

A large white Wirtgen cold-recycling machine is shown in the process of paving a road. Several workers in bright orange safety suits and hard hats are standing around the machine, monitoring the process. The machine has "WIRTGEN" written on its side. In the background, there are trees and a blue sky. The overall scene is a construction site for road paving.

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

Charles W. Schwartz
University of Maryland

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

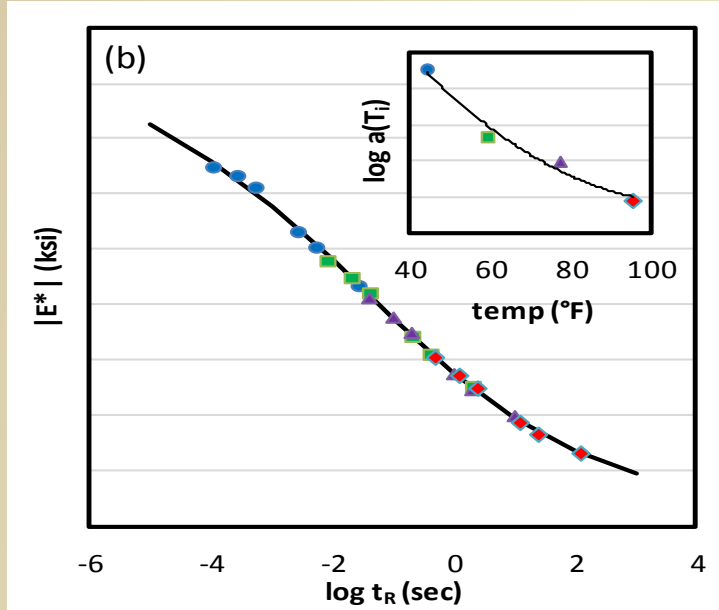
NCHRP 9-51 Project Objective

“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*

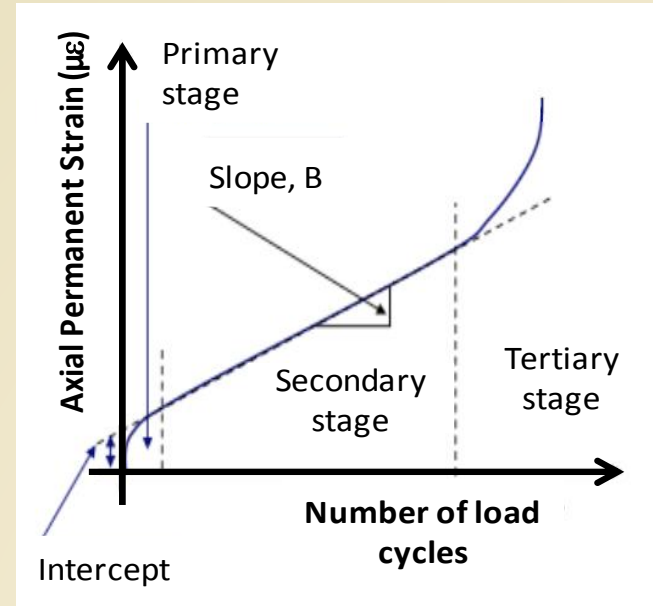
Focus on:

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

Structural Properties of Interest

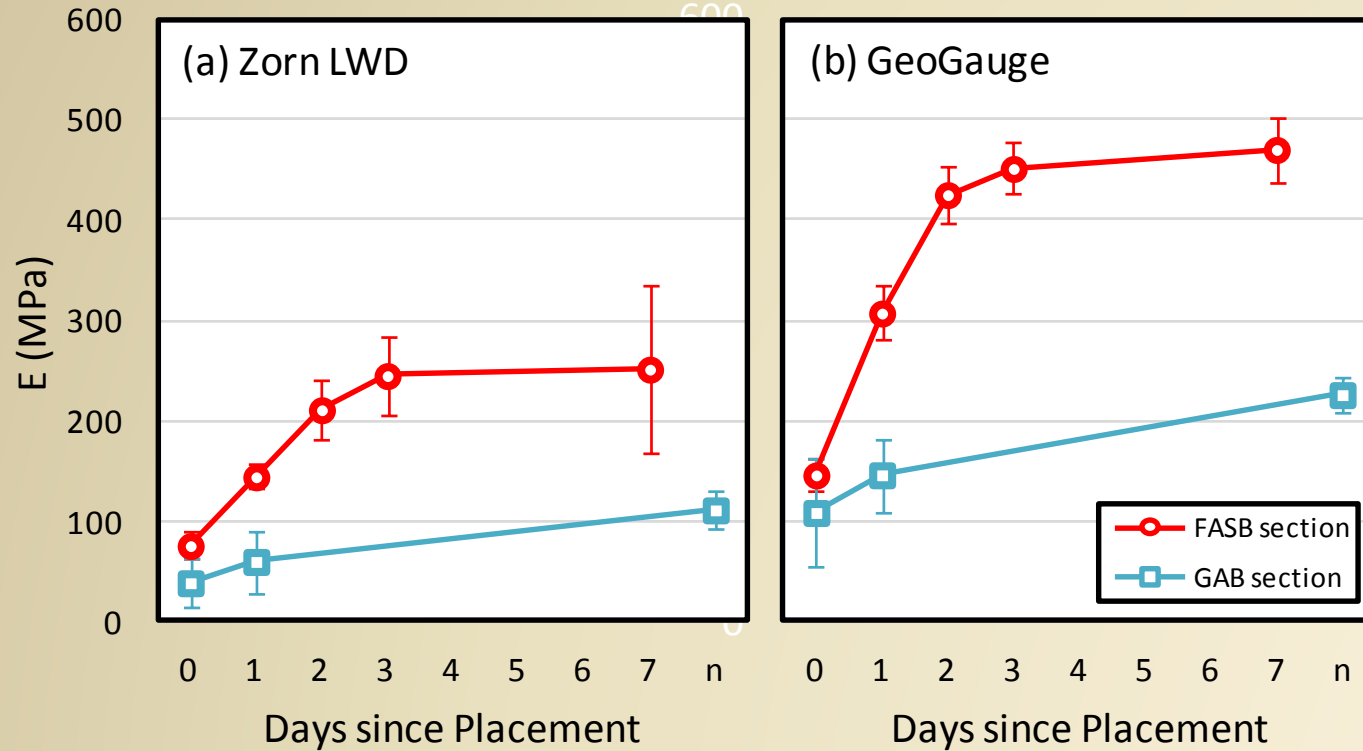


Stiffness: Dynamic Modulus



Permanent Deformations:
Slope and Intercept

CCPR Stiffness vs. Time



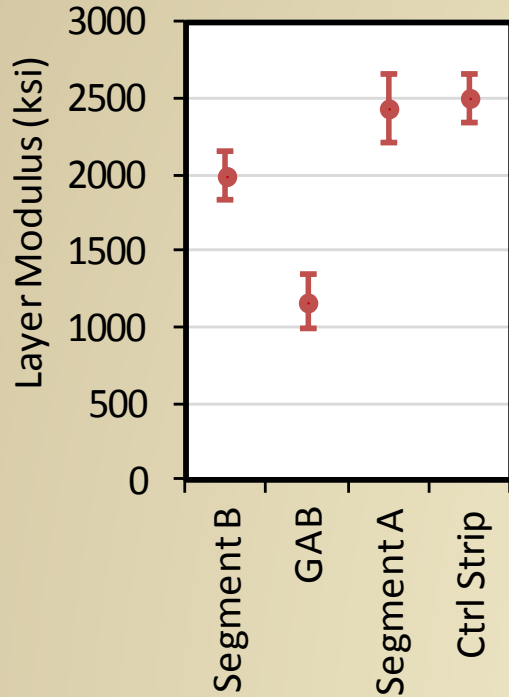
MD 295

Immediately
after placement

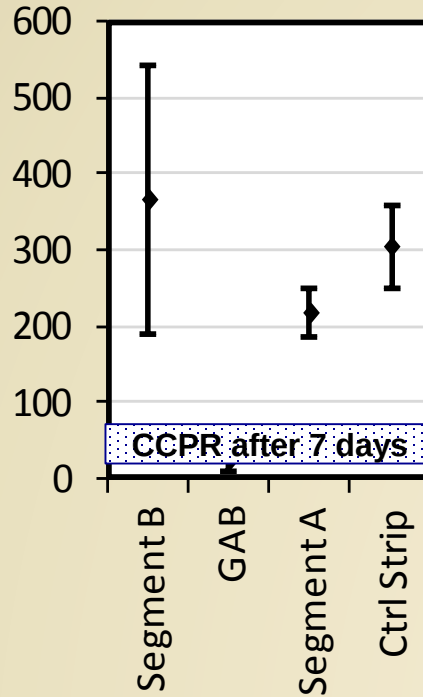
Drying vs. Curing?

