Texas A&M Transportation Institute

Lives, Time and Resources

NCHRP Project 9-52

Short-Term Laboratory Conditioning of Asphalt Mixtures

Texas A&M Transportation Institute
National Center for Asphalt Technology
Pavement Research Center

April 25, 2016

Aging of Asphalt Mixtures

- Laboratory aging protocols per AASHTO R 30
  - Mix design: STOA 2 hours at Tc
  - Performance testing: STOA 4 hours at 275°F
  - Field aging: LTOA 5 days at 185°F
- Mixture components and production parameters
  - Use of polymer modifiers
  - Inclusion of recycled materials
  - Advent of WMA technologies
  - DMP replacing BMP
  - Increased production temperature

Aging Characteristics ?

Research Objectives

- Validate laboratory STOA protocol to simulate plant aging of asphalt mixtures (Task I)
- Correlate field aging of asphalt mixtures with laboratory LTOA protocols (Task II)
- Identify factors affecting the aging characteristics of asphalt mixtures (Task III)

Field Projects

Connecticut
Florida
Indiana
Iowa
New Mexico
South Dakota
Texas (2)
Wyoming

Field Projects

Field Project	WMA	Production Temperature	Plant Type	RAP/RAS	Aggregate Absorption	Binder Source
Texas I	√			√		
Connecticut	√					
Wyoming	√	√				
South Dakota	√					
New Mexico	√			√		
Iowa	√	√			√	
Florida	√				√	
Indiana	√		√			
Texas II			√			√

