Structural Characteristics and Environmental Benefits of Cold-Recycled Asphalt Paving Materials

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National Pavement Preservation Conference
Nashville TN   October 12-14, 2016

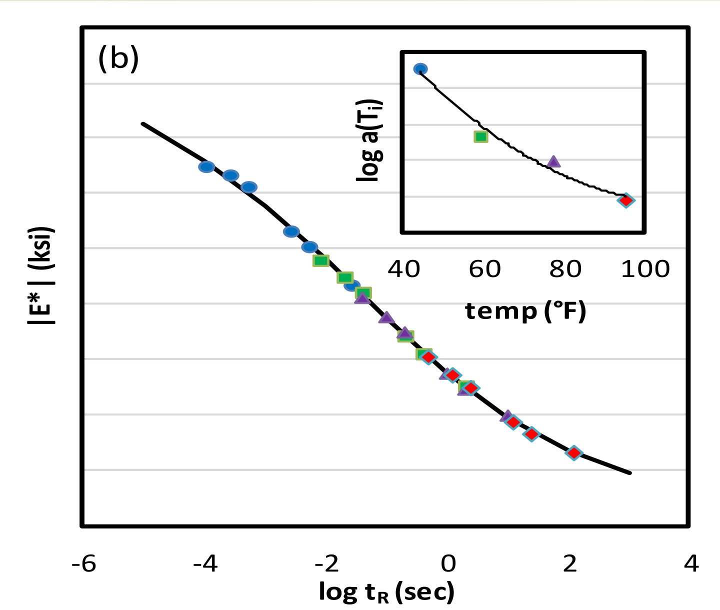
NCHRP 9-51 Project Objective

"Propose material properties and associated test methods and distress models for predicting the performance of pavement layers prepared with CIR of AC and FDR of AC with aggregate base and minimal amounts of subgrade material using asphalt-based materials." *NCHRP 9-51 RFP*

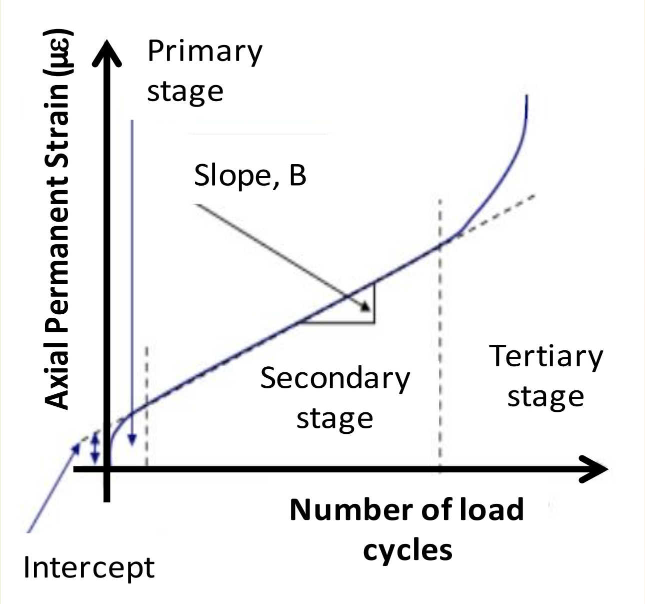
Focus on:

- In situ structural properties under field-cured conditions
- Material property inputs for MEPDG/AASHTOWare^{TM} Pavement ME Design®

Structural Properties of Interest

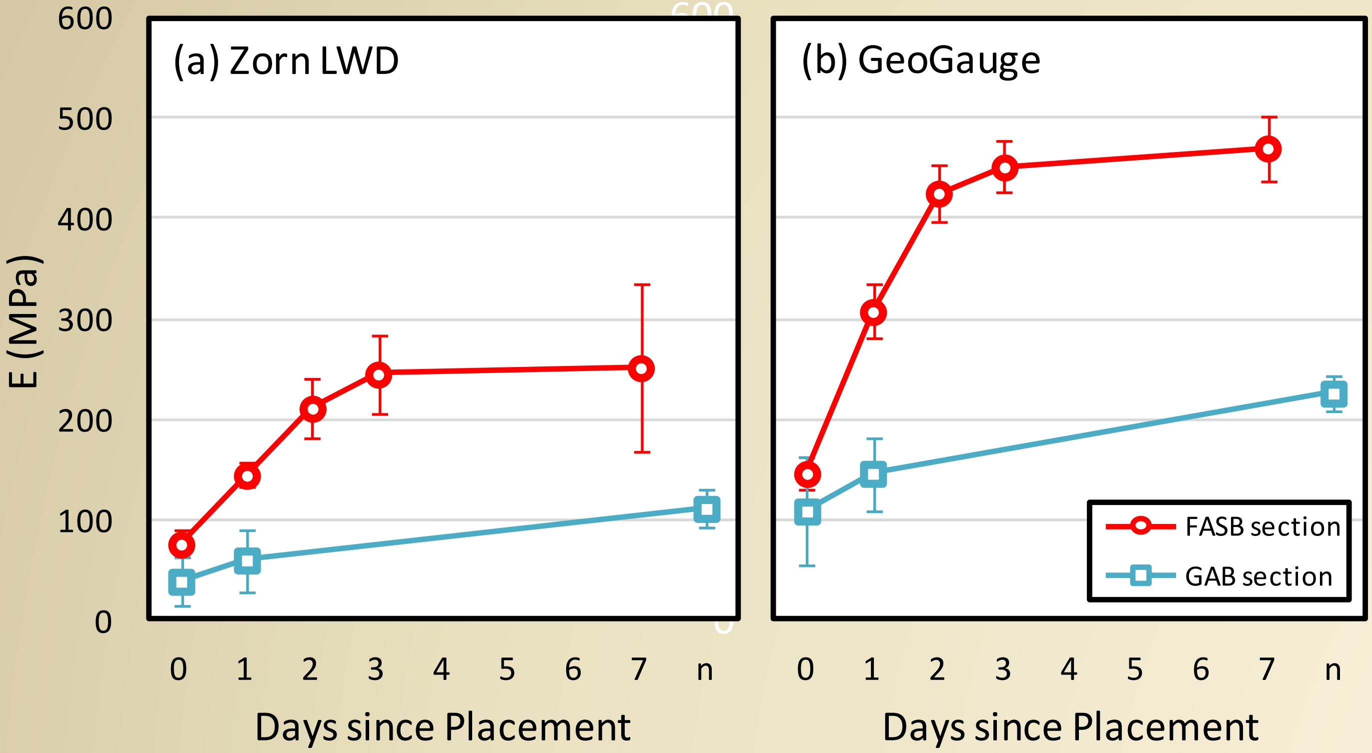


Stiffness: Dynamic Modulus



Permanent Deformations: Slope and Intercept

CCPR Stiffness vs. Time



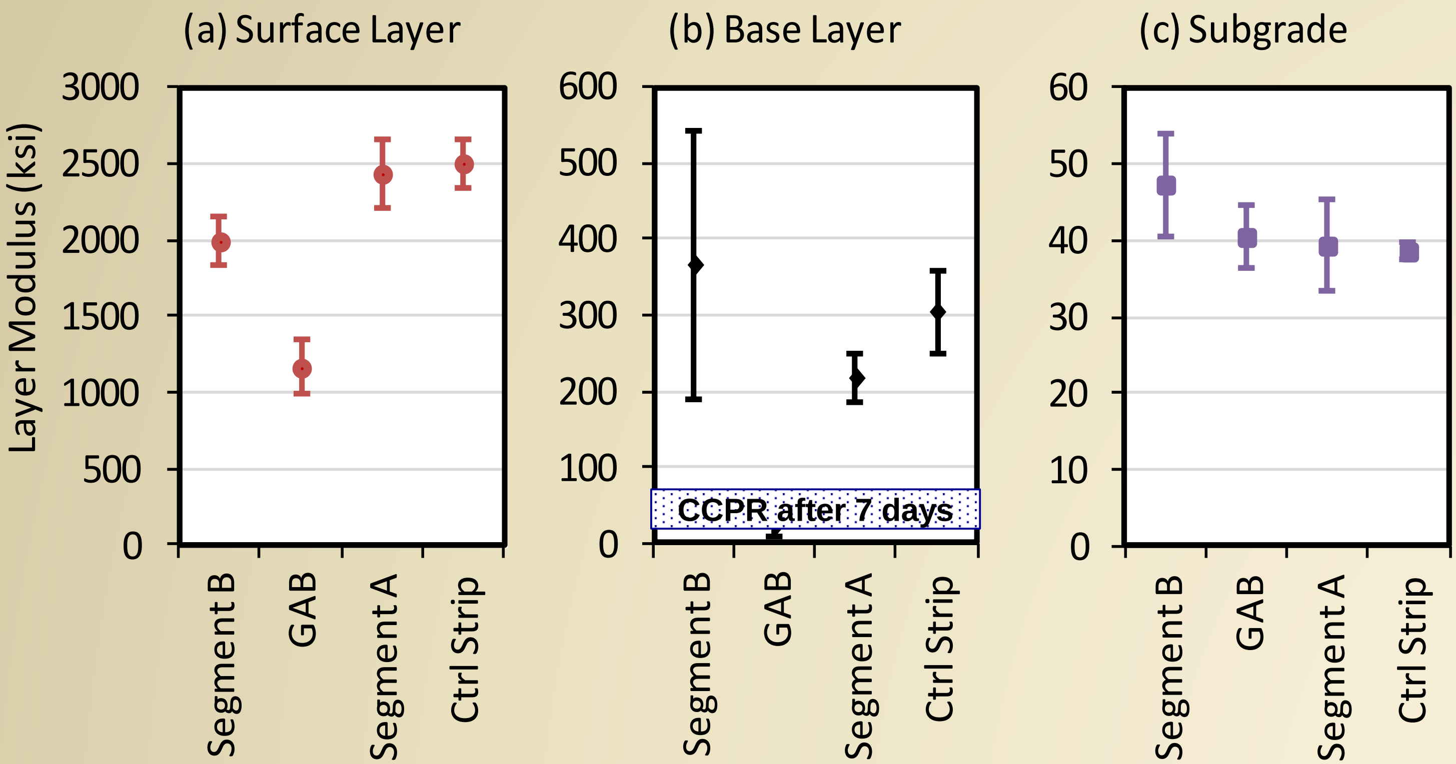
MD 295

Immediately after placement

Drying vs. Curing?

