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# Stone Matrix Asphalt in Wisconsin

**December 3, 2019**

# Presenters

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# Overview

- Historical Perspective
- Evolution of Specifications
- What We've Learned
- Next Steps

# Where Did it Begin…

- Began over in Europe and in 1990's the FHWA decided to bring it over to the United States
- In 1991 five states were selected for pilot projects:
  - Georgia
  - Indiana
  - Michigan
  - Missouri
  - AND…

- Wisconsin was the first project to be constructed on July 10, 1991
  - I-94 WB
  - 1.5" thick using Vestoplast polymer (no fiber)
  - 50 blow Marshall
  - 5.7% total ac
  - 185 tons/hour production
  - 2 tandem steel wheel rollers no vibratory

# WisDOT SMA Pilot Program Overview

## Objectives

1. Evaluate ease of construction of different SMA pavement types
2. Compare performance against standard HMA pavement
3. Analyze and develop criteria for future requirements and specifications


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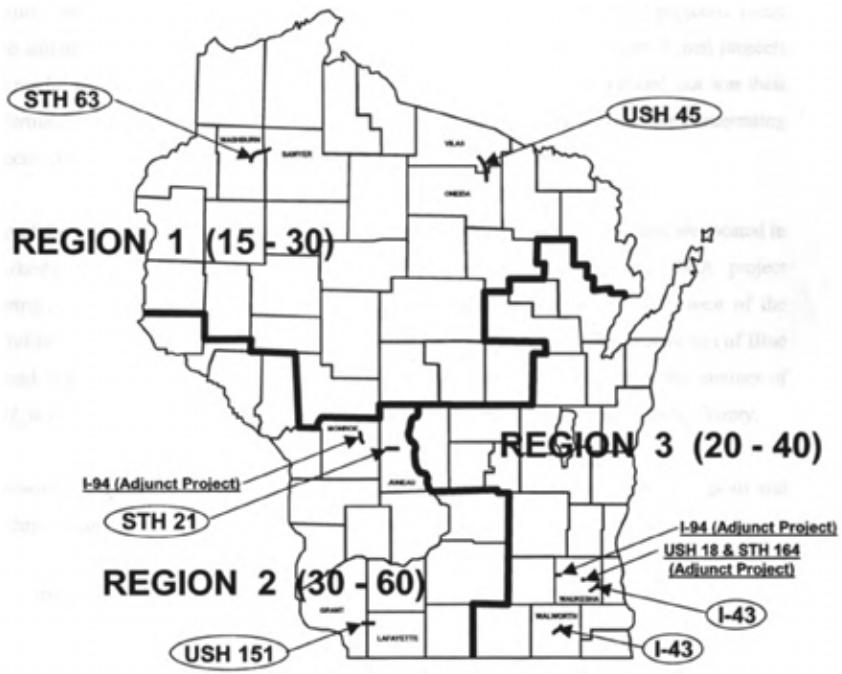
# WisDOT SMA Pilot Program




**Location of SMA Projects and Control Sections**
**Regions Separated by LA Wear Values**

- **Factors investigated**
  - Traffic
  - Aggregate LA Wear
  - Stabilizer type & dosage
  - NMAS (5/8” vs. 3/8”)
  - Base material
- **Performance monitoring after 5 years measuring the following:**
  - Pavement Distress Index (PDI)
  - Ride - IRI
  - Rutting/Cracking
  - Friction and Noise

# WisDOT SMA Pilot Program

## Detailed Project Information

| Project | Base Pavement | ADT/Yr. Const. | Max Agg. Size | Hardness Region | LA Wear |
|---|---|---|---|---|---|
| I-43, Waukesha | CRCP | 42,200<br>1992 | 3/8”<br>(9.5 mm) | 3 | 26 |
| I-43, Walworth | JRCP | 11,650<br>1993 | 5/8”<br>(16 mm) | 3 | 27 |
| USH 151, Lafayette | AC over thin-edged PCC | 6,350<br>1993 | 5/8”<br>(16 mm) | 3 | 38 |
| STH 21, Juneau | AC over dense base over PCC | 4,200<br>1994 | 3/8”<br>(9.5 mm) | 2 | 31 |
| USH 45, Vilas and Oneida | AC | 5,940<br>1993 | 5/8”<br>(16 mm) | 1 | 21 |
| STH 63, Washburn | AC | 5,872<br>1993 | 3/8”<br>(9.5 mm) | 1 | 24 |