CCPR Stiffness vs. Time

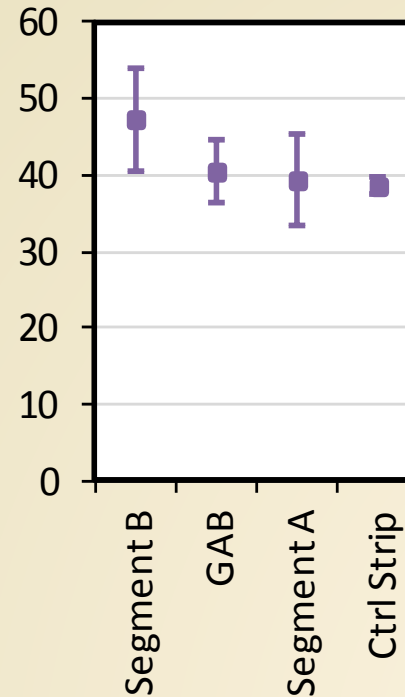
(a) Surface Layer



(b) Base Layer



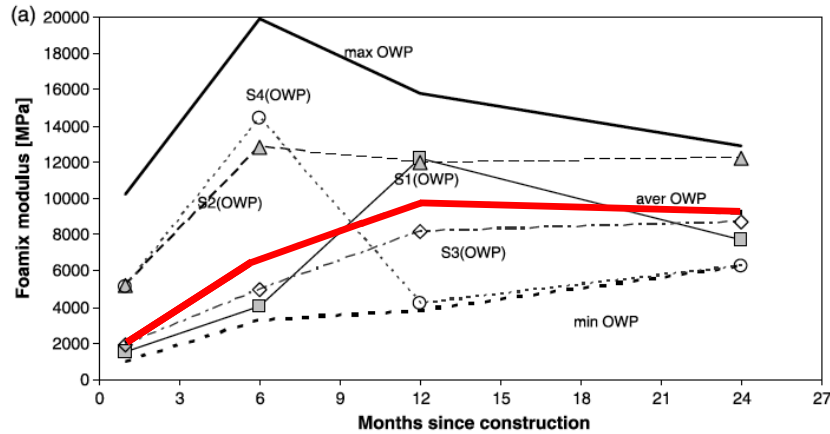
(c) Subgrade



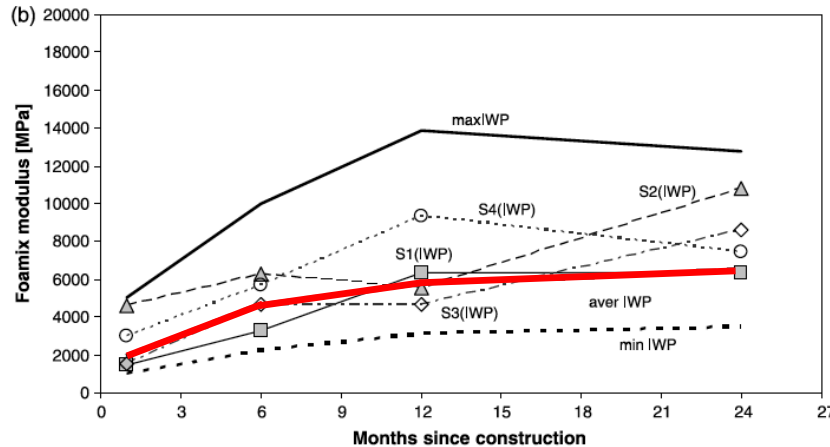
MD 295

4-6 months
after placement

CIR Stiffness vs. Time



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



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)



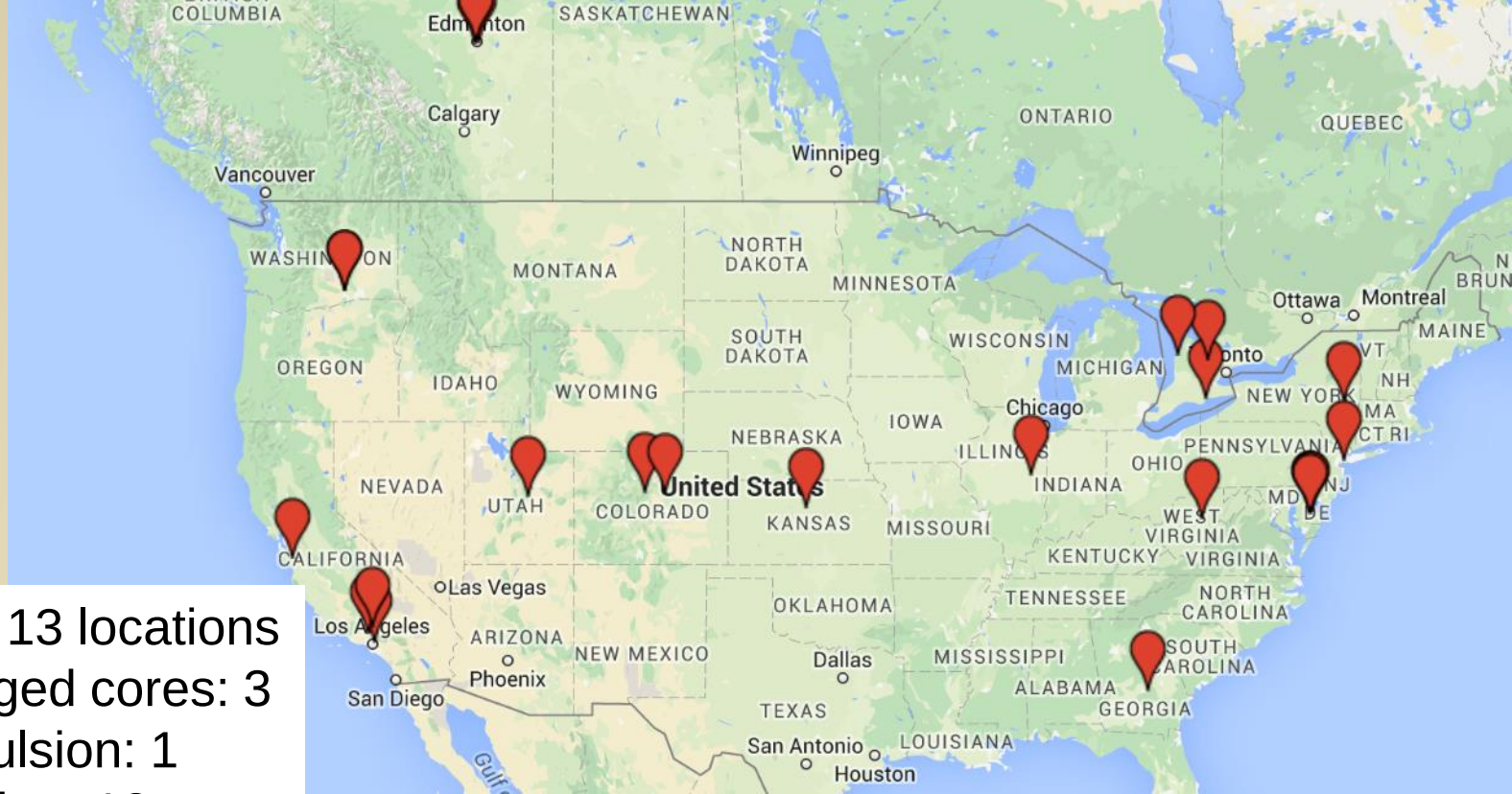
Colas Solutions (Todd Thomas)