Short-Term Conditioning

Validation of STOA Protocols

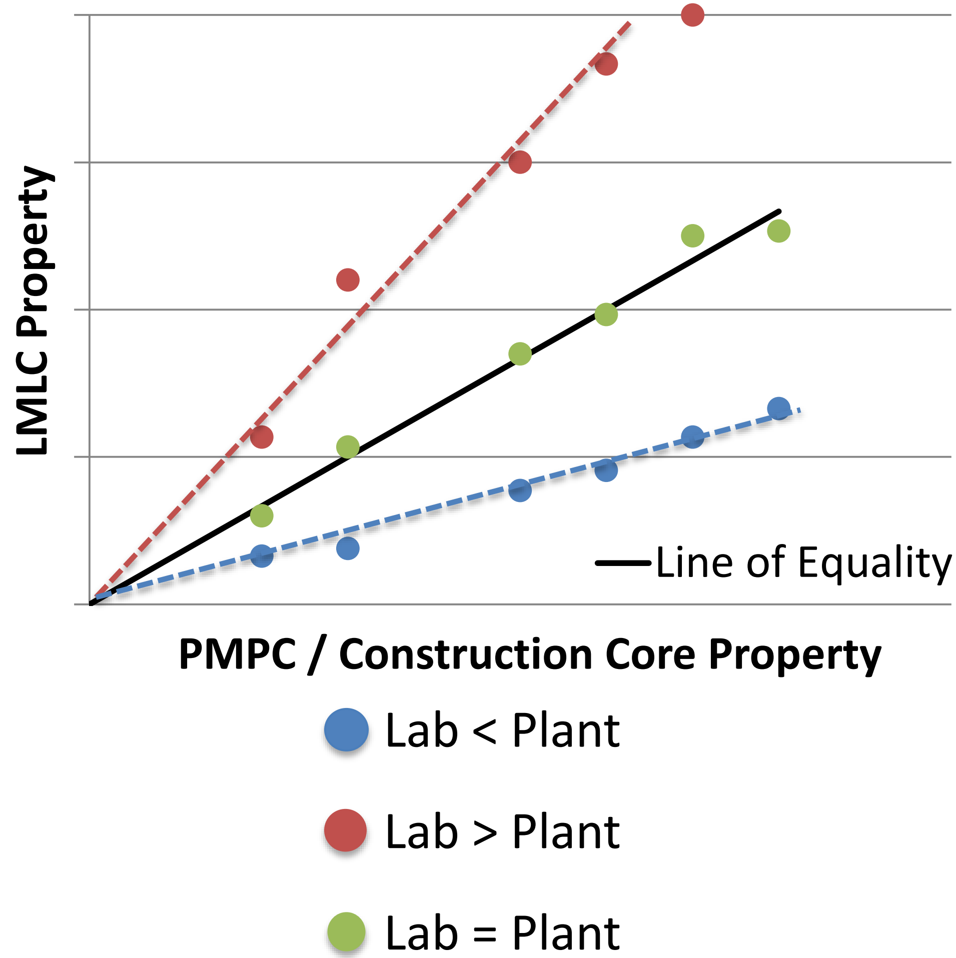
LMLC vs. PMPC & Construction Core

LMLC	PMPC
HMA 2h@275F	HMA Stabilize@275F
WMA 2h@240F	WMA Stabilize@240F

Volumetrics: G_{mm} & P_{ba}

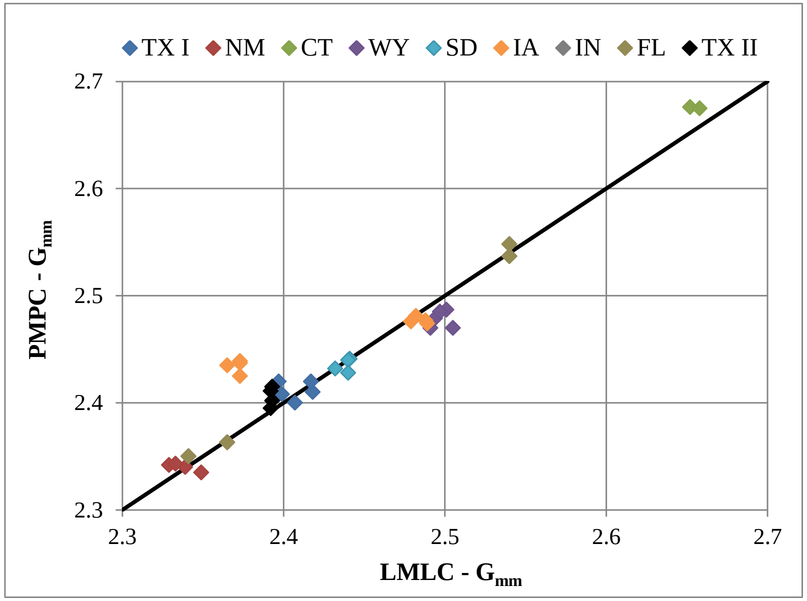
Stiffness: M_R & E*

Rutting Resistance: HWTT

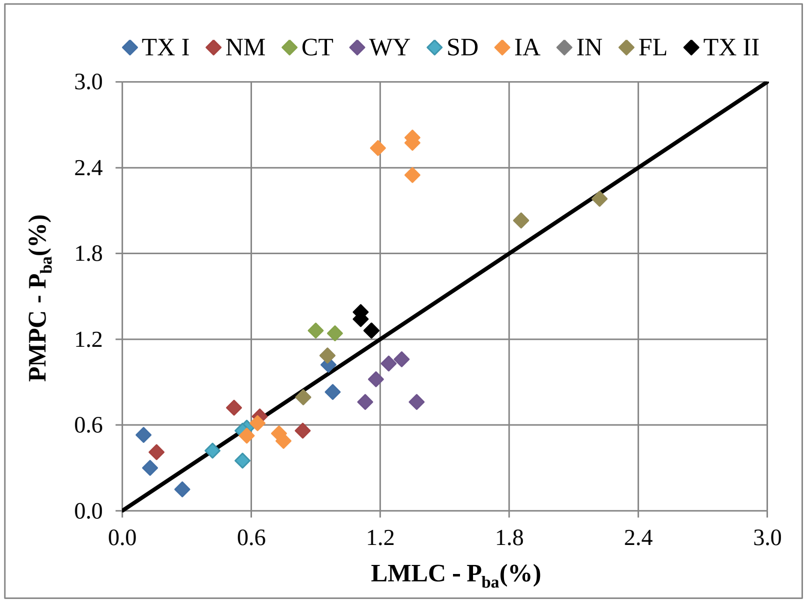


Mixture Volumetrics for LMLC vs. PMPC

Theoretical Maximum Specific Gravity (G_{mm})