# WisDOT SMA Pilot Project

## Test Section Layout

| Test Section | Description |
|---|---|
| F1 | SMA w/Cellulose Fiber Stabilizer |
| F2 | SMA w/ Mineral Fiber Stabilizer |
| P1 | SMA w/Polymer (Thermoplastic) Stabilizer (Low Dosage) |
| P2 | SMA w/Polymer (Thermoplastic) Stabilizer (High Dosage) |
| E1 | SMA w/Polymer (Elastomeric) Stabilizer (Low Dosage) |
| E2 | SMA w/Polymer (Elastomeric) Stabilizer (High Dosage) |
| Control | Dense Graded Asphalt Mix |

- Minimum 4000 foot test sections
- Minimum total project length = 5.5 miles

# WisDOT SMA Pilot Project

## Construction Details

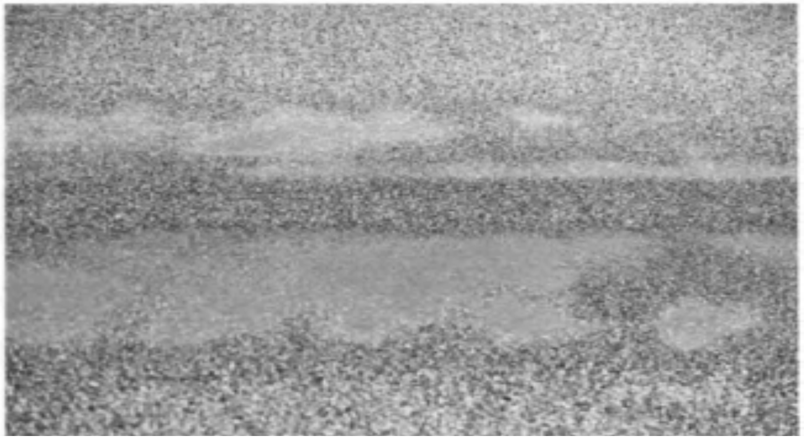
- Temperatures:
  - Mixing 295-310°F
  - Laydown 285-300°F
- Rolling Pattern:
  - Tightened for SMA to account for faster mix cooling

**Follow up efforts indicated an offset between core and nuclear gauge readings**

# WisDOT SMA Pilot Project

## Construction Issues - Bleeding

- Higher temperature sensitivity observed for polymer modified mixes
  - Draindown above 305°F
  - Sticks to truck box below 290°F
- Projects constructed well before the invention of WMA and compaction aid additives



# WisDOT SMA Pilot Project

## Performance – Cracking and PDI

| Test Sections (LA Wear Region) | % Cracking | | | PDI | | |
|---|---|---|---|---|---|---|
| | Mean SMA | Mean Control | %Diff. | Mean SMA | Mean Control | %Diff. |
| STH 63 (Reg 1) | **26** | **69** | **-63%** | **24** | **48** | **-51%** |
| STH 21 (Reg 2) | **72** | **78** | **-7%** | **20** | **27** | **-26%** |
| I-43 Wauk. (Reg 3) | **48** | **68** | **-29%** | **21** | **38** | **-45%** |
| USH 45 (Reg 1) | **11** | **12** | **-6%** | **19** | **13** | **49%** |
| USH 151 (Reg 2) | **52** | **67** | **-22%** | **25** | **30** | **-16%** |
| I-43 Wal. (Reg 3) | **6** | **38** | **-84%** | **18** | **47** | **-62%** |

- Pavement was surveyed pre-overlay. Cracking extent was used as a baseline to evaluate SMA effectiveness.
- PDI = f(Cracking, Flushing, Ravelling, Rutting) PDI > 60 triggers rehab

# SMA Field Survey

## Resistance to Reflective Cracking


- Overlaid existing PCC
- SMA used for mainline, HMA for shoulders
- Low to moderate severity of cracks were observed in shoulder
- Crack growth immediately stopped at SMA