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



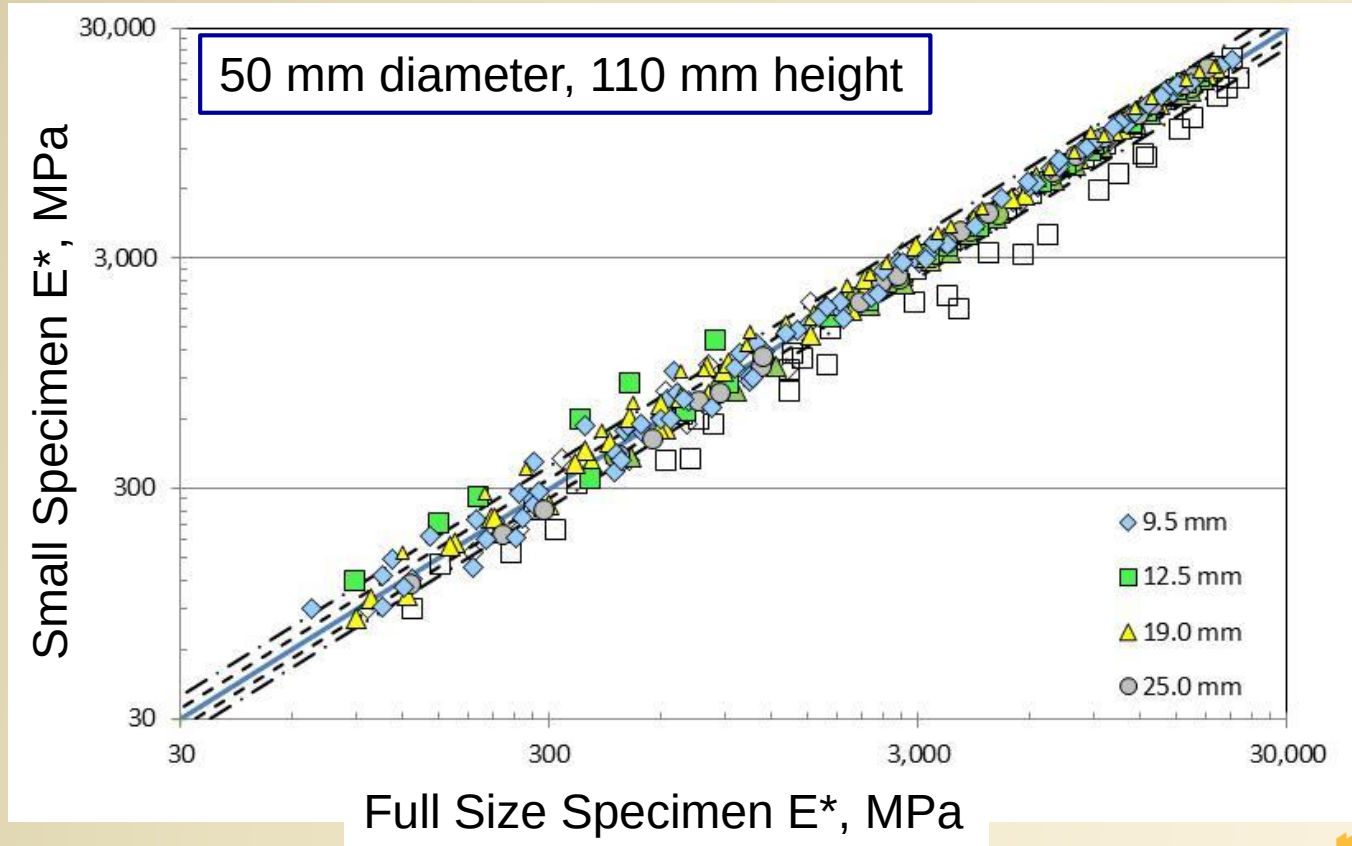


**3 to 6 inches
for CIR**



Bowers, Diefenderfer,
and Diefenderfer (AAPT 2015)

