Illinois Tollway	Overall Condition Rating Survey	13.5	9	**4.5**
Maryland SHA (Principal Arterial)	Rutting Cracking Index	21.8	19.6	**2.2**
Michigan DOT	Overall Distress Index	22.2	21.3	**0.9**
Pennsylvania DOT (Interstate)	Overall Pavement Index	21.1*	22.2	**-**
Pennsylvania DOT (Non-Interstate)	Overall Pavement Index	24.5*	11.0	**13.5**
Virginia DOT	Critical Condition Index	23.1	12.8	**10.3**

*Note: * PMS data from a limited number of pavement sections*

LCCA Case Studies

- To determine if the higher cost of SMA can be justified by the improved performance and extended service life
- Net present value (NPV)/equal uniform annual cost (EUAC) approach
  - Cost information from Market Analysis
  - Performance information from Performance Analysis
  - Assumption of 2-inch thick asphalt overlay
  - Analysis period selected using SMA's service life
  - Discount rate selected using agency's current practice
  - Routine maintenance costs and user costs not considered

NPV/EUAC Approach

- Present value of the first overlay cost (PV_0)
- Future value of the replacement overlay cost (FV)
- Salvage value at the end of the analysis period (SV)
- Discount rate (r)

$$NPV = PV_0 + \sum FV_i * \left[\frac{1}{(1+r)^{n_i}} \right] + SV * \left[\frac{1}{(1+r)^{n_s}} \right]$$

$$EUAC = NPV * \left[\frac{r(1+r)^{n_s}}{(1+r)^{n_s} - 1} \right]$$

Virginia DOT – Deterministic Approach

- SMA: $114/ton, 23 years service life
- Superpave: $89/ton, 13 years service life

Alternative 1: SMA

Year 0 — Year 23

PV_0 = $78,990

SV = $0

r = 4.0%

PV_{SV} = $0

NPV = $78,990 + $0 = $78,990

Alternative 2: Superpave Mixture

Year 0 — Year 13 — Year 23

PV_0 = $62,134

FV = $62,134

SV = ($14,339)

PV_{FV} = $37,316

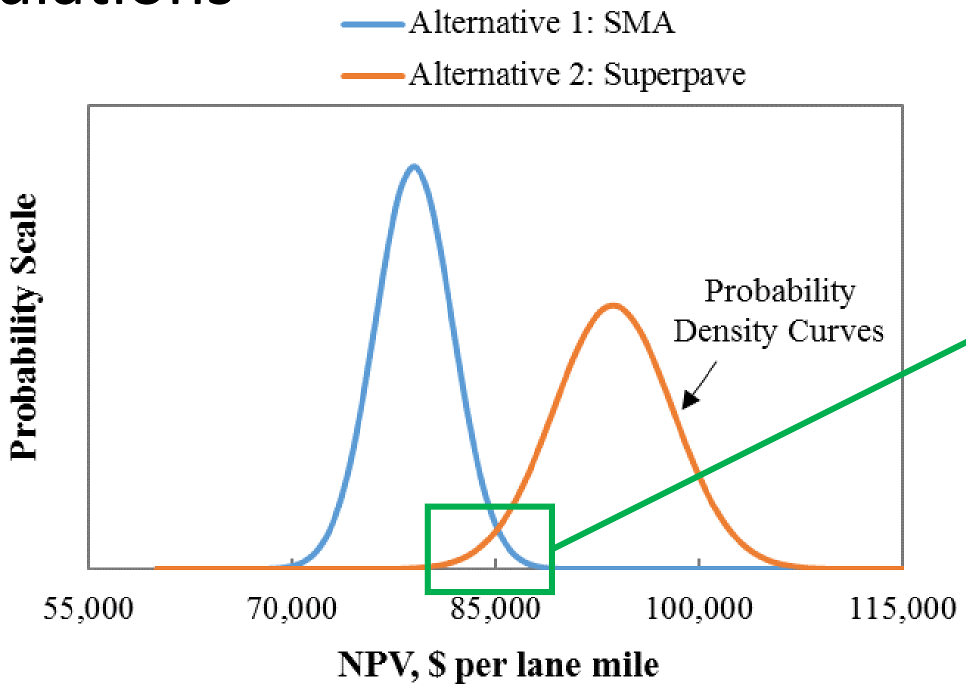
r = 4.0%

PV_{SV} = ($5,818)