Khosravifar, Schwartz, and Goulias (AHPC 2013)

CCPR Stiffness vs. Time

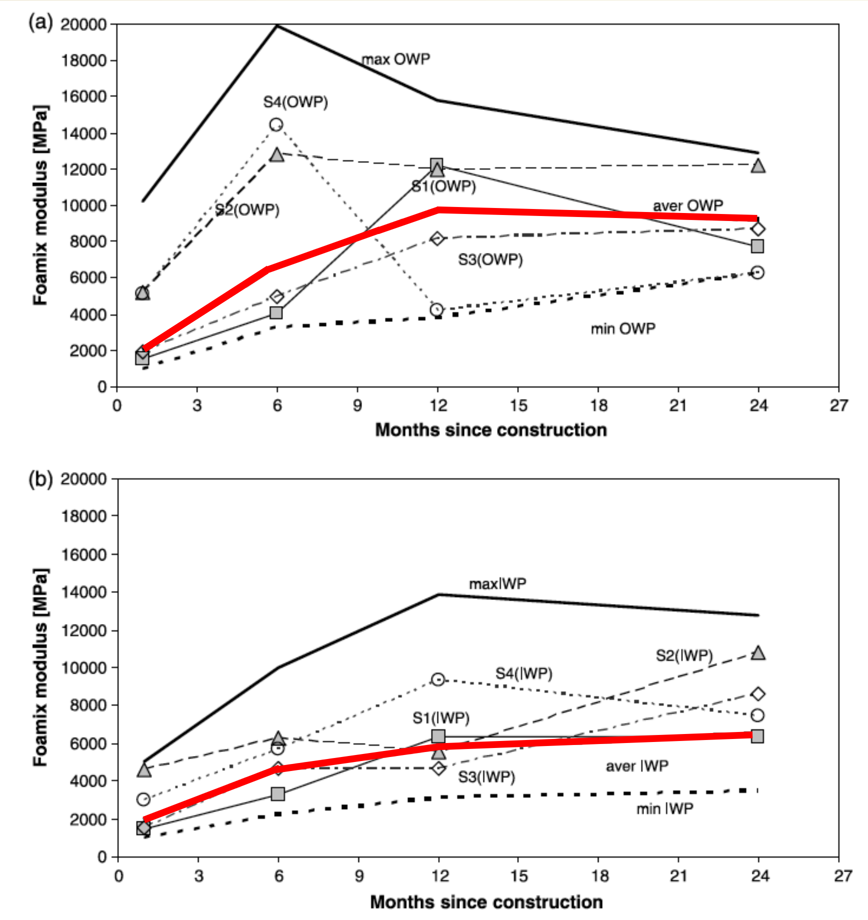


MD 295

4-6 months after placement

Khosravifar, Schwartz, and Goulias (AHPC 2013)

CIR Stiffness vs. Time



9 cm HMA over
25 cm foam stabilized recycled cement-treated base

Loizos (IJPE 2007)

NCHRP 9-51 Project Team

University of Maryland – College Park (Charles Schwartz/PI)

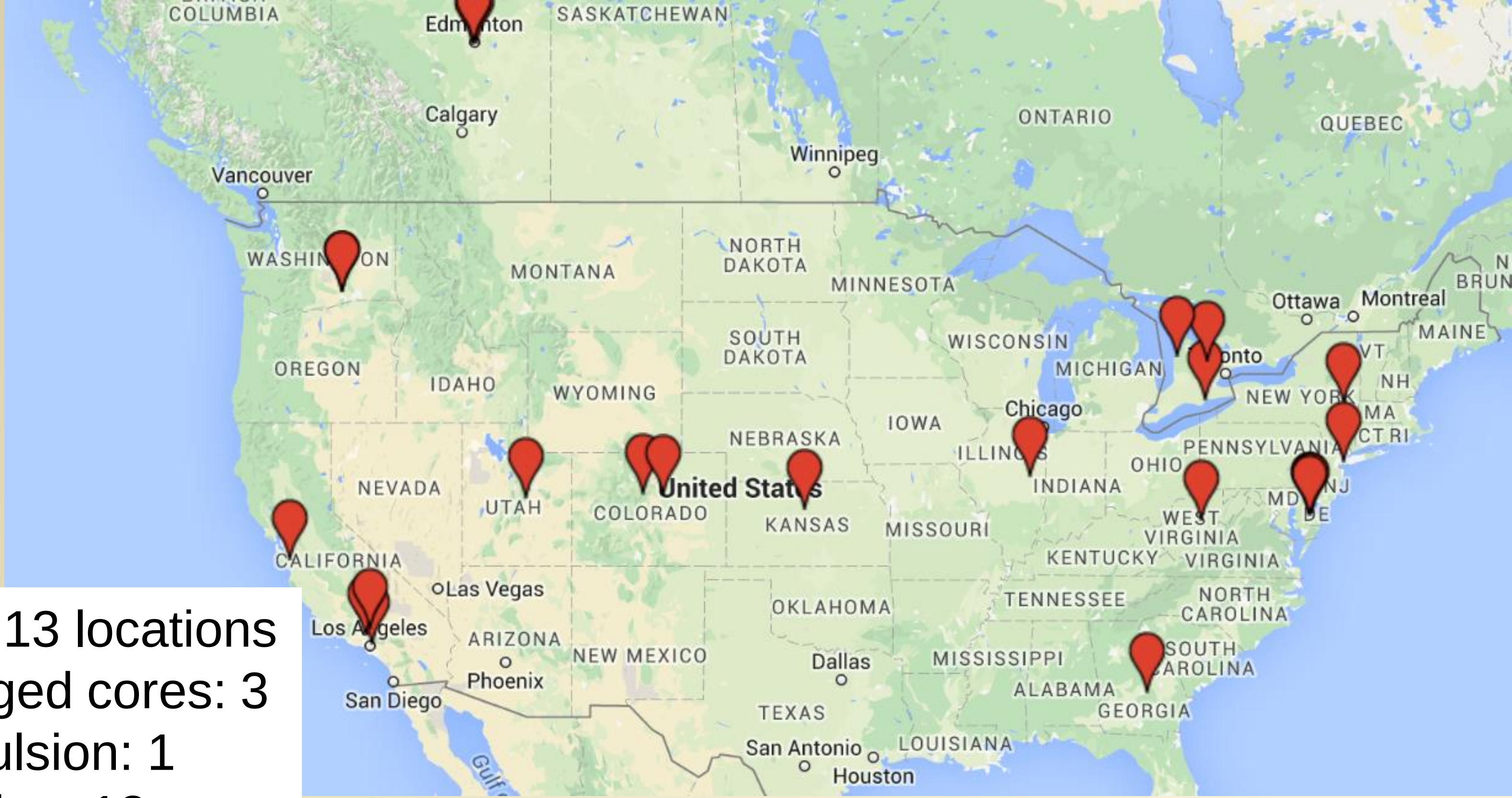
Virginia Center for Transportation Innovation and Research (Brian Diefenderfer/Co-PI)

Wirtgen America (Mike Marshall)

Colas Solutions (Todd Thomas)

NCHRP Program Manager: Ed Harrigan

NCHRP Panel Chair: Andrew Gisi, KS DOT



25 projects in 13 locations

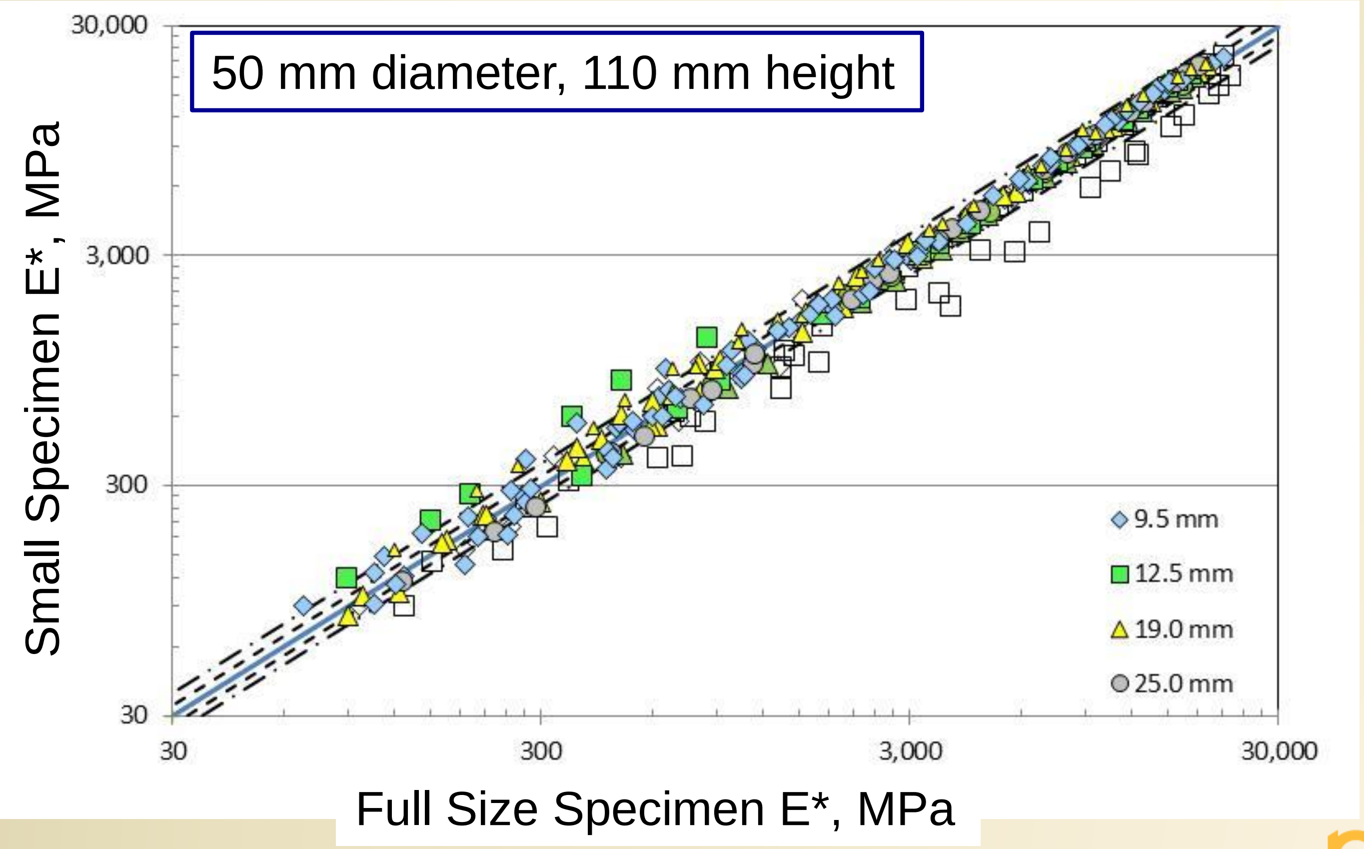
- Bad/damaged cores: 3
- CCPR emulsion: 1
- CIR emulsion: 12
- CIR foam: 3
- FDR foam: 4
- FDR emulsion: 2