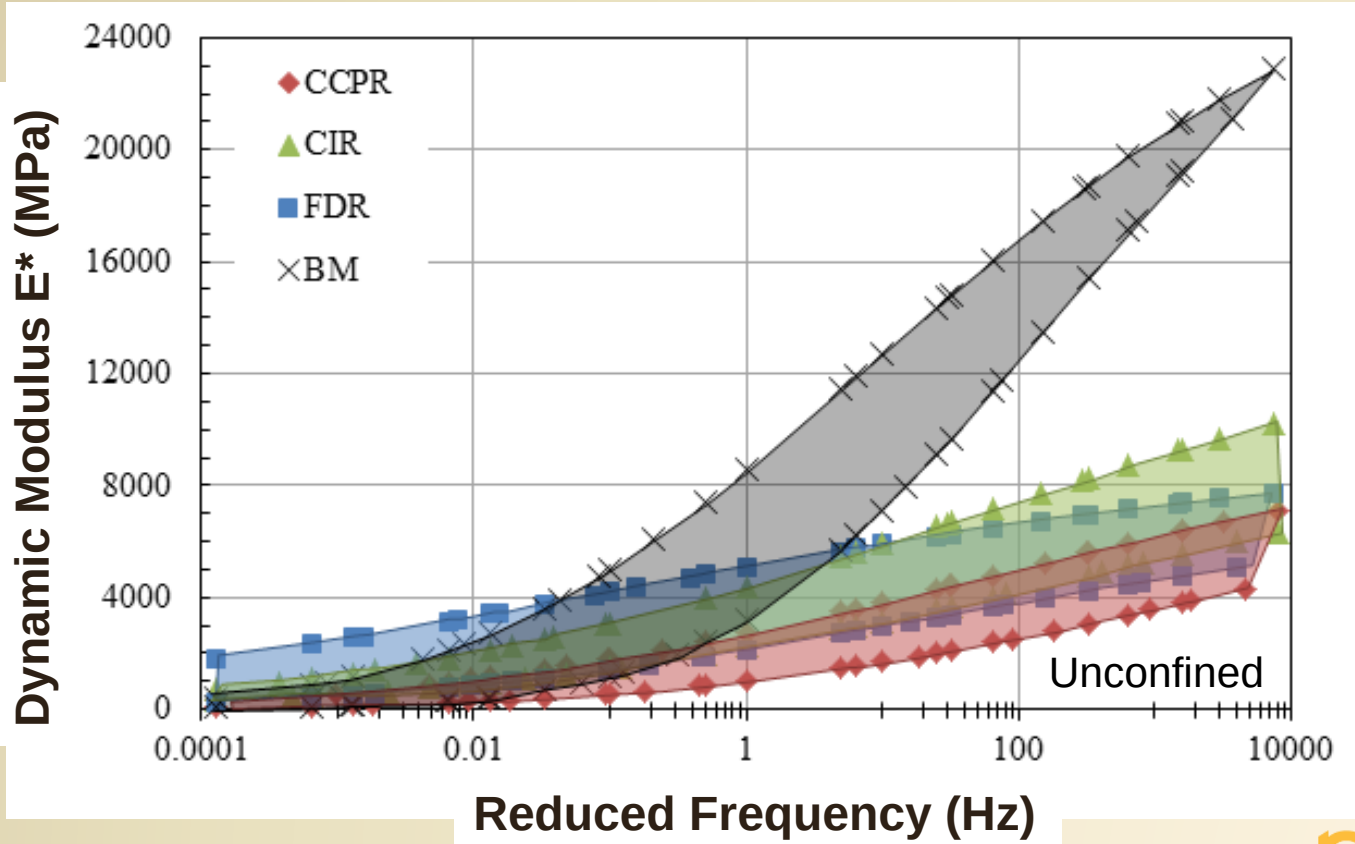
Full Size vs. Small Specimens



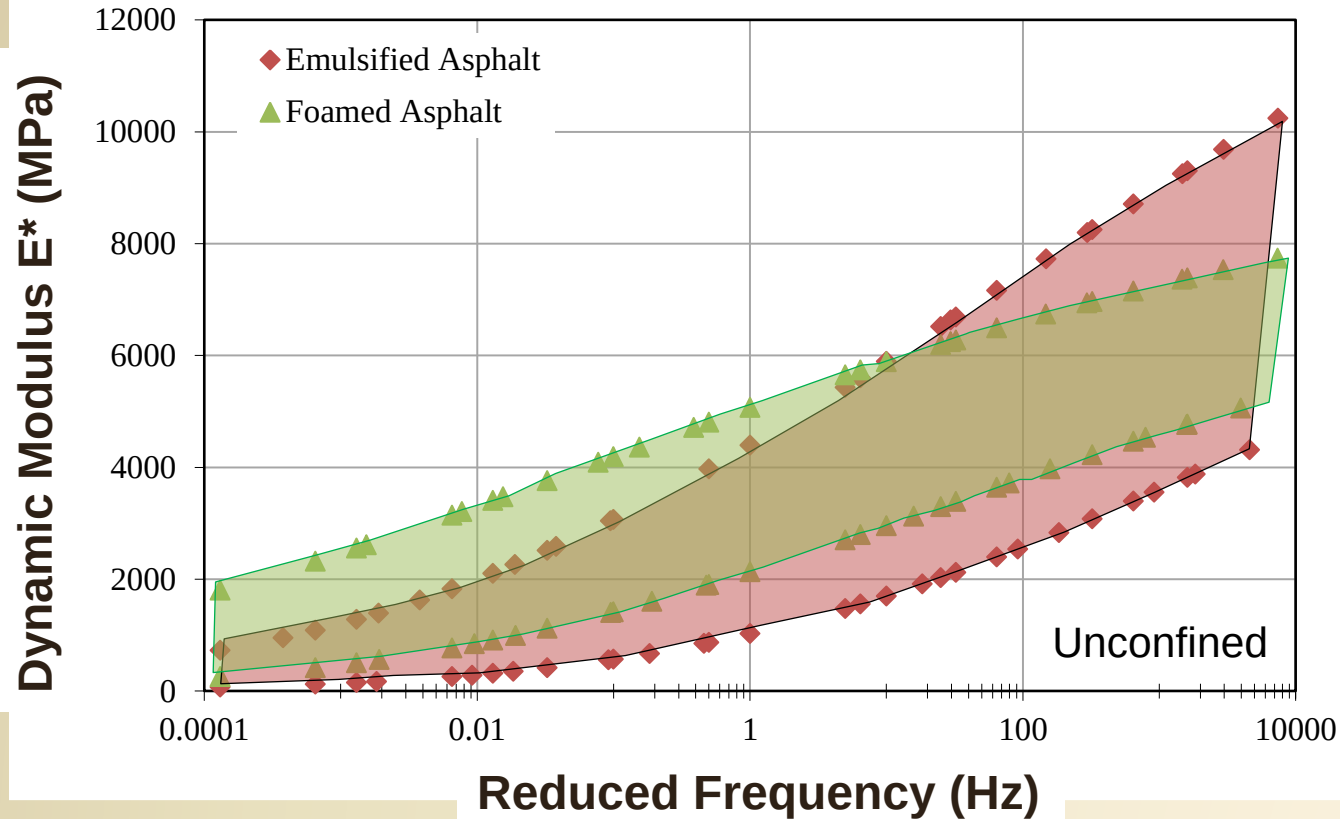
HMA



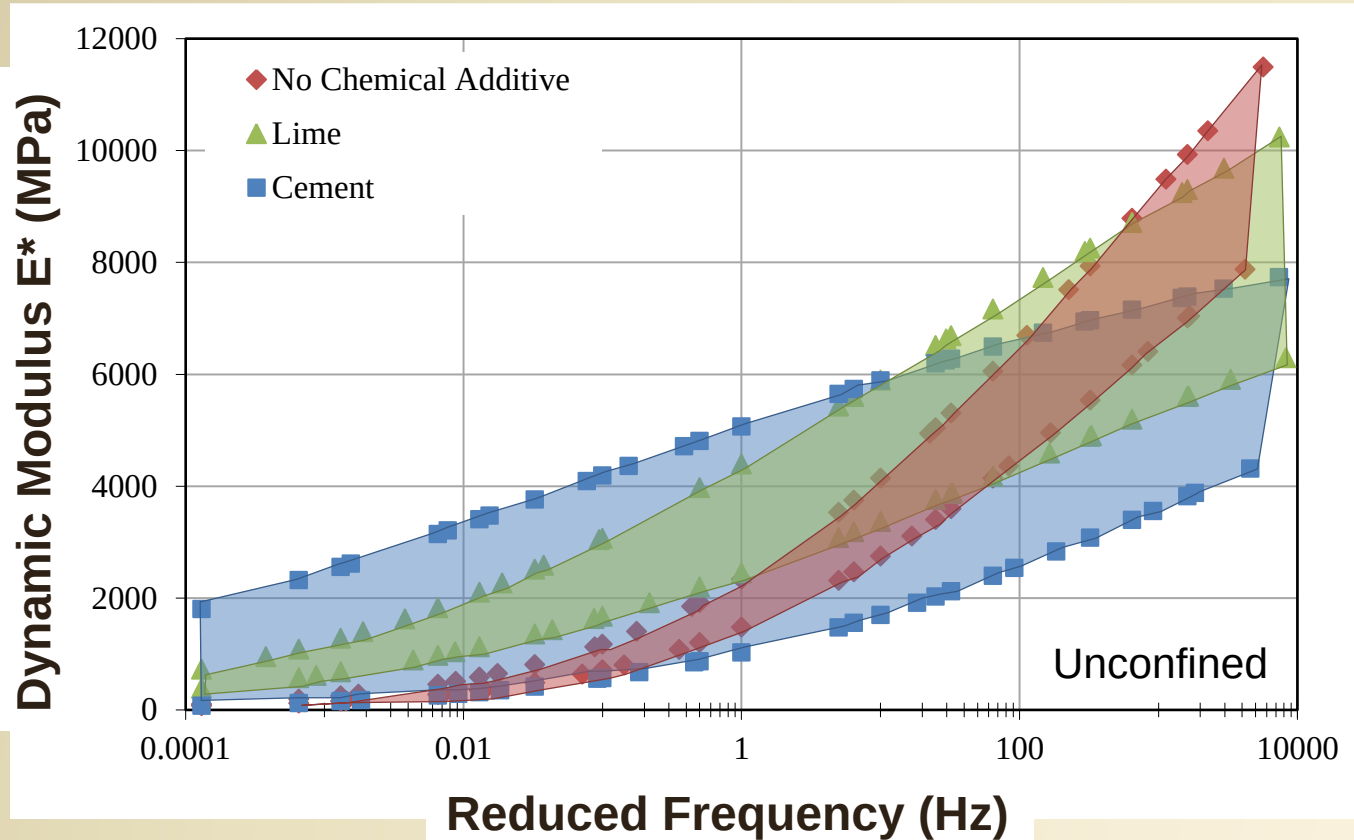
E* Envelopes - All



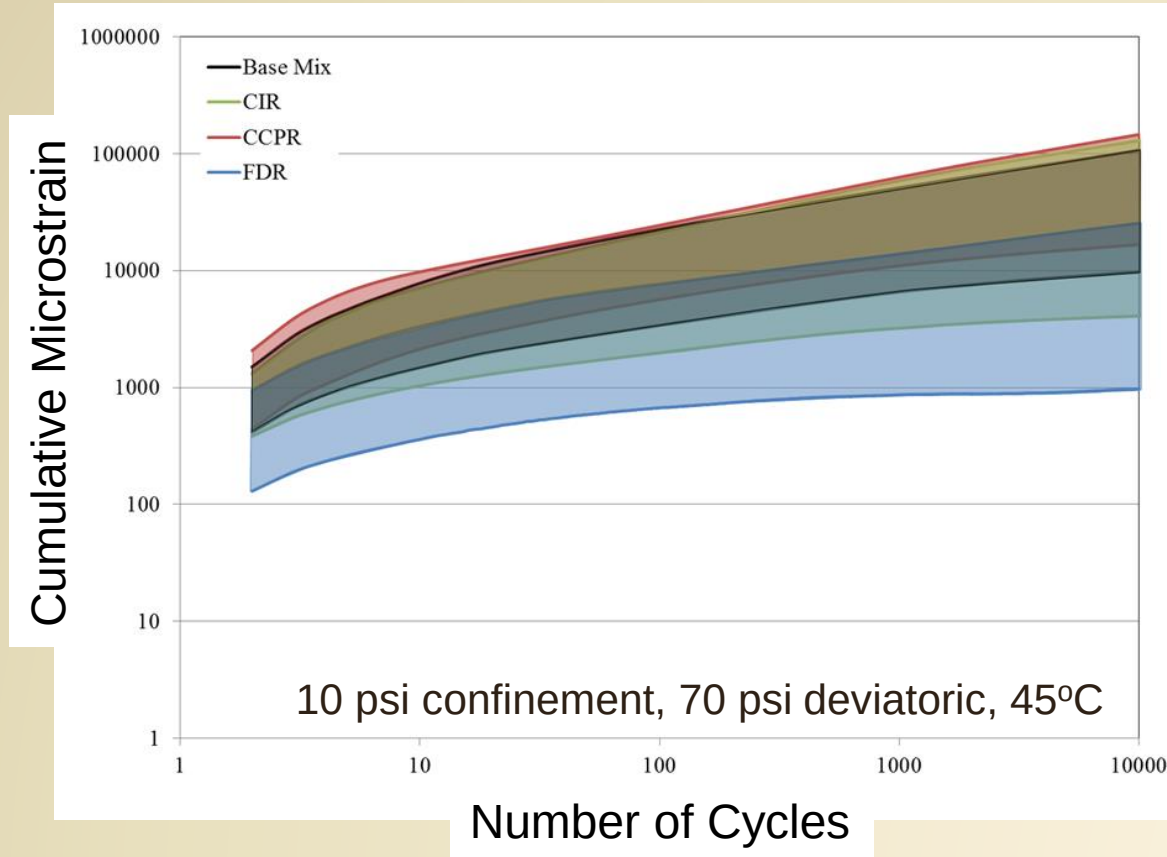
E* Envelopes – Stabilizer Type



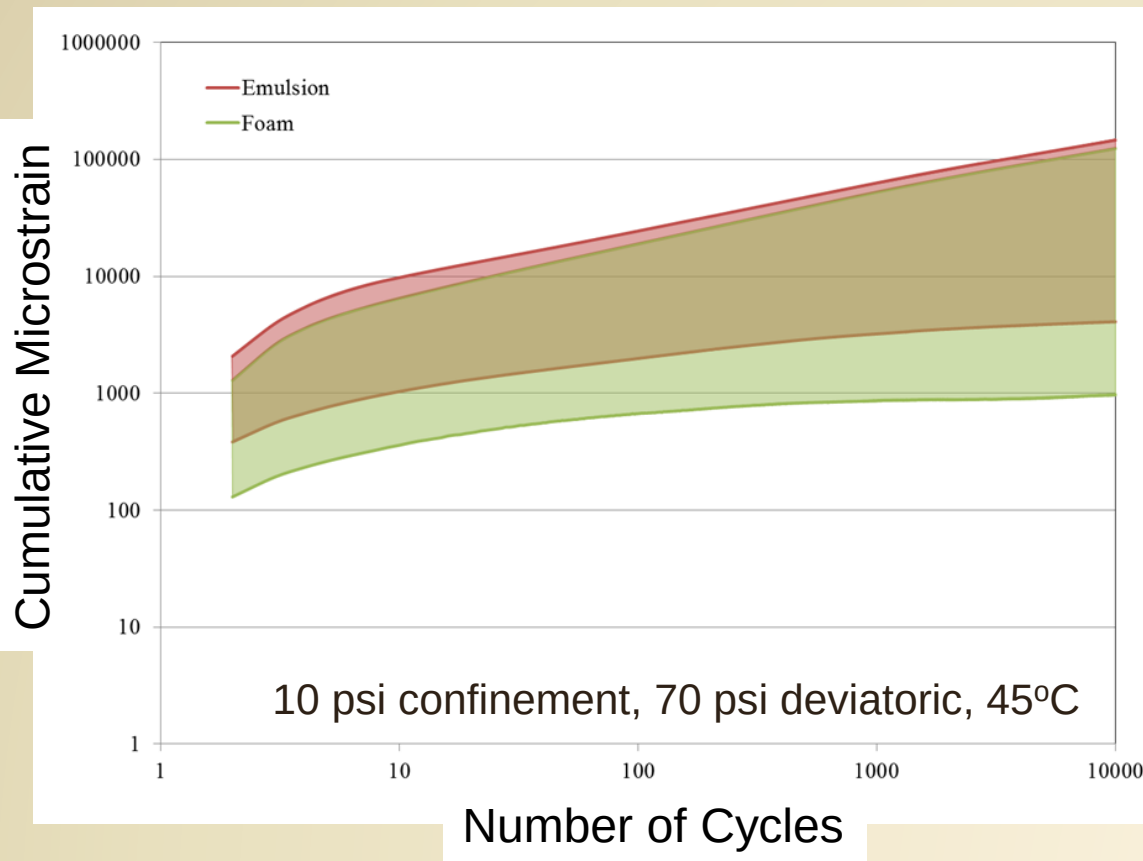
E* Envelopes – Active Filler



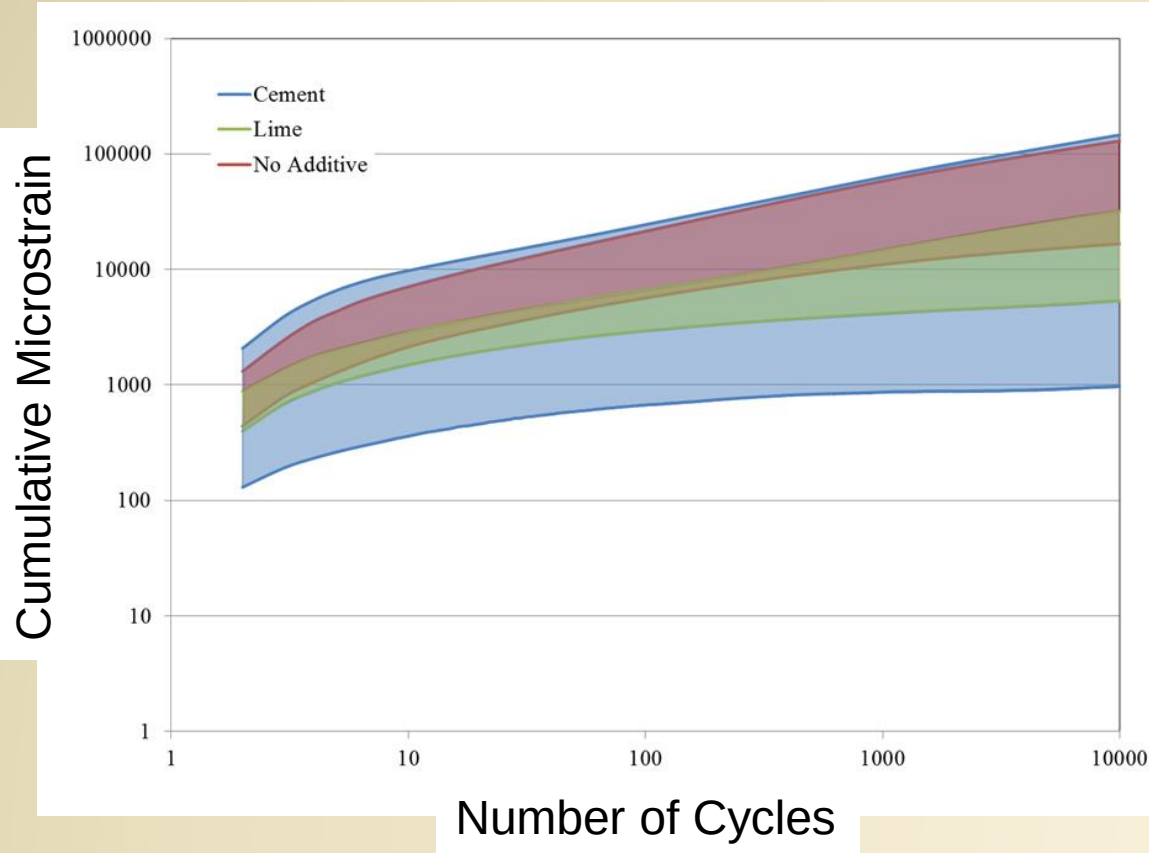
RLPD Envelopes - All



RLPD Envelopes – Stabilizer Type



RLPD Envelopes – Active Filler

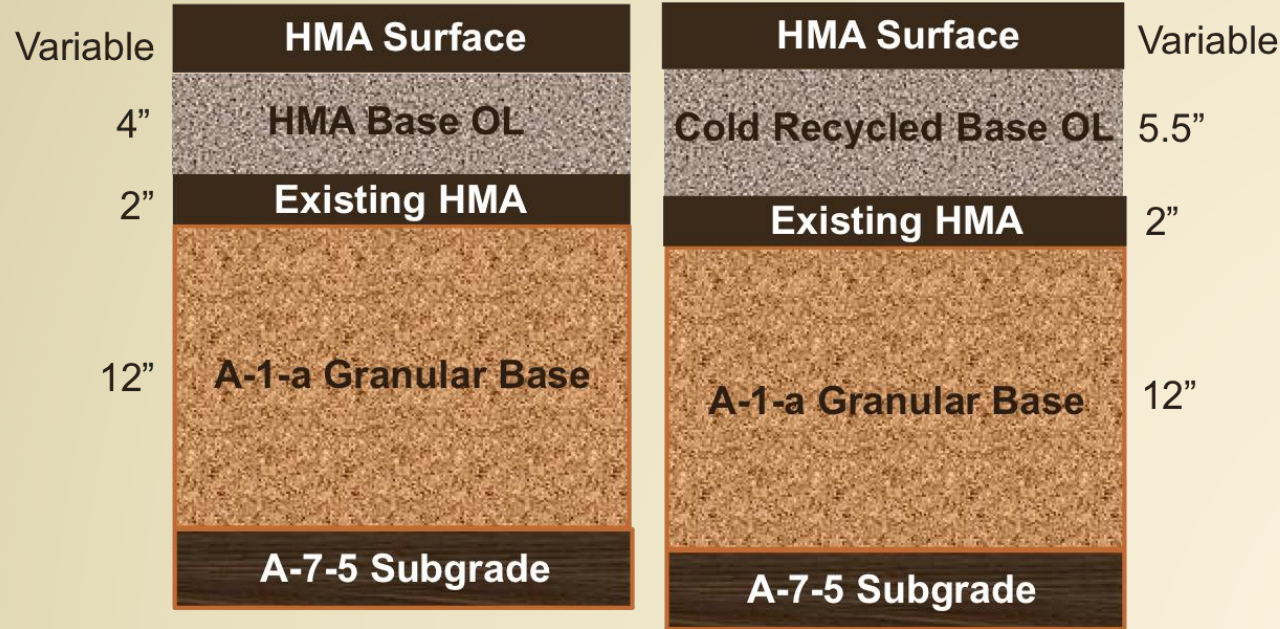


Performance Predictions

Structural layer
coefficient

Cold recycled: 0.32

HMA base (19mm): 0.40



HMA Rehab

Cold Recycled Rehab

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Overlay-OL:Project ▾ X

General Information

Design type: Overlay ▾

Pavement type: AC over AC ▾

Design life (years): 20 ▾

Existing construction: May ▾ 2010 ▾