## Mechanisms of Crack Prevention

- Gap-Graded Aggregate structure
- High asphalt content
- Polymer modified asphalt

# WisDOT SMA Pilot Project

## Conclusions

- Cracking resistance:
  - SMA 30% to 40% improvement
  - Results consistent with NCHRP Report 425 (Brown, 1999)
- Pavement performance (PDI):
  - SMA 40% improvement
- Effect of mix components:
  - Los Angeles Abrasion Resistant (LAR):
    - High quality aggregate (low LAR) had 52% better cracking resistance than HMA
    - High LAR 14% better

# WisDOT SMA Pilot Project

## Conclusions

- Effect of mix components:
  - Stabilizers:
    - All performed better than traditional hot mix
- Overall the pilot project program was a success which led to the use of SMAs in Wisconsin

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# Evolution of SMA Specifications

# Evolution of SMA Specifications

## Key Aspects

- Mix Design
  - Maximum aggregate size
  - Selection of gyration levels
  - Recycled materials
- Test Strip
  - Main objectives
  - Acceptance
- Density Testing
  - Nuclear gauges vs. cores

# Evolution of SMA Specifications

## Mix Design

| Parameter | Past | Current | Discussion |
|---|---|---|---|
| NMAS | 12.5 mm | 12.5 mm & 9.5 mm | Success with smaller NMAS mixes. Allows for thinner lifts and higher VMA |
| Design Gyrations | 75 | 65 | Adjustments made to address varying aggregate hardness throughout the state |
| Recycled Materials | None | RAP, RAS, or FRAP up to 15% PBR | Work has shown benefits of using recycled binders (15% PBR limits risk) |
| WMA Additives | Didn't exist | Allowed | Draindown is influenced by viscosity. WMA additives help the temperature sensitivity issue referenced in the pilot project. |

# Evolution of SMA Specifications
## Test Strip & Density Testing

- Purpose of Test Strip
  1. Verify mix meets volumetric requirements
  2. Establish rolling pattern
  3. Correlate nuclear gauge to cores to determine offset
  4. Verify mix integrity (i.e. no broken aggregate)

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# Evolution of SMA Specifications

## Test Strip & Density Testing

- Density Testing
  - Past: Acceptance based on mean of 12 nuclear density readings from the test strip
  - Current: Gauge vs. Core correlation accomplished in the test strip and used throughout the project
  - Target density of 93% $G_{mm}$

WI STH 53, 2011

# SMA Next Steps

## Specification Changes for 2018

- New SMA STSP for statewide use (STSP 460-030)
  - Goal was to marry the SS460 and NWR specifications
  - Increased Samples for Gmm & Gmb testing
  - Required Corelok® to properly test air voids (4.5%)
  - Material transfer device required
  - Test strip requirement
  - SMA minimum density target of 93.0% mainline
  - Incentive eligibility per standard QMP

# SMA Next Steps

## Mix Design Changes for 2018

- Minimum 5.5% percent effective binder
- Unified VMA requirements
  - 16.0% for 12.5mm (#4)
  - 17.0% for 9.5mm (#5)
- Binder modification required (no “S” grades)

# SMA Next Steps
## FDM Changes for 2018

- Guidance added to FDM
  - SMA considered for traffic >2M ESALs (FDM 14-10-5.9.2)
  - Consider on important corridor (backbone) routes with heavy truck traffic (HT)
  - Can be used on new construction or resurfaces
  - Performs well where reflective cracking is expected

# SMA Next Steps
## Specification Changes for 2019

- Updated SMA STSP 460-030
  - Cellulose fiber stabilizing additive required
  - Asphalt binder content testing required
  - SMA minimum density
    - 92.0% for shoulders & equivalent (offsets applied to all SMA)
  - SMA test strip approval criteria
    - Department will test 1 of 2 mixture split QC samples
    - QV test fails Va or QV/QC test results exceed testing tolerances (0.015 for Gmm or Gmb), dispute resolution by BTS