3 to 6 inches for CIR




Bowers, Diefenderfer,
and Diefenderfer (AAPT 2015)

Full Size vs. Small Specimens



HMA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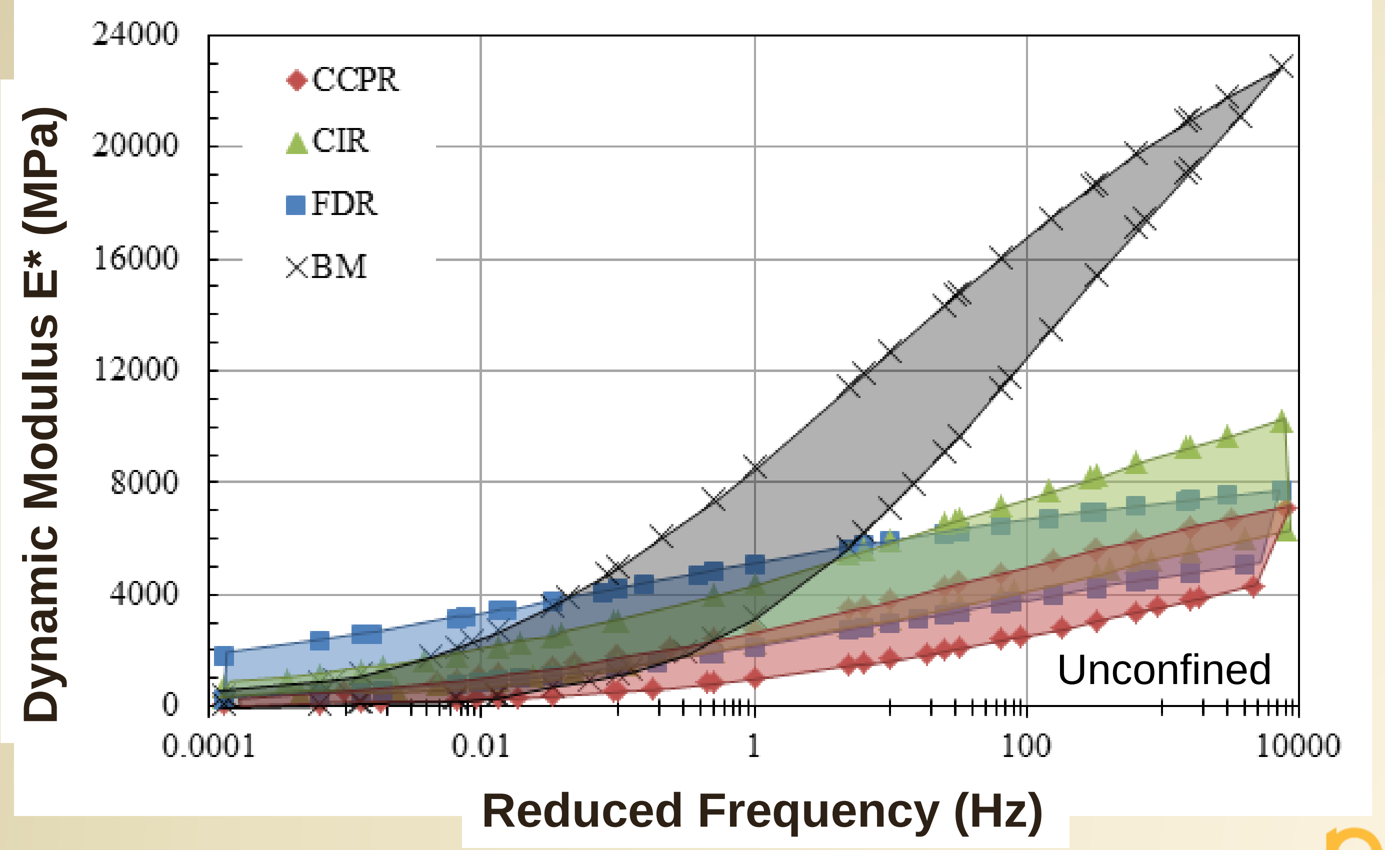
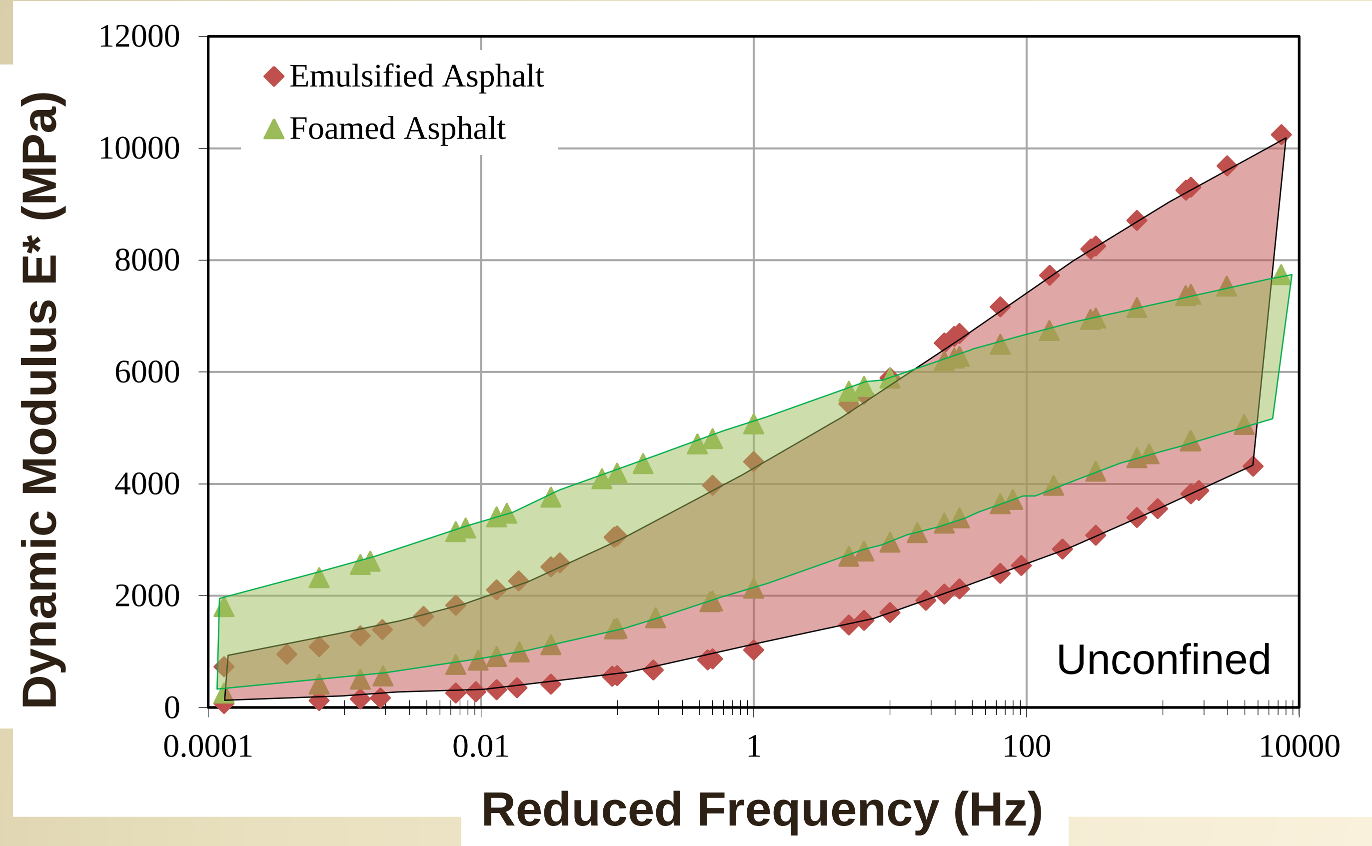
E* Envelopes - All