Pavement construction: June ▾ 2013 ▾

Traffic opening: Septer ▾ 2013 ▾

☐ Special traffic loading for flexible pavements

[+ Add Layer](#)
[- Remove Layer](#)



[Click here to edit Layer 2 Flexible : Default asph](#)

[Click here to edit Layer 4 Non-stabilized Base :](#)

[Click here to edit Layer 5 Subgrade : A-7-5](#)

Performance Criteria	Limit	Reliability
Initial IRI (in/mile)	63	
Terminal IRI (in/mile)	172	90
AC top-down fatigue cracking (ft/mile)	2000	90
AC bottom-up fatigue cracking (% lane area)	25	50
AC thermal cracking (ft/mile)	1000	50
Permanent deformation - total pavement (in)	0.75	90
Permanent deformation - AC only (in)	0.25	90

AC Layer Properties ▾

Endurance limit (microstrain) ☒ **100**

Layer interface ☒ **Full Friction Interface**

☒ **Rehabilitation**

Condition of existing flexible paver ☒ **Rehabilitation Level:3**

☒ **Identifiers**

Display name/identifier	
Description of object	
Author	
Date created	9/30/2015 2:51 AM
Approver	
Date approved	9/30/2015 2:51 AM
State	

Condition of existing flexible pavement

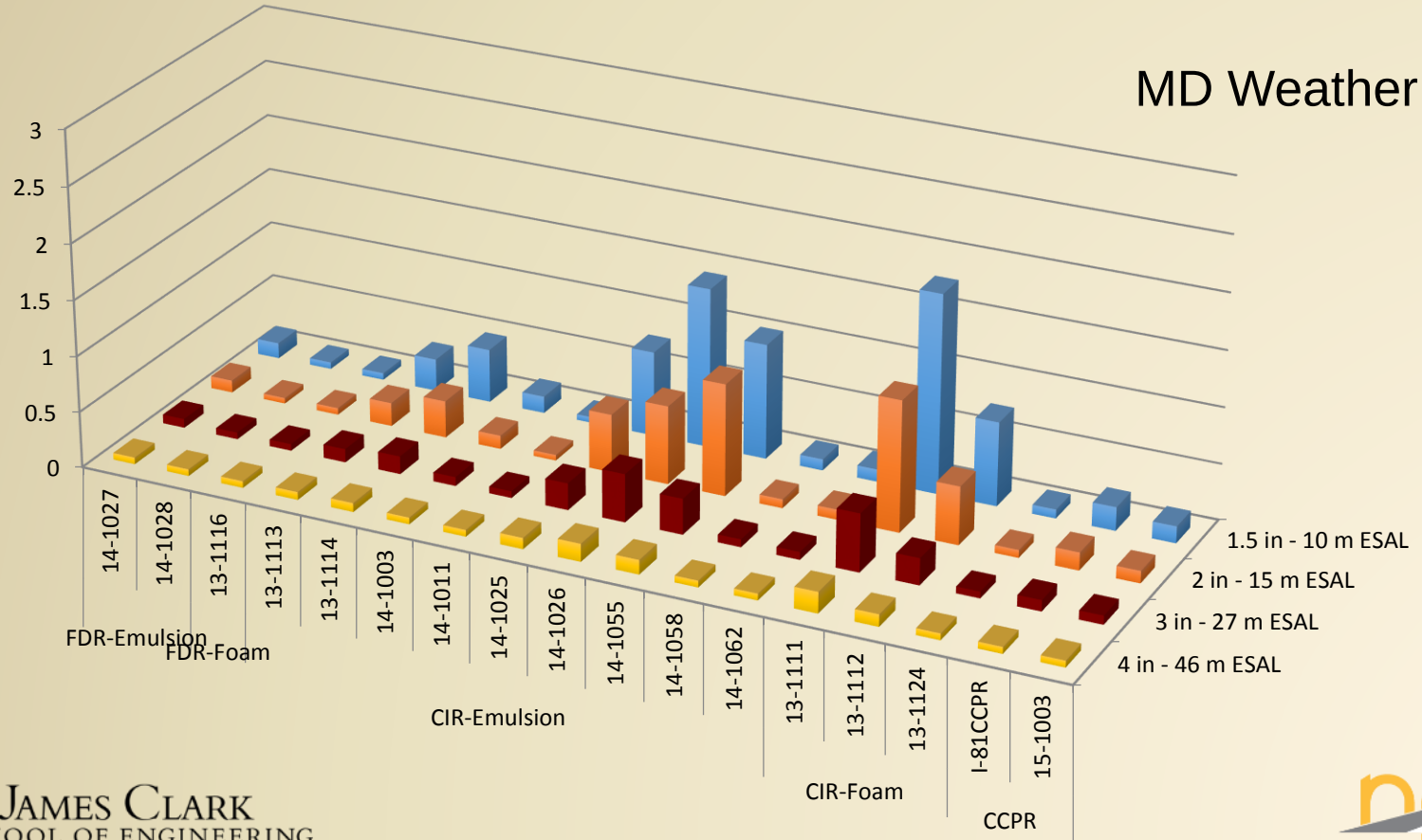
Rehabilitation inputs for the existing flexible pavement.

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



Performance Predictions

MD Weather

Rutting (in)

3

2

1

0

1.5 in/
10M ESAL 2 in/
15M ESAL 3 in/
27M ESAL 4 in/
46M ESAL

CCPR
CIR
FDR

HMA

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

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

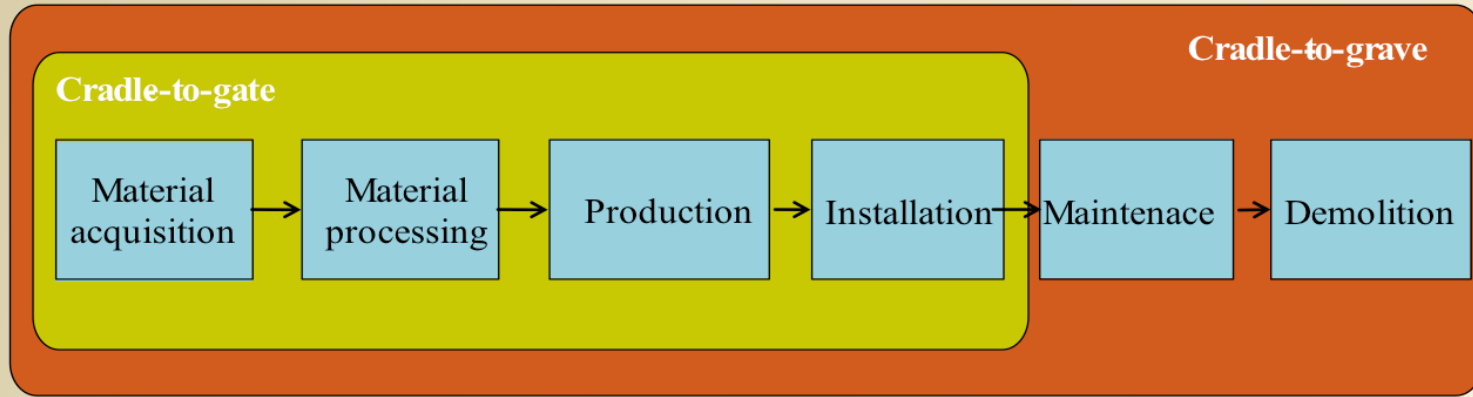
Verified Carbon Standard (VCS) Program

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	Emissionary Inc Maryland Industrial Partnerships Straughan Environmental
Contact	Qingbin Cui, 301-405-8104, cui@umd.edu