# SMA Next Steps

## Specification Changes for 2020

- Updated SMA STSP 460-030
  - Credits for delayed test strips added
  - Mix Design criteria deleted
- Updated Standard Spec 460
  - Mix Design criteria added

# 2017 SMA Projects

| Region | Route | County | Tons |
|---|---|---|---|
| Northwest | STH 29 | Chippewa | 51,000 |
| Northeast | STH 172 | Brown | 29,700 |
| Southeast | I-94 | Waukesha | 600 |
| Northwest | STH 13 | Bayfield | 15,300 |
| | | TOTAL | 96,600 |

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# 2018 SMA Projects

| Region | Route | County | Tons |
|---|---|---|---|
| Southeast | I-898 | Milwaukee | 21,600 |
| Northwest | STH 13 | Ashland | 26,600 |
| Northwest | I-94 | St Croix | 13,500 |
| Northeast | US 41 | Brown, Oconto | 11,500 |
| Northwest | US 53 | Douglas, Washburn | 6,600 |
| Northwest | US 2 | Bayfield | 11,000 |
| Northwest | US 53 | Douglas | 35,000 |
| Southeast | I-94 | Kenosha, Racine | 1,500 |
| | | TOTAL | 127,300 |

# 2019 SMA Projects

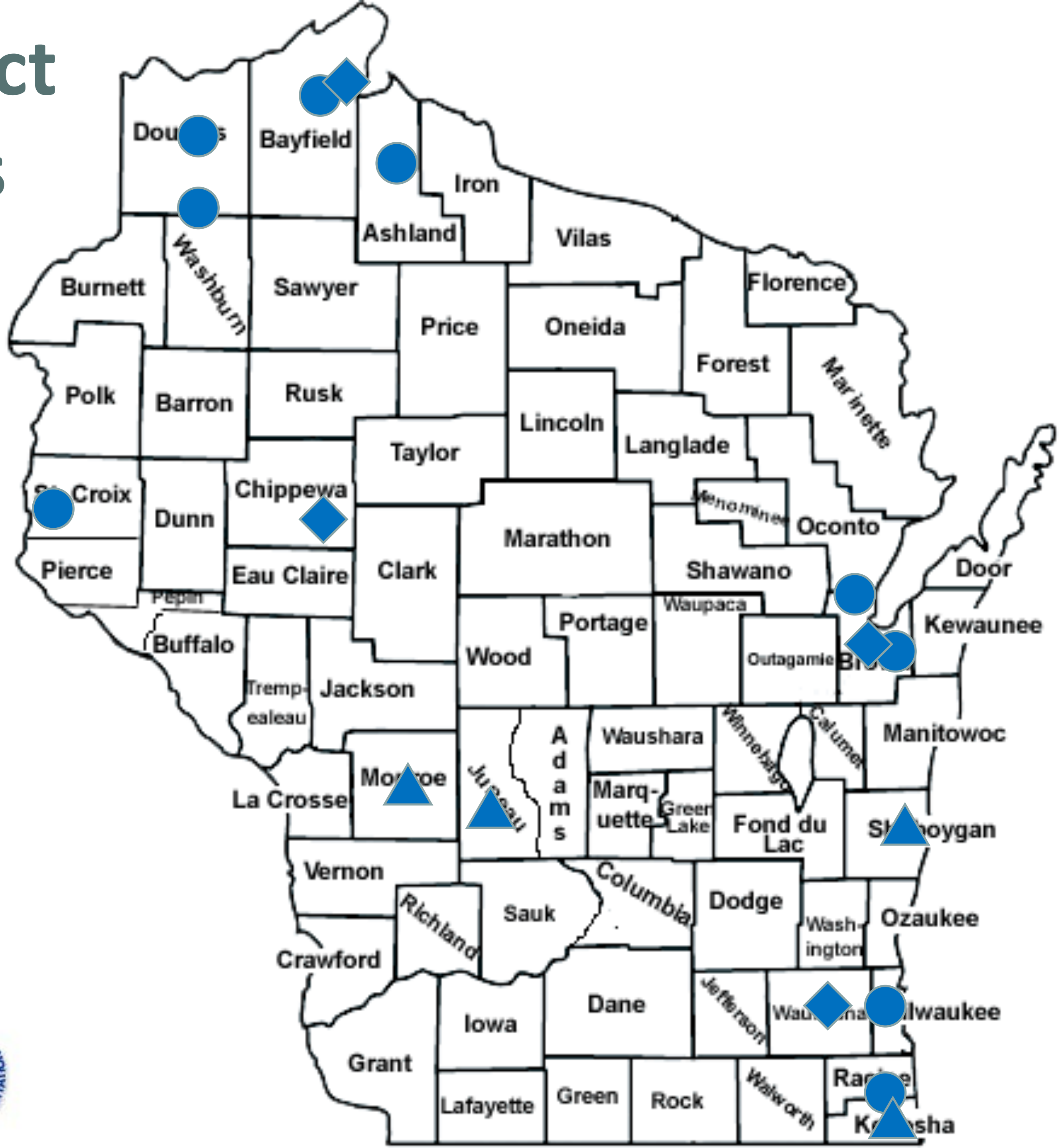
| Region | Route | County | Tons |
|---|---|---|---|
| Southwest | I-90 | Monroe | 32,300 |
| Southwest | I-90/94 | Juneau | 20,100 |
| | | TOTAL | 52,400 |