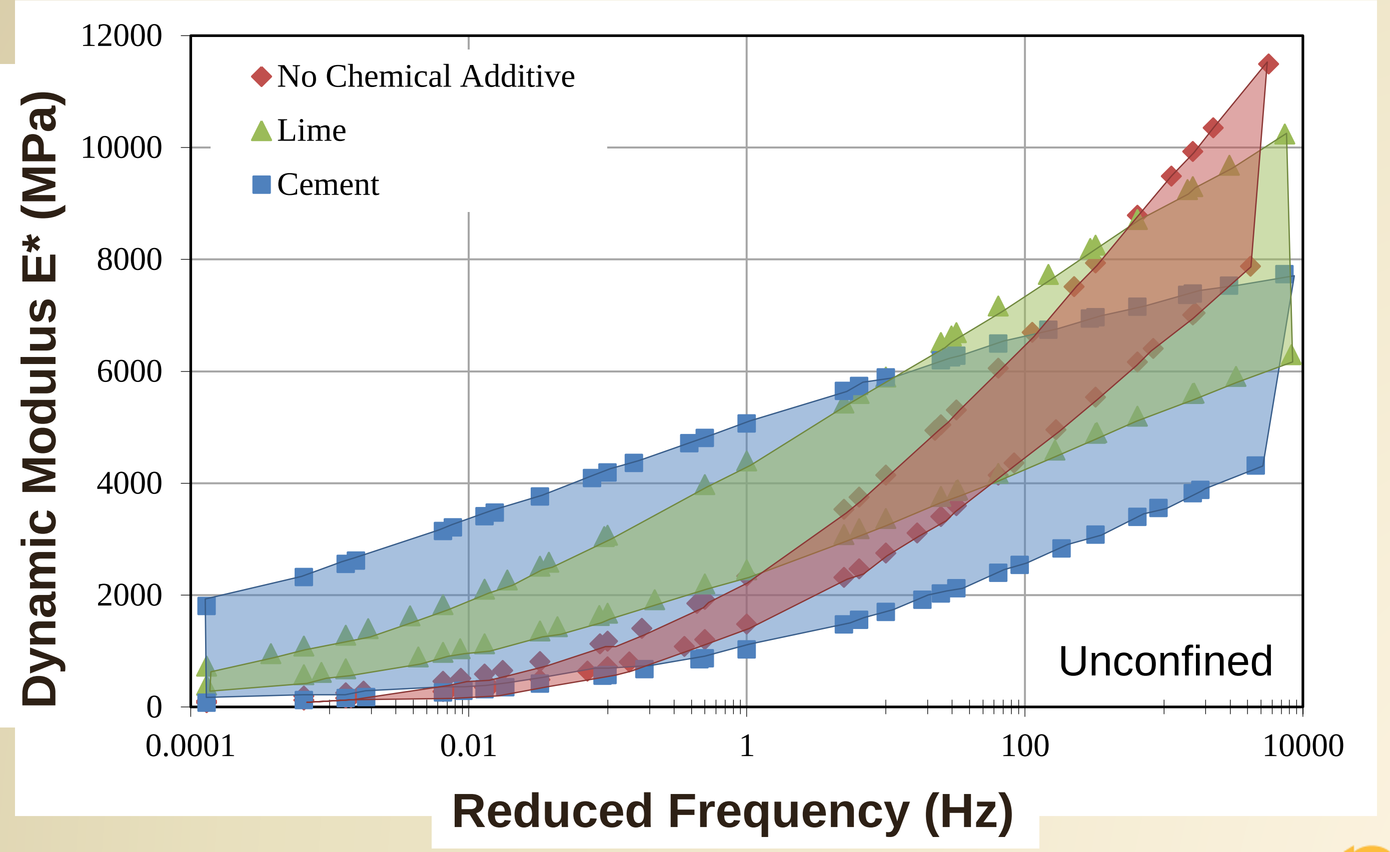
Diefenderfer, Bowers, Schwartz, Farzenah, and Zhang (TRR 2016)

E* Envelopes – Stabilizer Type



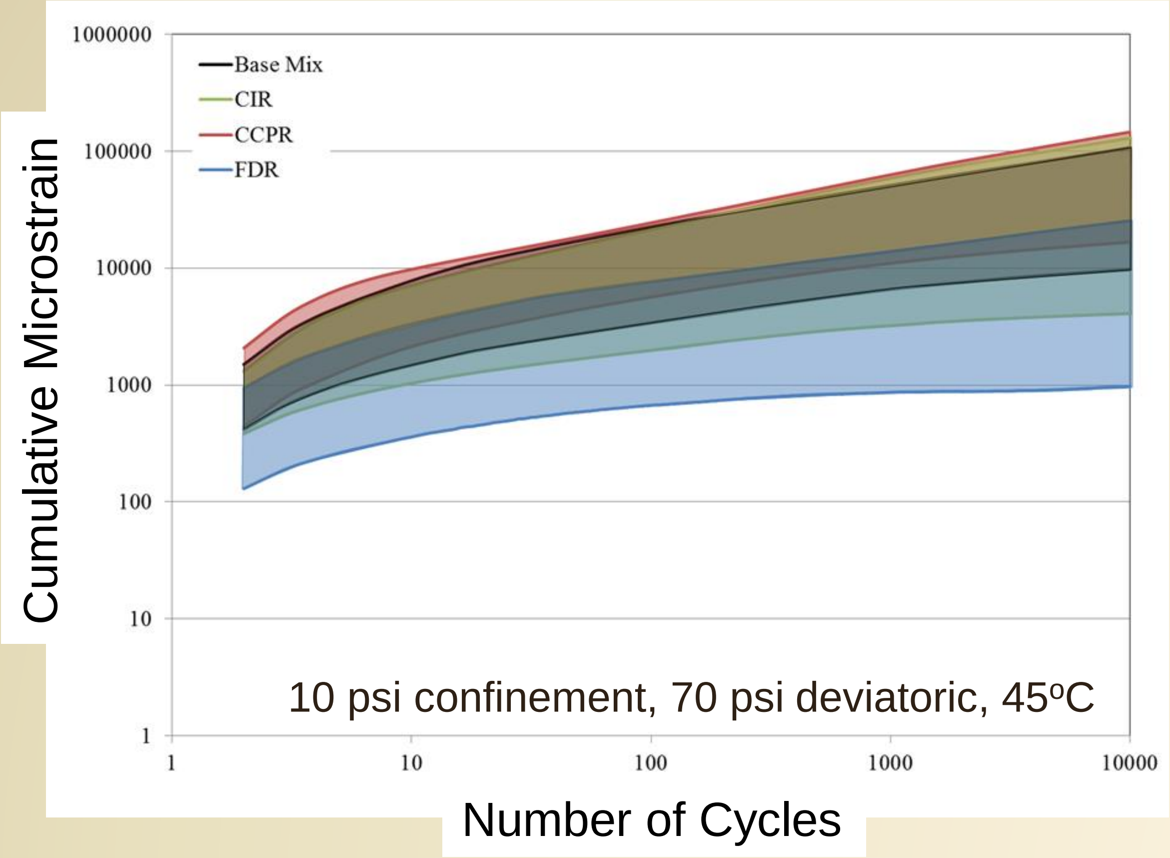
Diefenderfer, Bowers, Schwartz, Farzenah, and Zhang (TRR 2016)

E* Envelopes – Active Filler



Diefenderfer, Bowers, Schwartz, Farzenah, and Zhang (TRR 2016)

RLPD Envelopes - All



Bowers, Diefenderfer, and Schwartz (TRB 2017)

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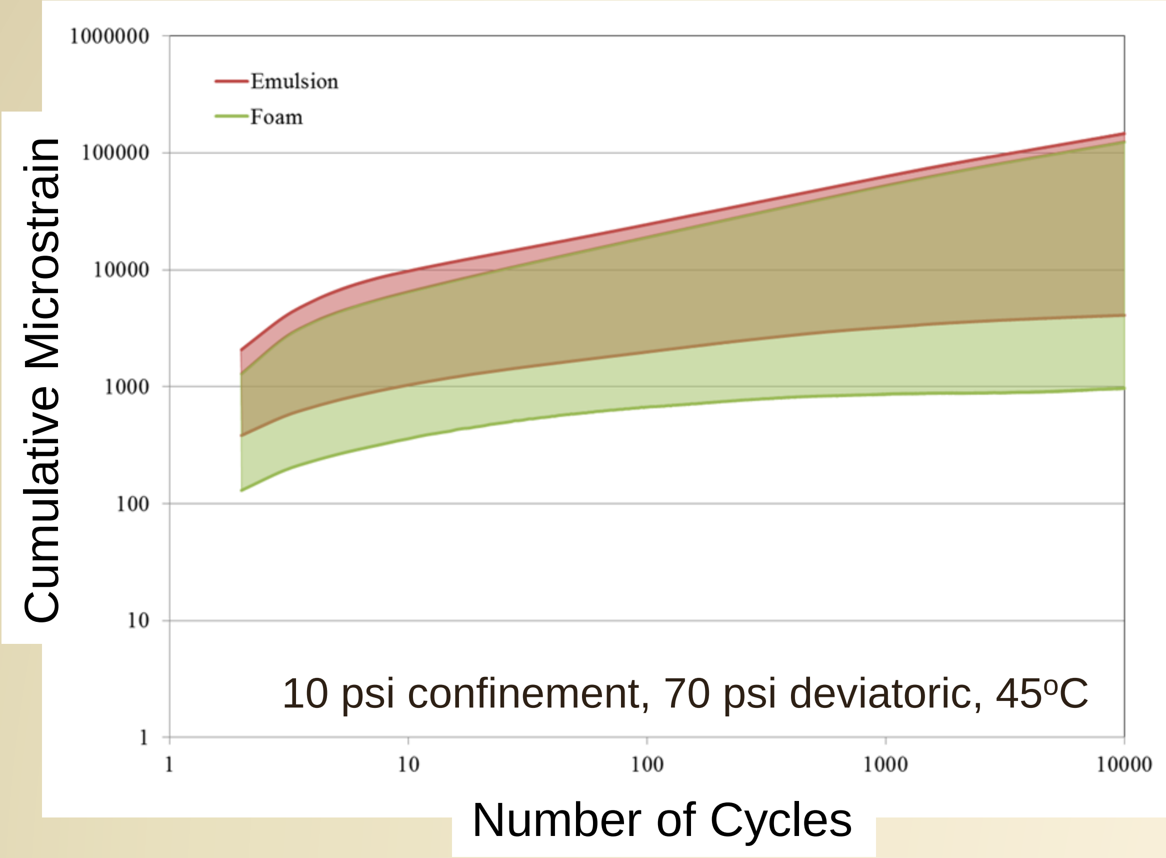
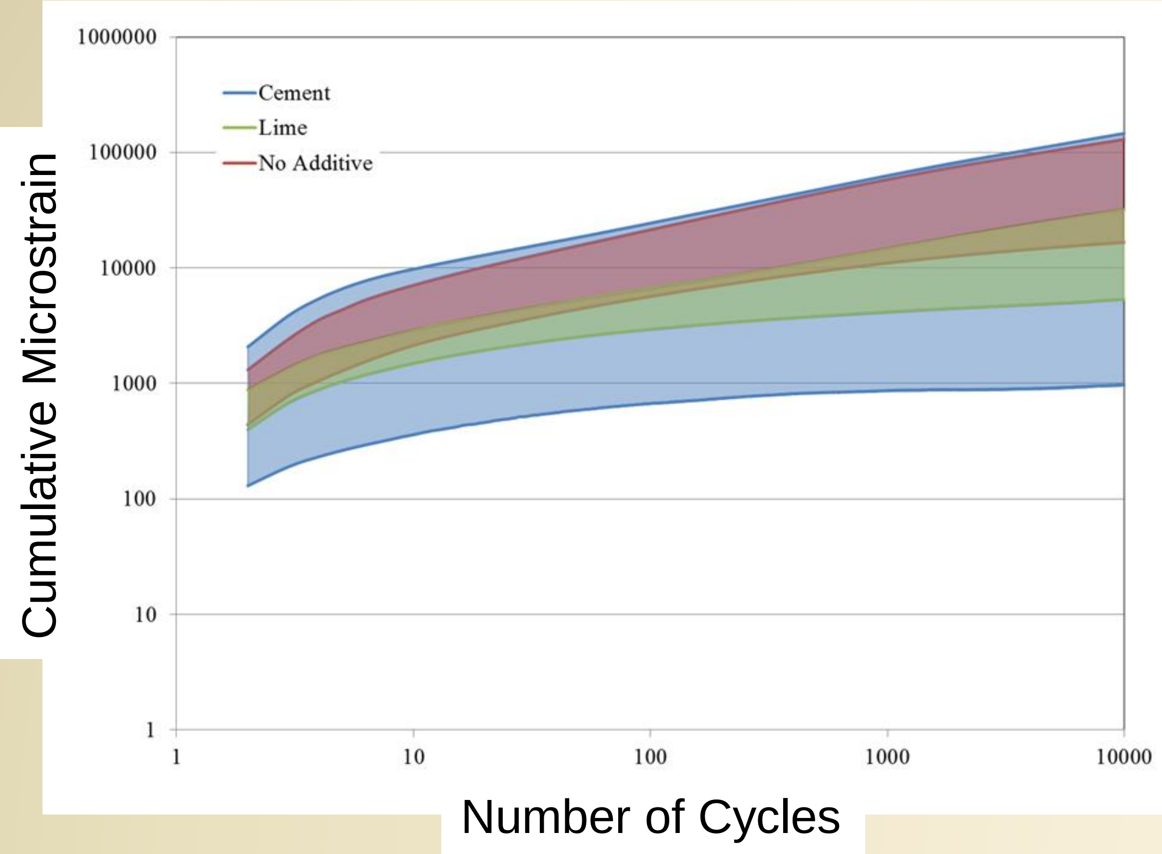
RLPD Envelopes – Stabilizer Type