Emission Estimation Boundaries

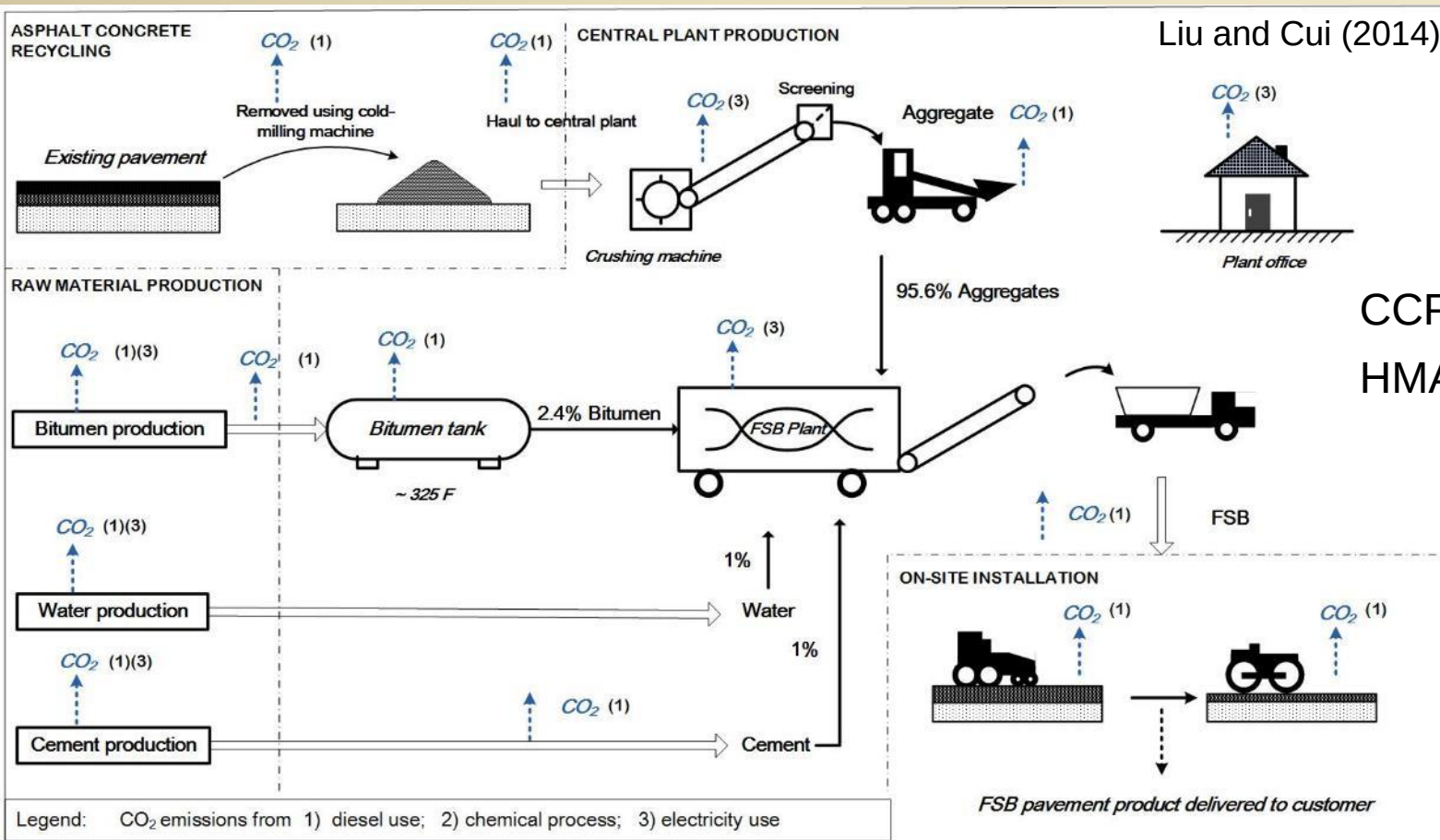
According to *Publicly Available Specification 2050*:



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

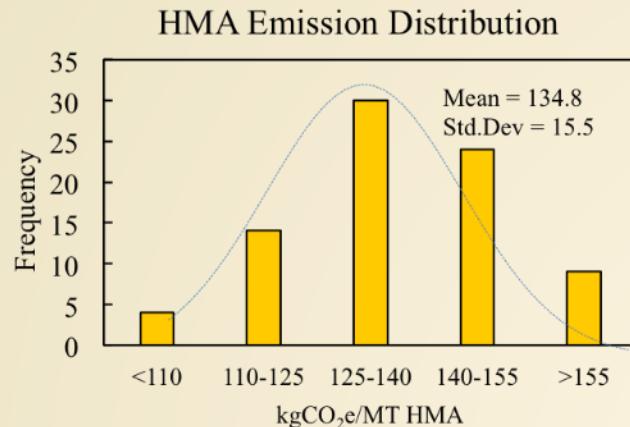
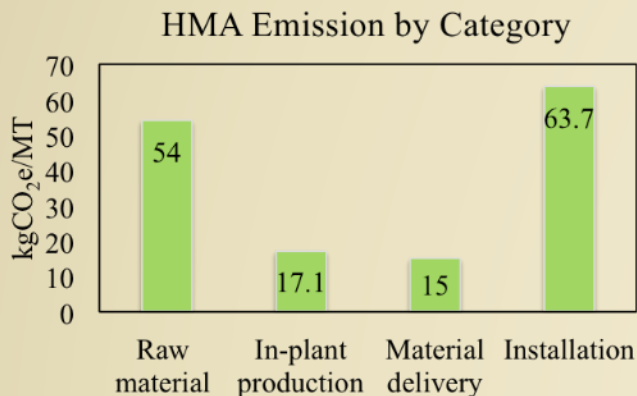
CO₂ Emissions: HMA, CCPR FSB



HMA Emission Estimation

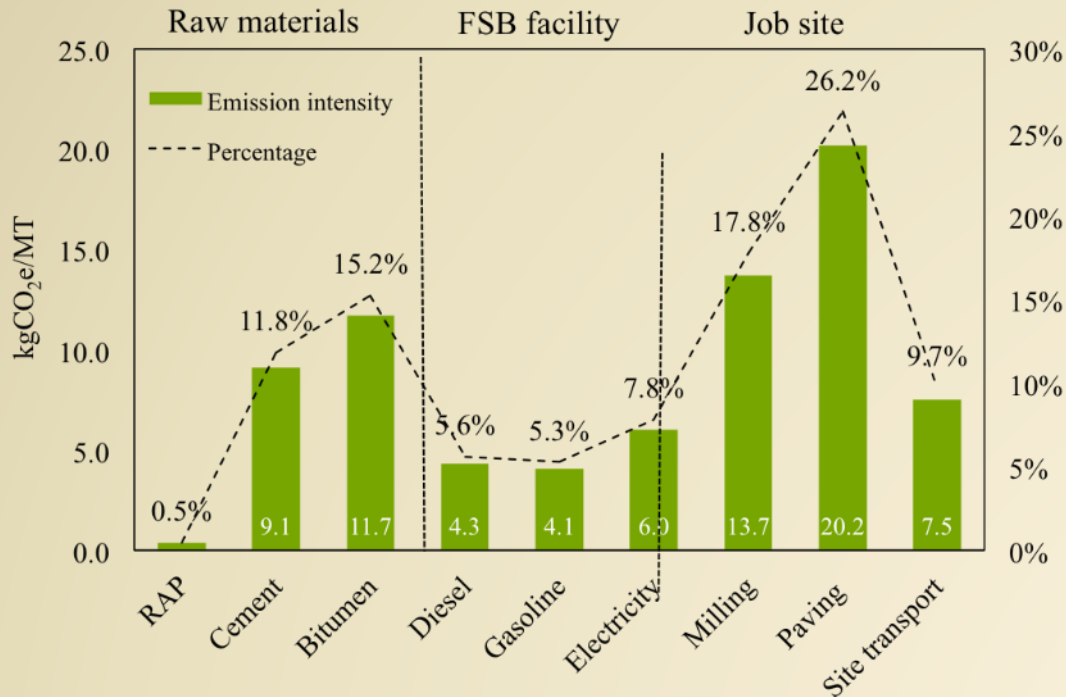
Project type	Hauling distance	Average emission (kgCO ₂ e/MT)	Standard deviation
Parking lot	≤ 40 miles	134.8	15.5
Parking lot	> 40 miles	170.3	33.6
Roadway	undefined	121.9	19.8