# 2020 SMA Projects

| Region | Route | County | Tons |
|---|---|---|---|
| Northwest | US 2 | Douglas | 5,700 |
| Northwest | I-94 | St Croix | 14,200 |
| Southeast | I-94 | Waukesha | 46,600 |
| Southeast | I-94 | Milwaukee | 20,900 |
| | | TOTAL | 87,400 |

# SMA Project Locations

2019
2018
2017

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# SMA Project Locations

**2020** ★


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# What We've Learned

# What We've Learned

Numerous SMAs with 10-15 years performance history

- Stabilization:
  - Polymer modified asphalt cement (PMAC):
    - Low temperature grade of -28°C or -34°C
    - Use of "H", "V", or "E" modification
  - Fibers have been used successfully as well with and without PMAC
  - Fines:
    - Off spec fly ash (6% - 8%) has been used for economics and sustainability (i.e. keep material out of landfill)
    - Also used lime fines on numerous SMA projects
  - Successfully used WMA additives and reduced plant temps
  - RAS has had a positive impact on mixtures (<5% by weight)

# What We've Learned

- Aggregate:
  - Wear resistant and consistent gradation, particle shape is critical (cubical particle shape both coarse and fine)
- Lab:
  - Limit technicians for consistency with sampling and splitting of materials
  - Keep utensils/equipment clean
- Construction:
  - Emphasize consistency in paver speed, rolling pattern (breakdown roller close to paver), etc…

# What We've Learned

- Production:
  - Heat the plant prior to shipping mix to the project
  - Proper loading to prevent segregation
  - Consistent mix production rates including feed rates of fillers/fibers/dust/recycle/etc…
  - Mix is temperature sensitive

# What We've Learned

- Consistency of off-spec fly ash
  - Material is a by-product…lime and moisture content can vary
  - Variance causes clumping and other issues with feed
  - Improvement observed with lime fines
  - Filler and fines are not the same
    - Fines reincorporated into mix should be that from the SMA design aggregates

# What We've Learned

- Eliminate draindown/bleeding issues in the field
- Mix trouble shooting can be different for SMA
- Tack bonding is critical to achieve proper compaction
- Focus on density along the longitudinal joint (vertical)
- QC/QA testing inconsistencies
  - Significant differences in QC and verification testing
    - Try to run mixtures hot to hot as much as possible
    - Discuss comparison testing prior to start up
    - Larger sample sizes for additional specimens (Gmm/Gmb)
    - Required use of CoreLok® to establish Gmb

# What We've Learned

- QC/QA testing inconsistencies
  - Comparisons:
    - Run sample comparisons if possible prior to start up
  - Communication:
    - Review test protocols before project
  - Training:
    - Regular industry/agency joint SMA testing workshops

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# Next Steps…Performance Testing