Bowers, Diefenderfer, and Schwartz (TRB 2017)

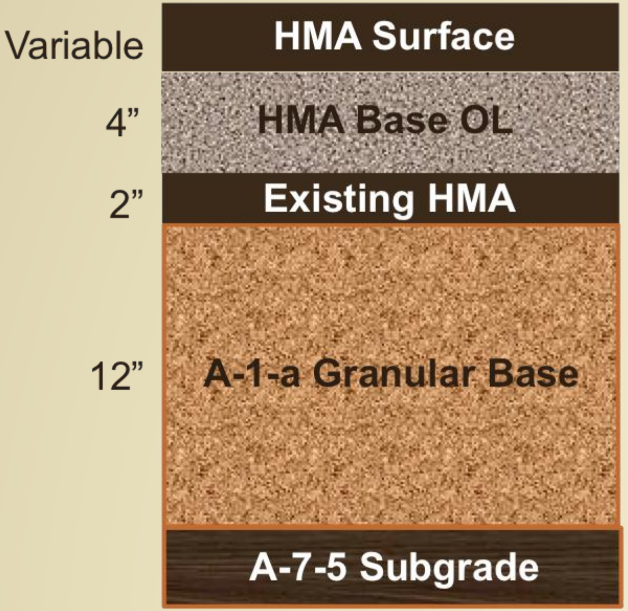
RLPD Envelopes – Active Filler



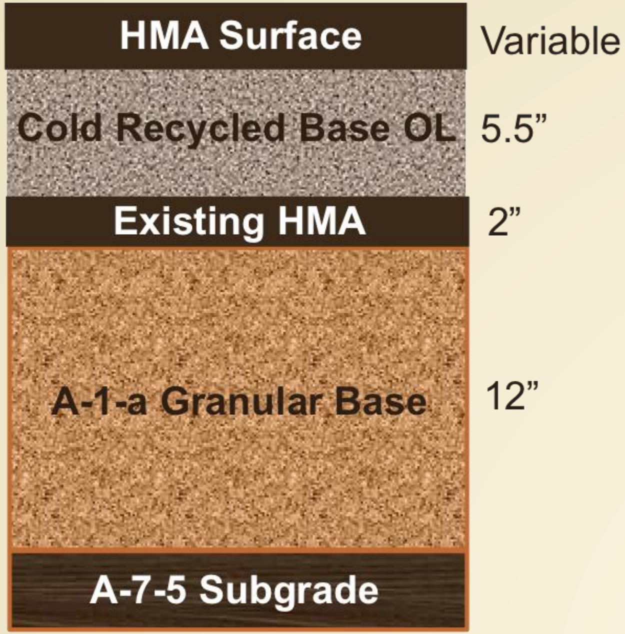
Bowers, Diefenderfer, and Schwartz (TRB 2017)

Performance Predictions

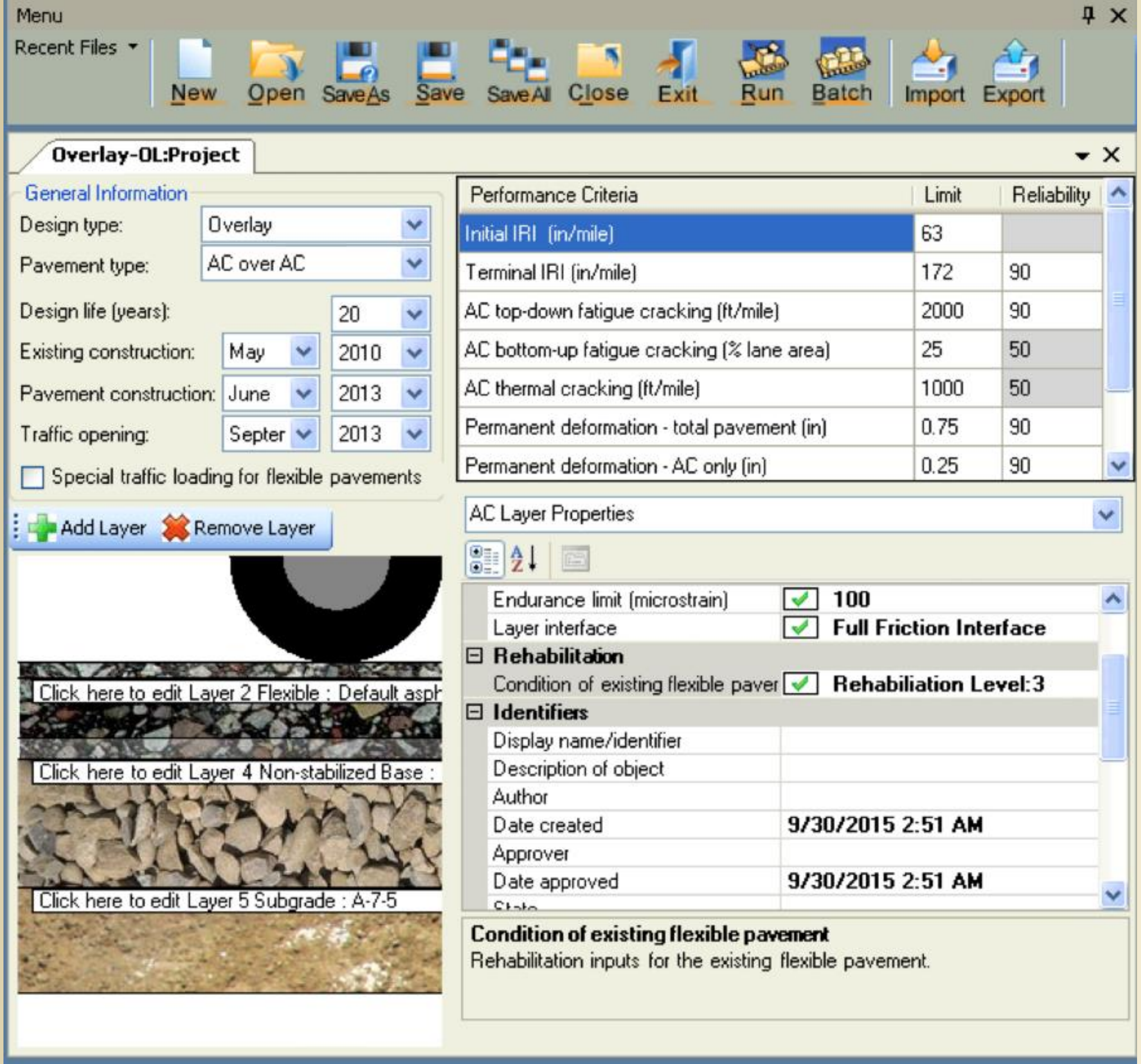
Structural layer coefficient
- Cold recycled: 0.32
- HMA base (19mm): 0.40