Average of 134.8 kgCO₂e/MT HMA



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

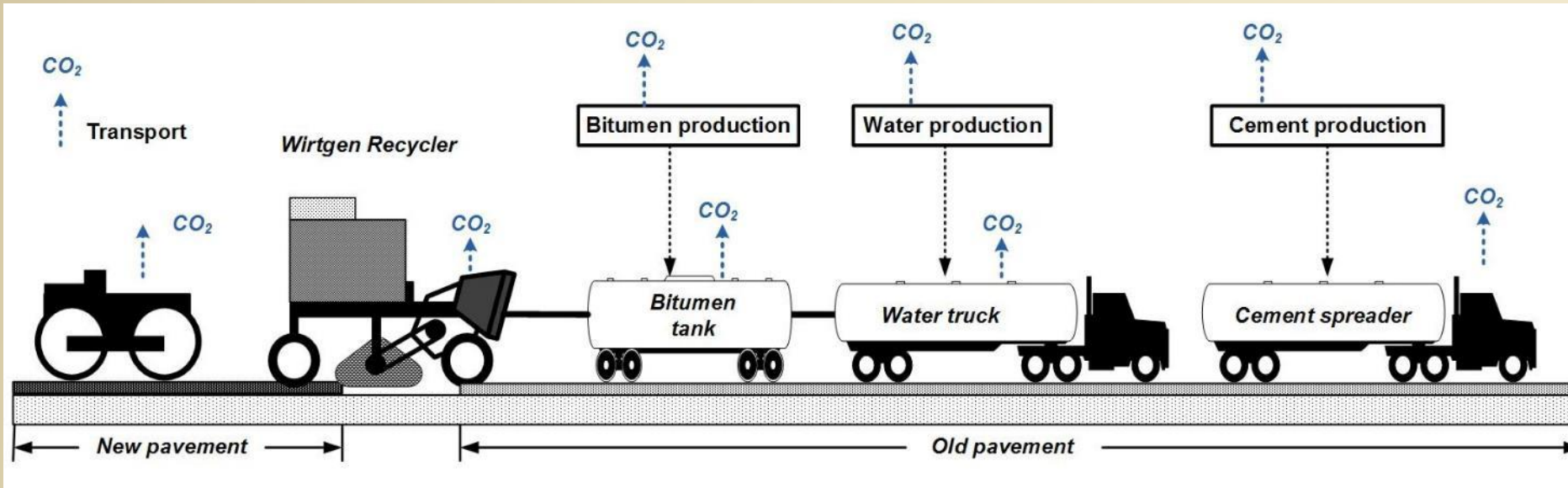
CCPR FSB Emission Estimation



**In total, 76.9 kgCO₂e/MT FSB
(43% reduction from HMA)**

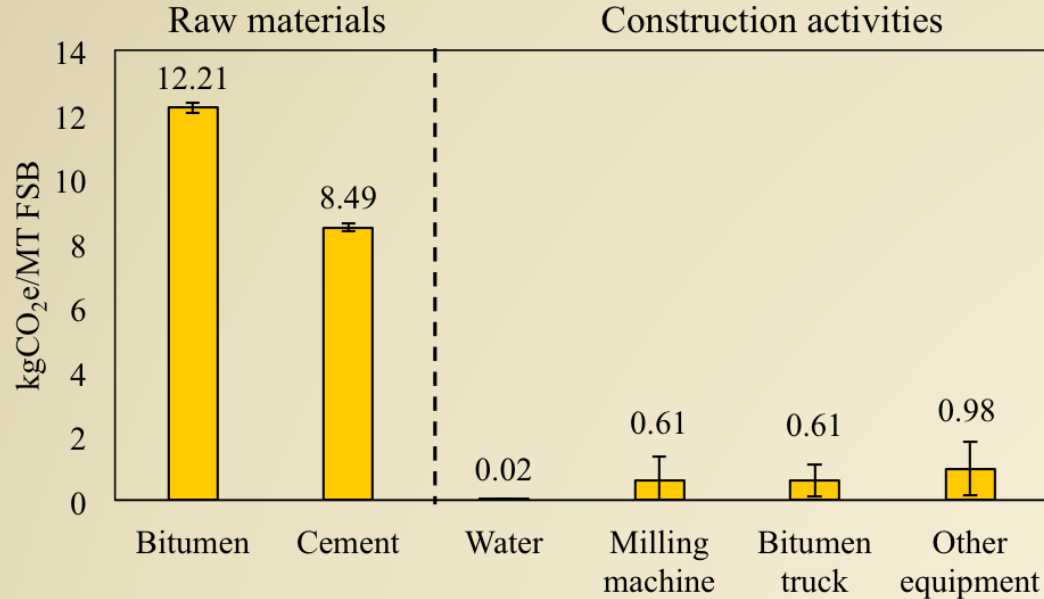
Production data collected onsite at Global Emissionary LLC
in Forestville, MD from March 2012 to May 2013

CO₂ Emissions: CIR FSB



Liu and Cui (2014)

CIR FSB Emission Estimation



**In total, 22.9 kgCO₂/MT FSB
(83% reduction from HMA)**

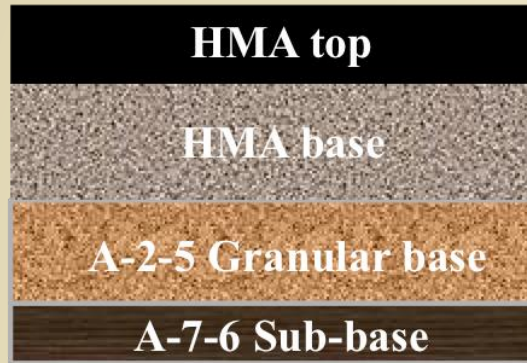
Data was collected from one project performed in Carrollton in October 2012 and three projects performed in Hayward in July 2013.

Emission Intensity Adjusted by Structure

Structural layer
coefficient

FSB: 0.32

HMA base (19mm): 0.40



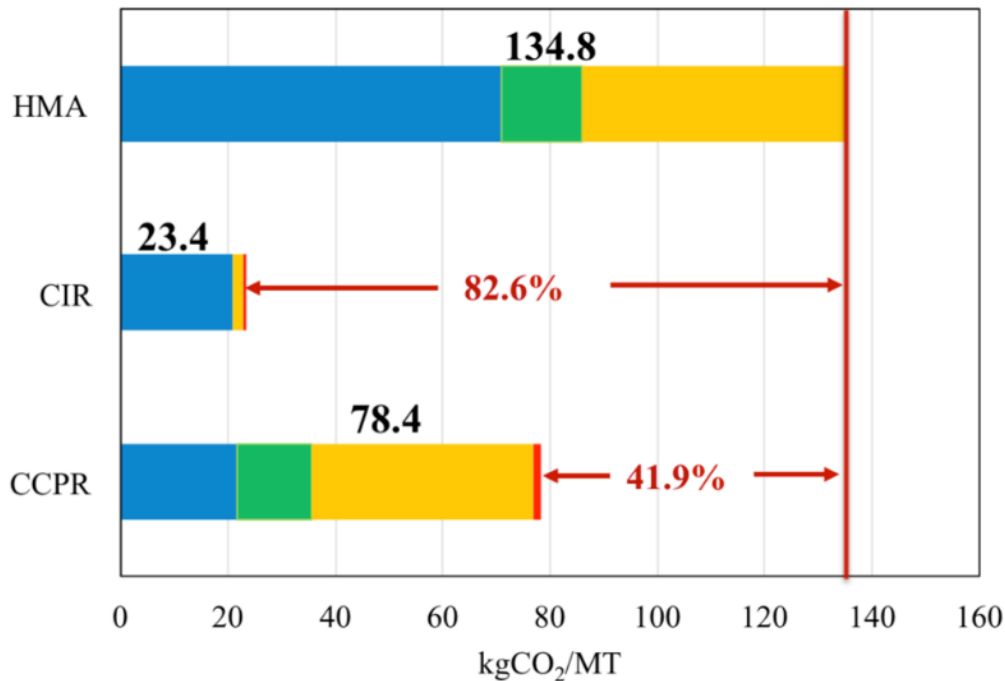
HMA Pavement



FSB Pavement

25% thicker
18% less dense

Emission Intensity Comparison



Mat'l Cost Savings: ~\$20/ton (CCPR)

Carbon Credit Value

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

- Raw material production
- Plant production
- Installation
- Performance adjustment

**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

Contact Info:

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A. JAMES CLARK
SCHOOL OF ENGINEERING