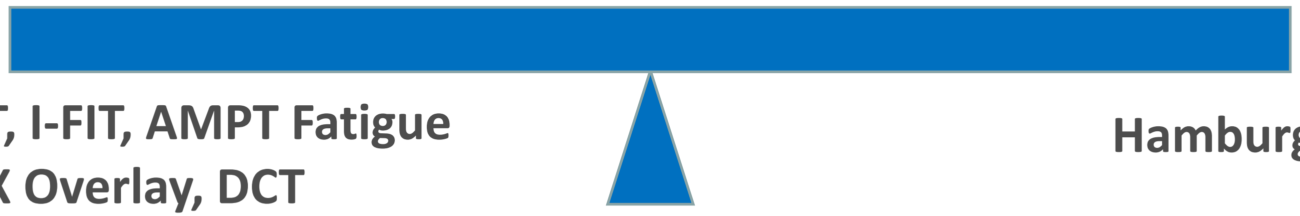
# SMA Next Steps

## Mixture Performance Testing

1. **Performance based selection of stabilizer system & AC Content**

Cracking

Rutting



**IDEAL-CT, I-FIT, AMPT Fatigue**
**TX Overlay, DCT**

**Hamburg, iRLPD**

2. **Quality Assessment**

- Draindown
- Aging resistance
- Moisture Damage Resistance
- Other aspects unique to SMA?

- Is current drain down test sufficient?
- Design mix based on performance, adjust for draindown if needed

# SMA Next Steps
## Mixture Performance Testing

- Limits: SMAs are considered high quality products, define testing requirements accordingly
- Transition from prescriptive to performance based specifications Examples:
  - Is PG 58-28H + Fibers equivalent to PG 58-28V + Filler?
  - Evaluate higher levels of modification
- Quantitative evaluation of new products
  - Inclusion of RAP/RAS or GTR. How much?
  - Plastomers vs. Elastomers
  - Different stabilizers (fibers, fillers, etc.)
- Show the additional service life in LCCA inputs

# SMA Next Steps

## Performance Testing Examples - TxDOT

**Table 3. CTIndex Criteria for Asphalt Mixes (Zhou et al. 2018).**

| Mix Type | $CT_{Index}$ | OT Cycles |
|---|---|---|
| Crack Attenuating Mix | 320 | 750 |
| Thin Overlay Mix | 185 | 300 |
| SMA | 145 | 200 |
| Superpave mixes | 105 | 120 |
| Dense-graded mixes | 65 | 55 |

- Results suggest that SMA mixes have higher cracking resistance than conventional surface courses