HMA Rehab



Cold Recycled Rehab



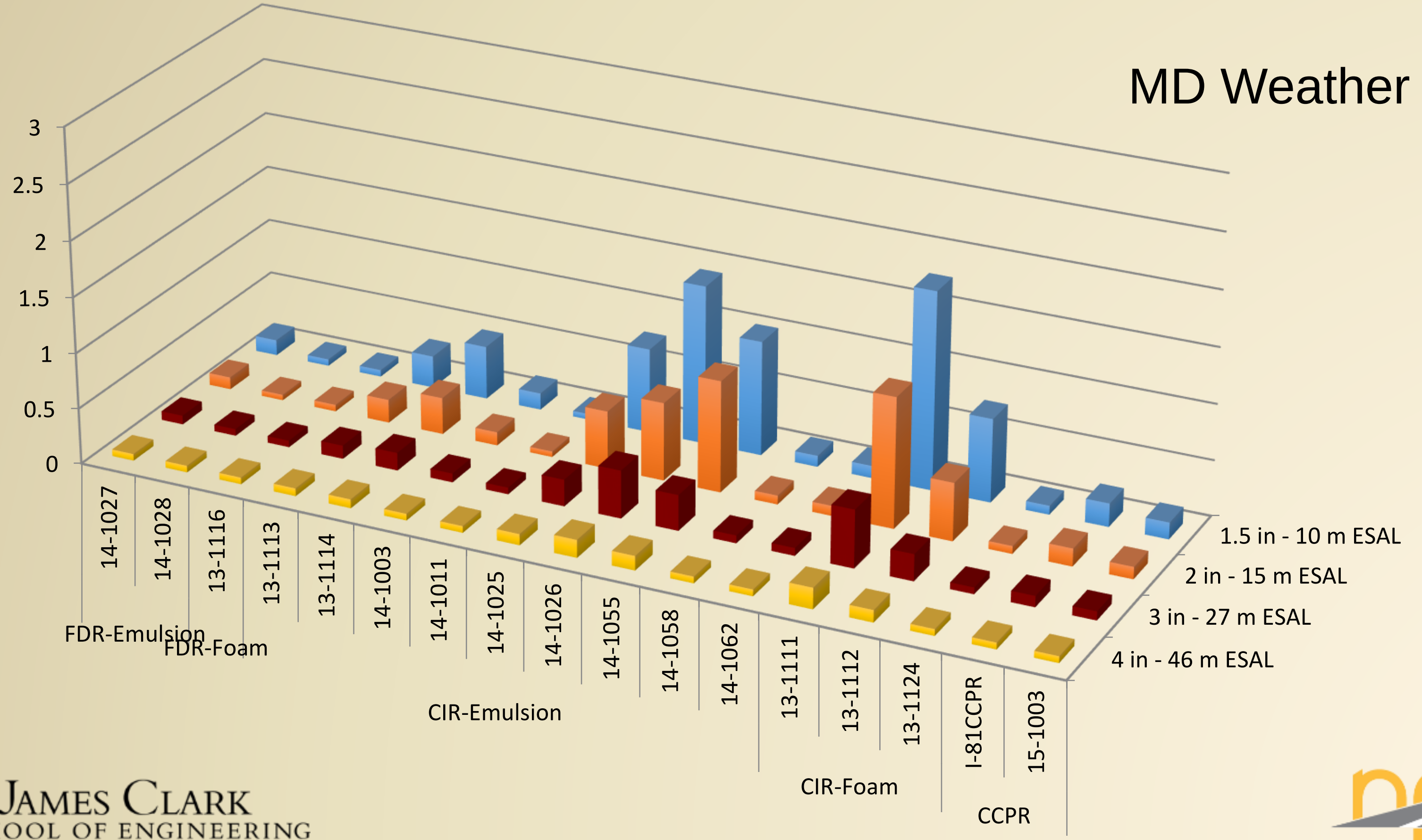
Pavement ME Design

Version 2.0

Analysis Inputs

- HMA surface course thicknesses: 1.5, 2, 3, and 4 inches
- A-1-a base resilient modulus: 25000 psi
- A-7-5 subgrade resilient modulus: 5000 psi
- Traffic: 10M – 46M ESALs
- Climate: Minnesota, Maryland, Arizona
- Level 1 material properties for HMA (surface/base), cold recycled mixes
  - Dynamic modulus
  - RLPD
- Default global calibration (no recycled sections included)

Performance Predictions



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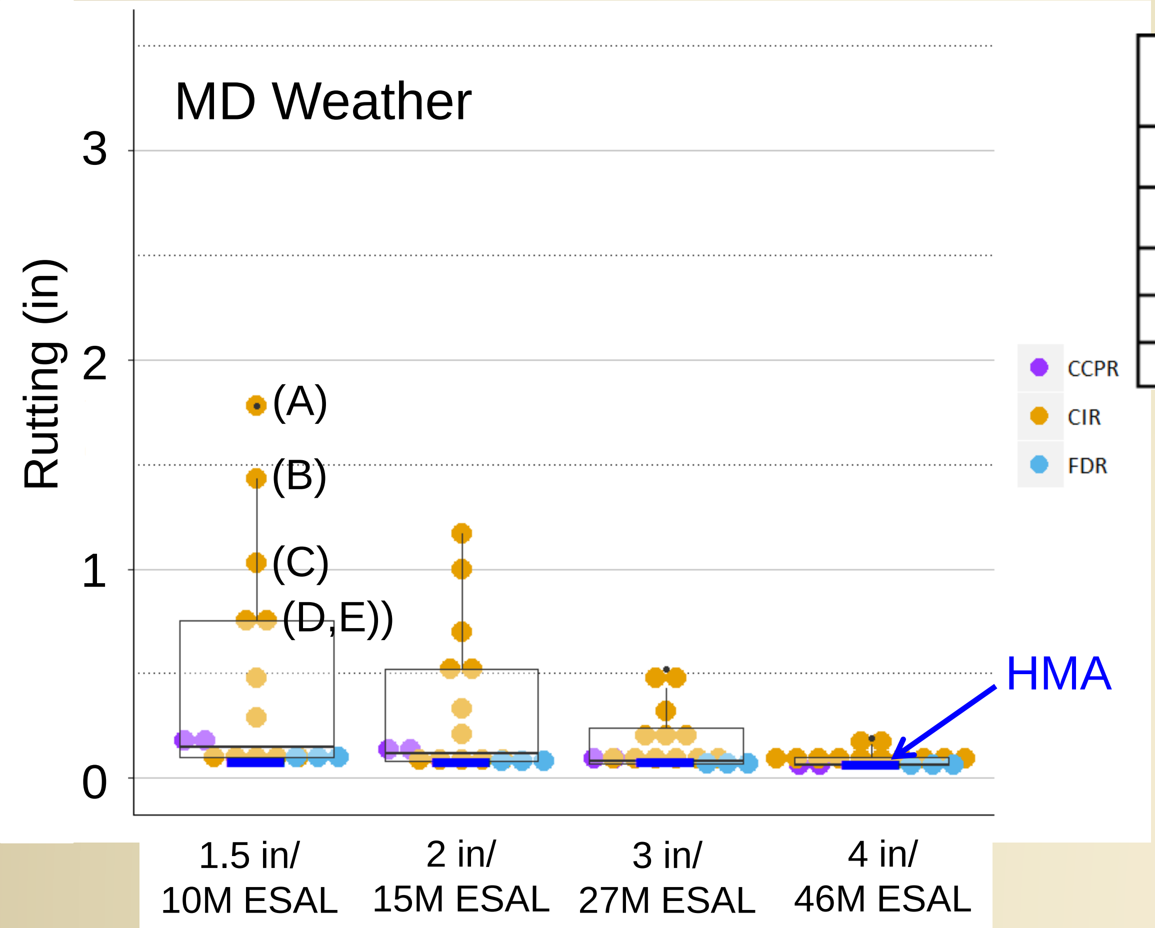
Performance Predictions



		E* Lower Shelf	RLPD Intercept	RLPD Slope
A	Foam			↑
B	Emul	↓	↑	↑
C	Emul	↓		↑
D	Emul		↑	↑
E	Foam		↑	↑

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Conclusions: Structural Properties

- Field-cured structural properties required for MEPDG:
  - FDR/CIR/CCPR E* values ~50% those of HMA
    - Slightly lower for foam, emulsion CIR
  - CIR/CCPR RLPD behavior similar to HMA (base mix)
  - FDR RLPD slightly better than HMA

- *Preliminary* Pavement ME Design® results: Well-designed cold recycled materials after thickness adjustment give performance comparable to HMA

Environmental Benefits

- Ambient temperature along with production and installation
- 100% recycled materials
- Minimize transportation
- Reduce the bitumen content by 60% over HMA

- Eliminate use of energy stocks to heat aggregates
- Eliminate emission from quarry
- Reduce the use of diesel
- Reduce the bitumen embodied emissions

Contributors:

- Qingbin Cui (UMD)
- Xiaoyu Liu (UMD)
- Global Emissionary LLC
- Strachan Environmental Consulting

Liu, Cui, Schwartz *Journal of Environmental Management* 132 (2014) 313-322

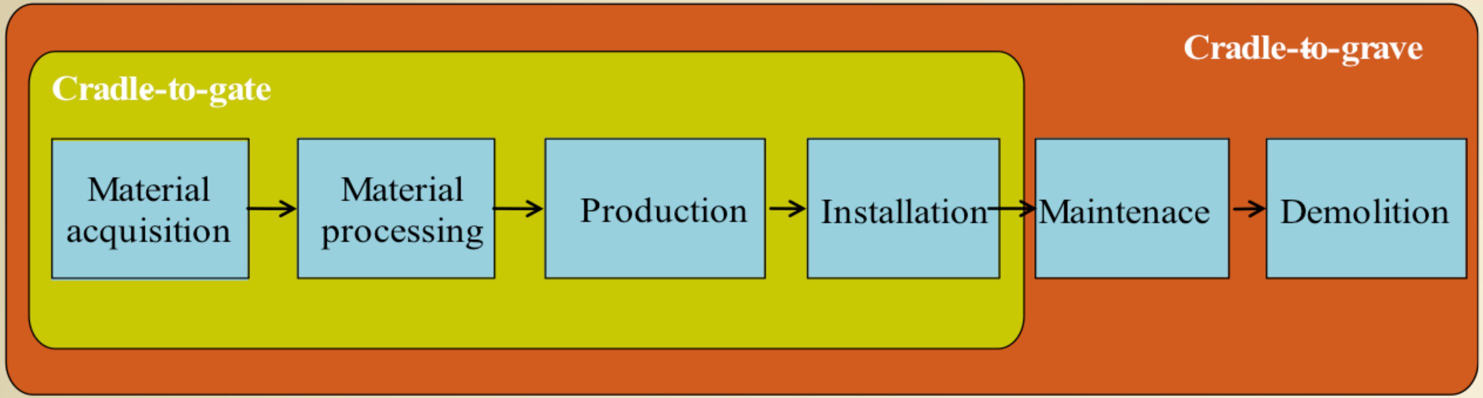
Verified Carbon Standard (VCS) Program

METHODOLOGY FOR PAVEMENT APPLICATION USING FOAM STABILIZED BASE (FSB)