NPV = $62,134 + $37,316 - $5,818 = $93,632

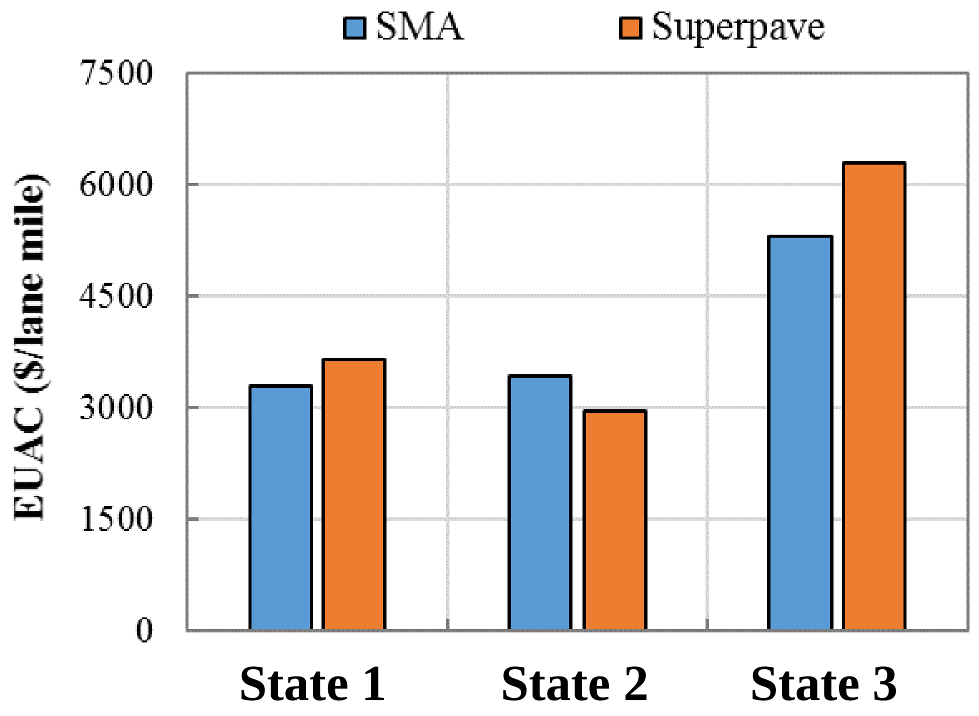
Virginia DOT – Probabilistic Approach

- PV_0, FV, and r following normal distributions
- NPV probability distribution curves generated based on 1,000 Monte Carlo simulations



Less than 1% probability that SMA is not as cost-effective as the comparable Superpave mix

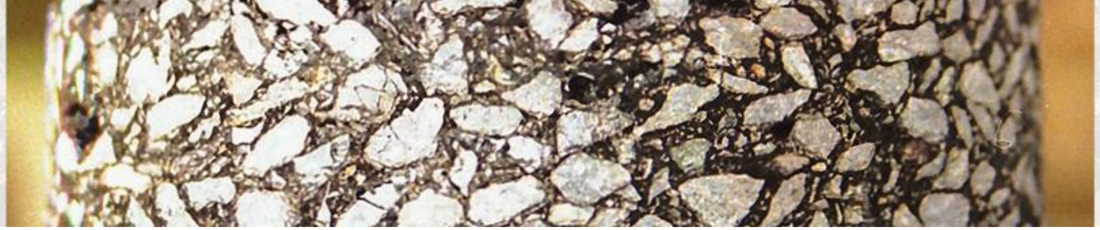
LCCA Case Study Summary



No consistent conclusions for comparing the life-cycle cost benefits of SMA versus comparable Superpave mix

Conclusions

- Currently 18 SHAs use SMA on a routine basis
- SMA was $6 to $31/ton more expensive than Superpave mixes with polymer modified asphalt binders
- SMA generally had equivalent or better performance than Superpave mixes on similar trafficked highways; in cases where SMA had better performance, the life extension varied from 1 to 13 years among the states and varied for different pavement types
- The cost effectiveness of SMA versus Superpave mixes depends on the relative level of significance from increased cost versus extended service life



Thank you!

Any questions?

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