# SMA Next Steps

## Performance Testing Examples Illinois

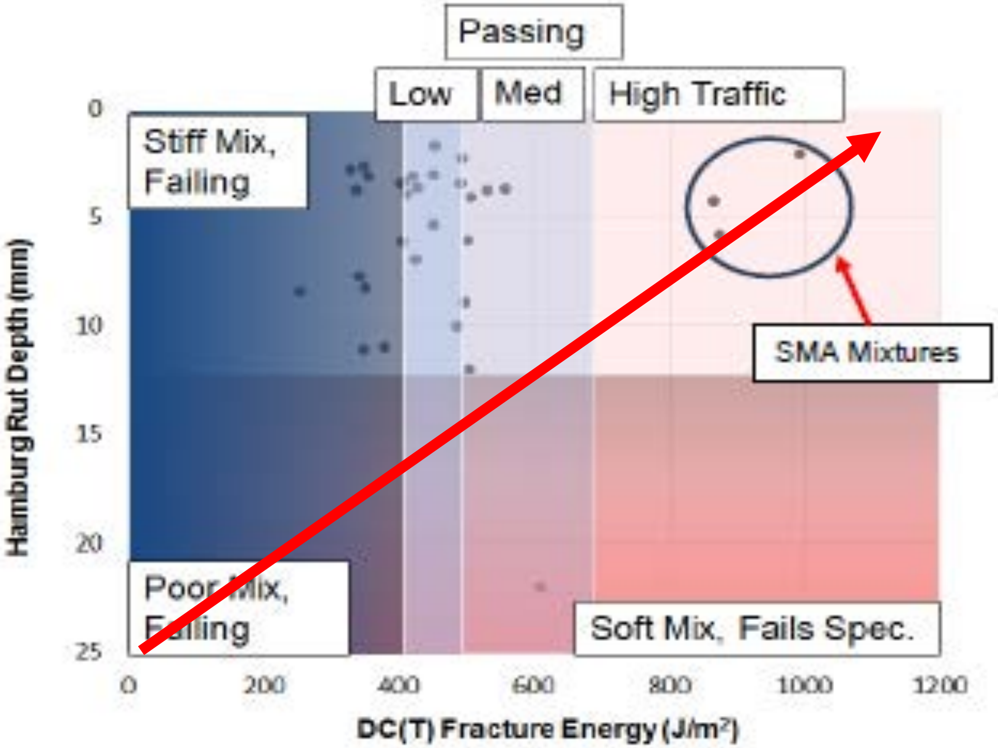



**Figure 12.** *Hamburg-DC(T) Plot for Recent Mixtures Tested in Illinois, with Typical Specification Limits Superimposed.*