Title	**Methodology for Pavement Application using Foam Stabilized Base (FSB)**
Version	1.0
Date of Issue	July 23, 2014
Type	Methodology
Sectoral Scope	Material Manufacturing, Construction
Prepared By	Emissionairy Inc Maryland Industrial Partnerships Straughan Environmental
Contact	Qingbin Cui, 301-405-8104, cui@umd.edu

Emission Estimation Boundaries

According to *Publicly Available Specification 2050*:



The cradle-to-gate boundaries exclude GHG emissions associated with:

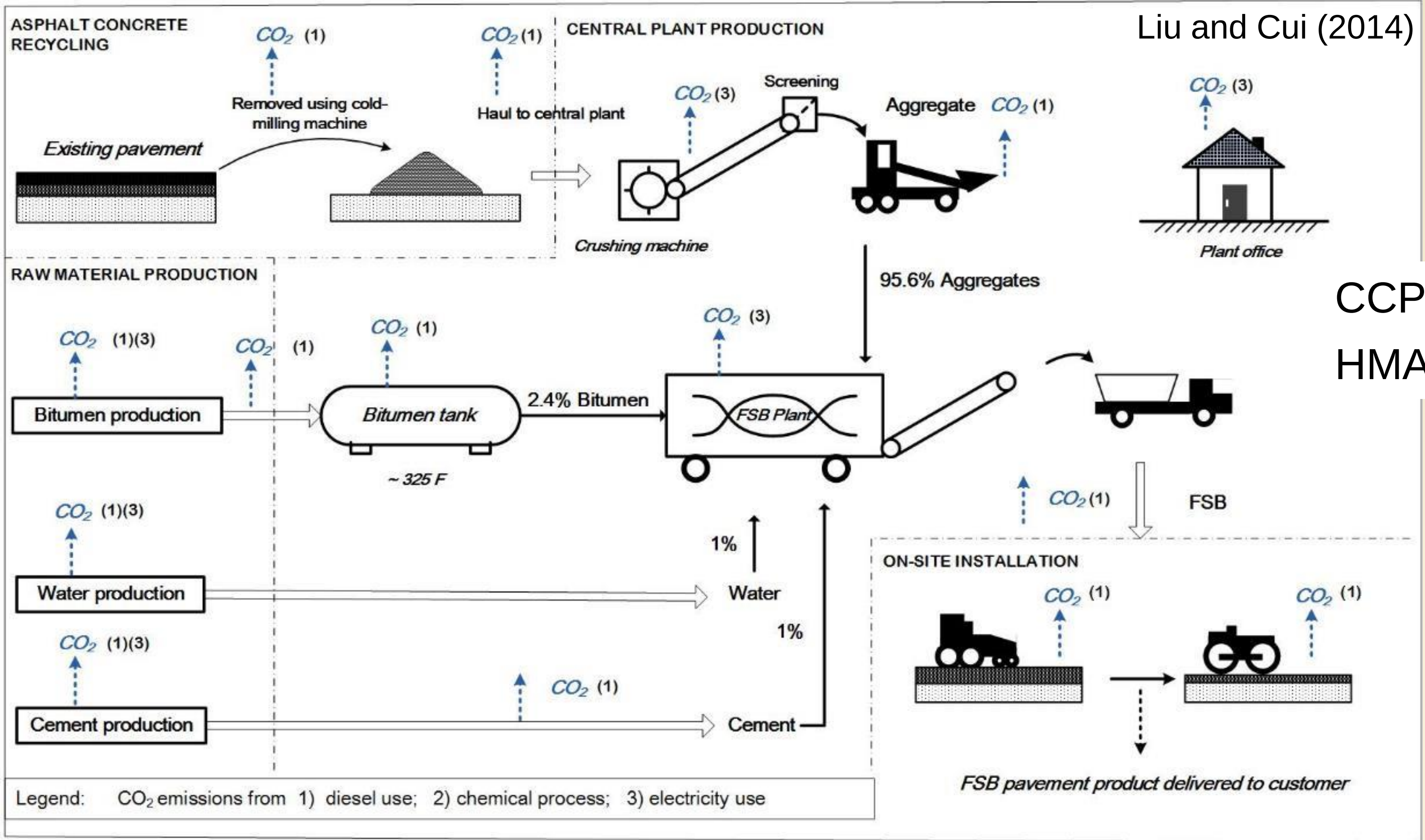
1) Maintenance, demolishment and replacement activities

2) Production of capital goods having lifetimes longer than 1 year

3) Transport of employees to and from their normal place of work

CO_2 Emissions: HMA, CCPR FSB

Liu and Cui (2014)

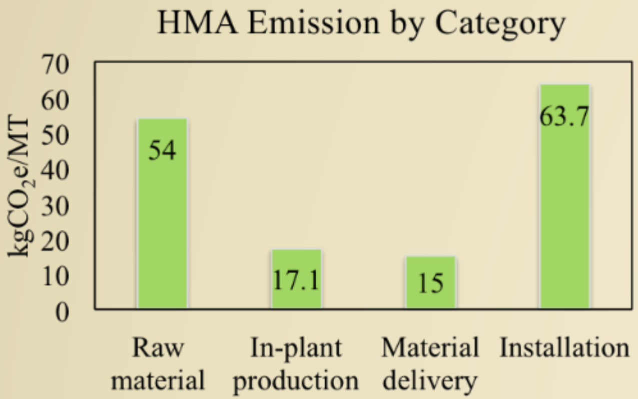


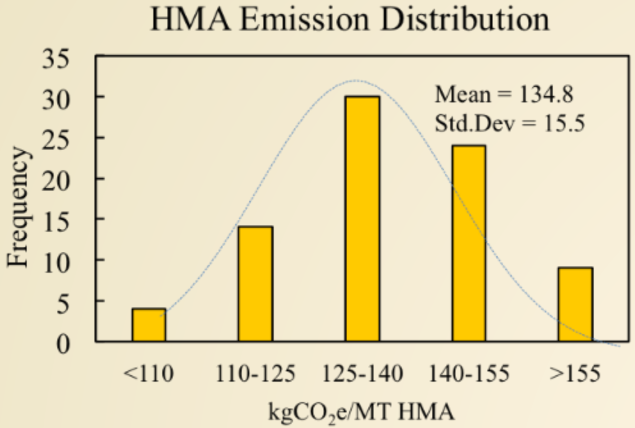
CCPR FSB shown; HMA similar

HMA Emission Estimation

Project type	Hauling distance	Average emission ($kgCO_2e/MT$)	Standard deviation
Parking lot	≤ 40 miles	134.8	15.5
Parking lot	> 40 miles	170.3	33.6
Roadway	undefined	121.9	19.8

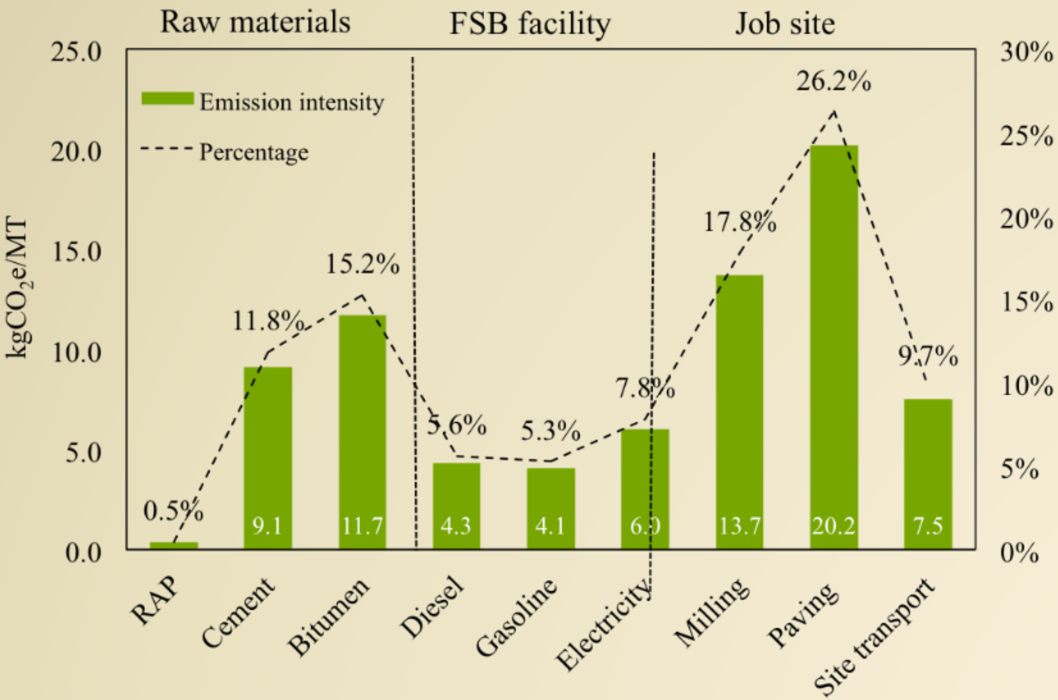
Average of 134.8 $kgCO_2e/MT$ HMA





Data collected from 16 HMA plants and 15 projects in MD and VA

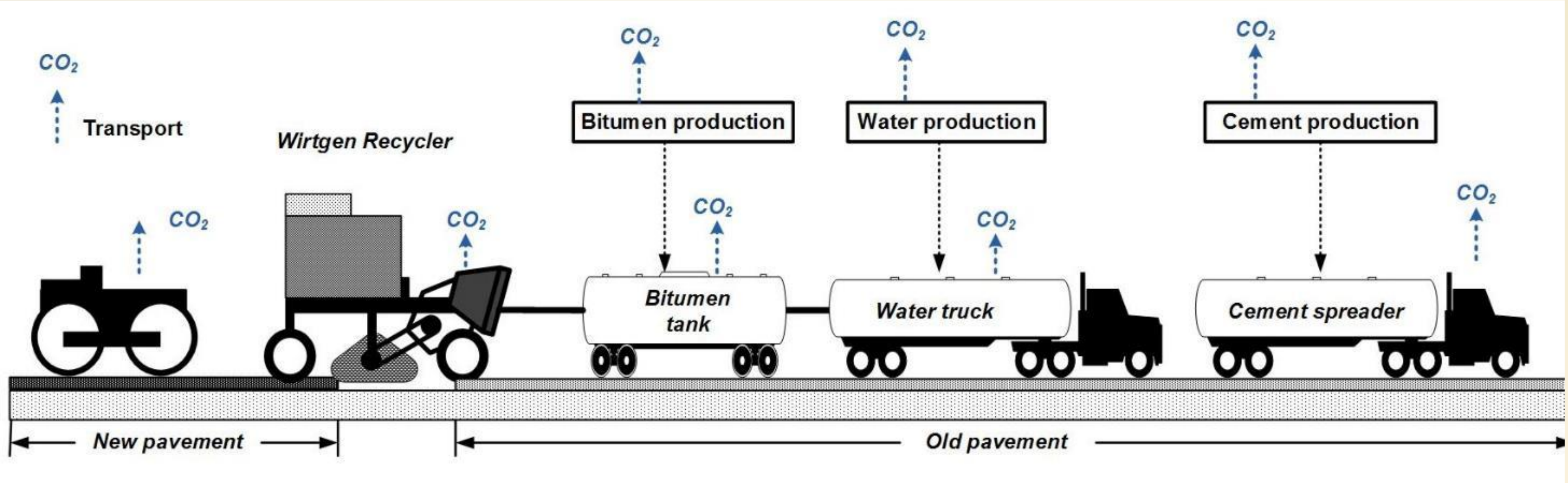
CCPR FSB Emission Estimation



In total, 76.9 $kgCO_2e$/MT FSB
(43% reduction from HMA)