Improving Performance

# SMA Next Steps

## Performance Testing Examples – IL Tollway

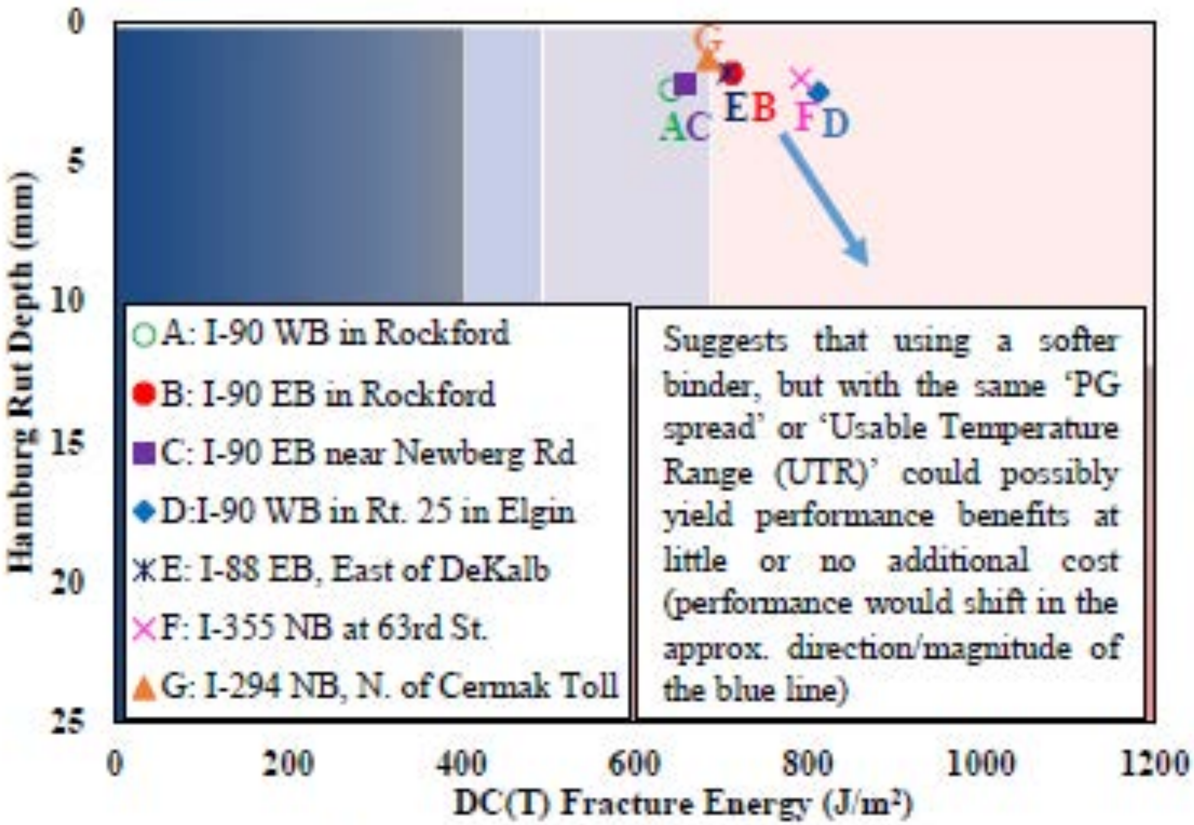


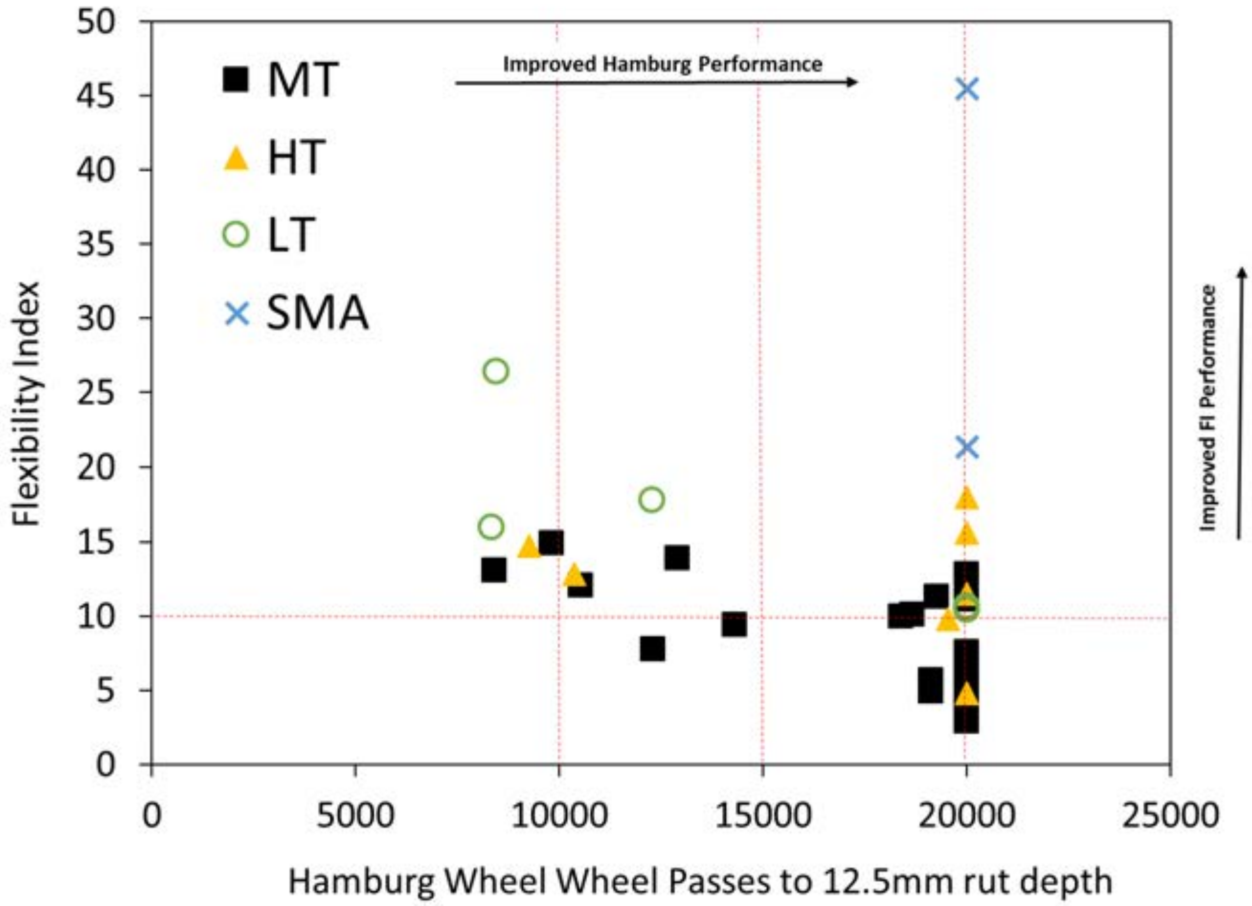

**Figure 8.** *Performance-space diagram of test sections.*

All SMA Mixes

- Minimal rutting
- High fracture energy for cracking resistance

# SMA Next Steps

## Performance Testing Examples – WisDOT



Thank You!!!!

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