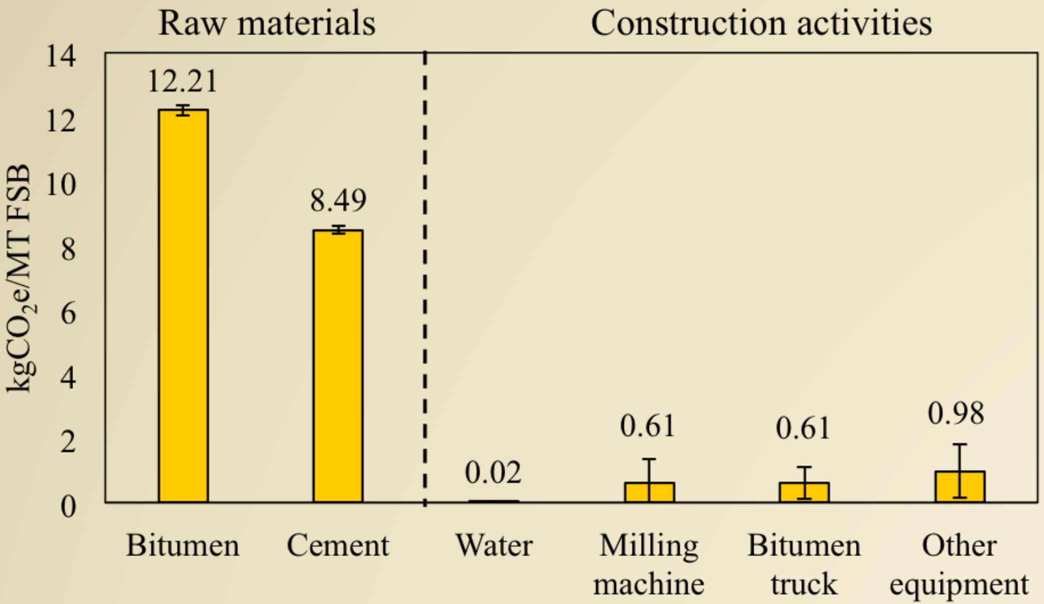
Production data collected onsite at Global Emissionairy LLC
in Forestville, MD from March 2012 to May 2013

CO_2 Emissions: CIR FSB



Liu and Cui (2014)

CIR FSB Emission Estimation



In total, 22.9 $kgCO_2$/MT FSB
(83% reduction from HMA)

Data was collected from one project performed in Carrollton in October 2012 and three projects performed in Hayward in July 2013.

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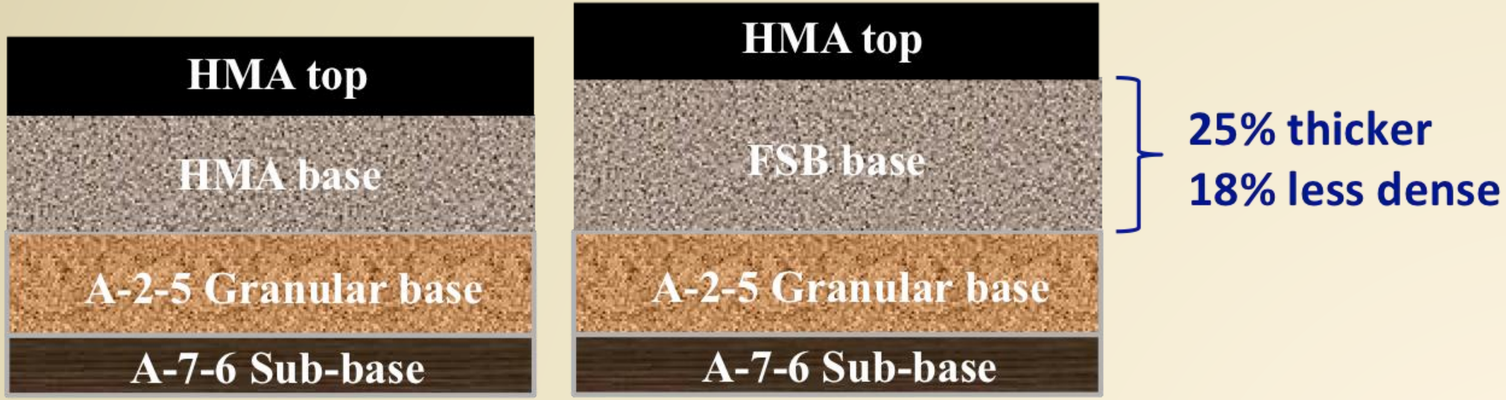
Emission Intensity Adjusted by Structure

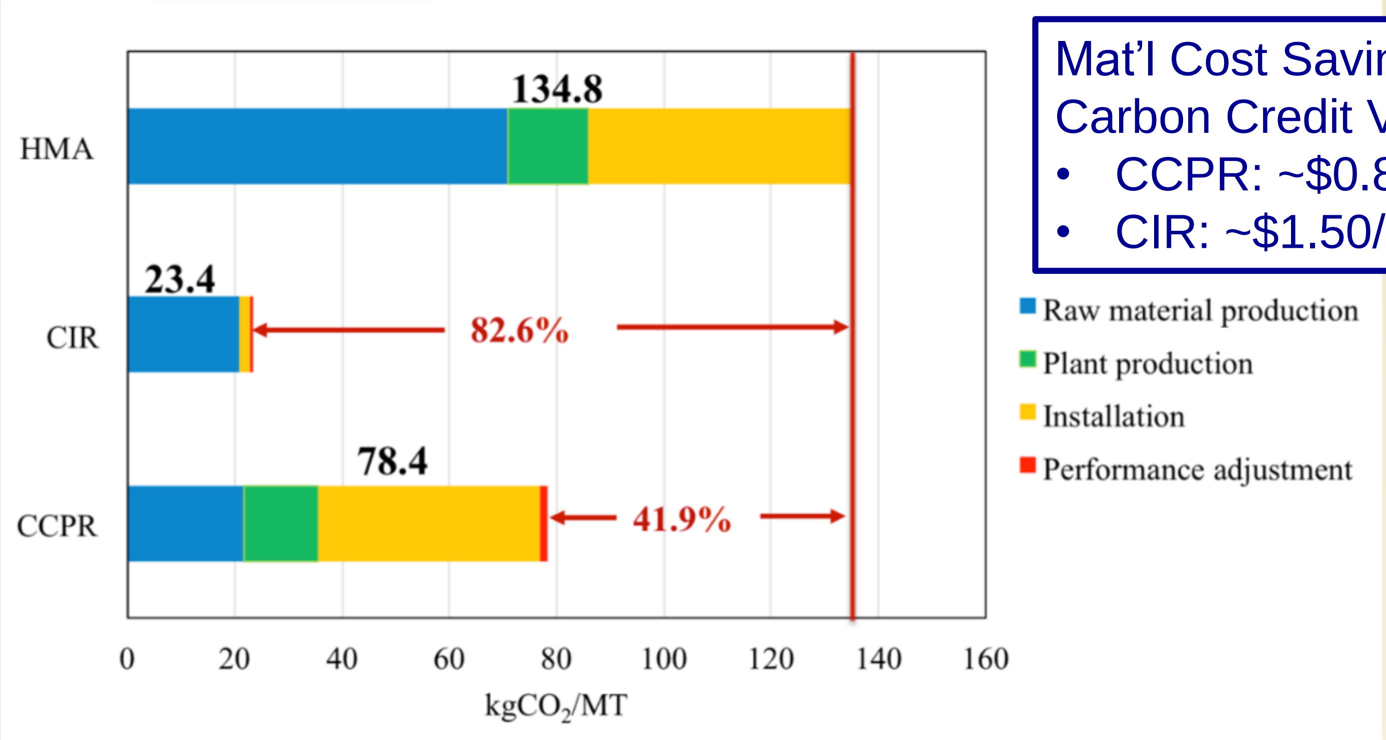
Structural layer coefficient

- FSB: 0.32
- HMA base (19mm): 0.40



HMA Pavement **FSB Pavement**

Emission Intensity Comparison



Mat'l Cost Savings: ~$20/ton (CCPR)
Carbon Credit Value

- CCPR: ~$0.80/ton
- CIR: ~$1.50/ton

Lower density nearly compensates for extra thickness.

Conclusions: GHG Emissions

- Cold-recycled FSB provides substantial GHG reductions vs. HMA. On a per ton basis:
  - 43% reduction for CCPR
  - 83% reduction for CIR

- For fair comparison, must factor in differences in density, structural characteristics:
  - AASHTO 93: 25% more FSB thickness vs. HMA
  - FSB 130 pcf vs. HMA 160 pcf
  - GHG reductions on an adjusted per ton basis:
    - 42% reduction for CCPR
    - 80% reduction for CIR

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