Percent of Absorbed Asphalt ($\%P_{ba}$)



Equivalent volumetrics for lab mix vs. plant mix

STOA representative of absorption and aging during production

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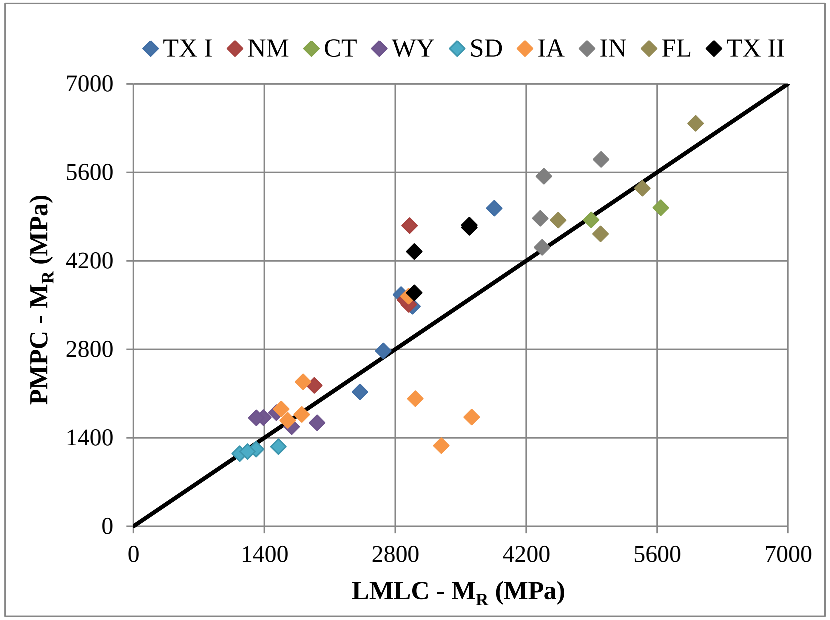
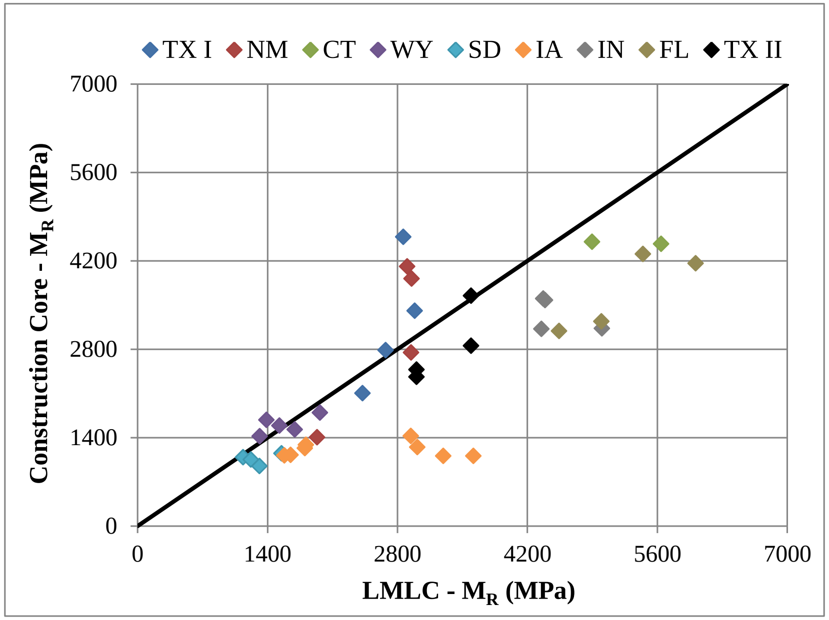
TAStes

M_R Stiffness at 25°C/10Hz

LMLC vs. PMPC



LMLC vs. Construction Core



Equivalent M_R for LMLC vs. PMPC

Slightly lower M_R stiffness for construction core vs. LMLC due to higher AV

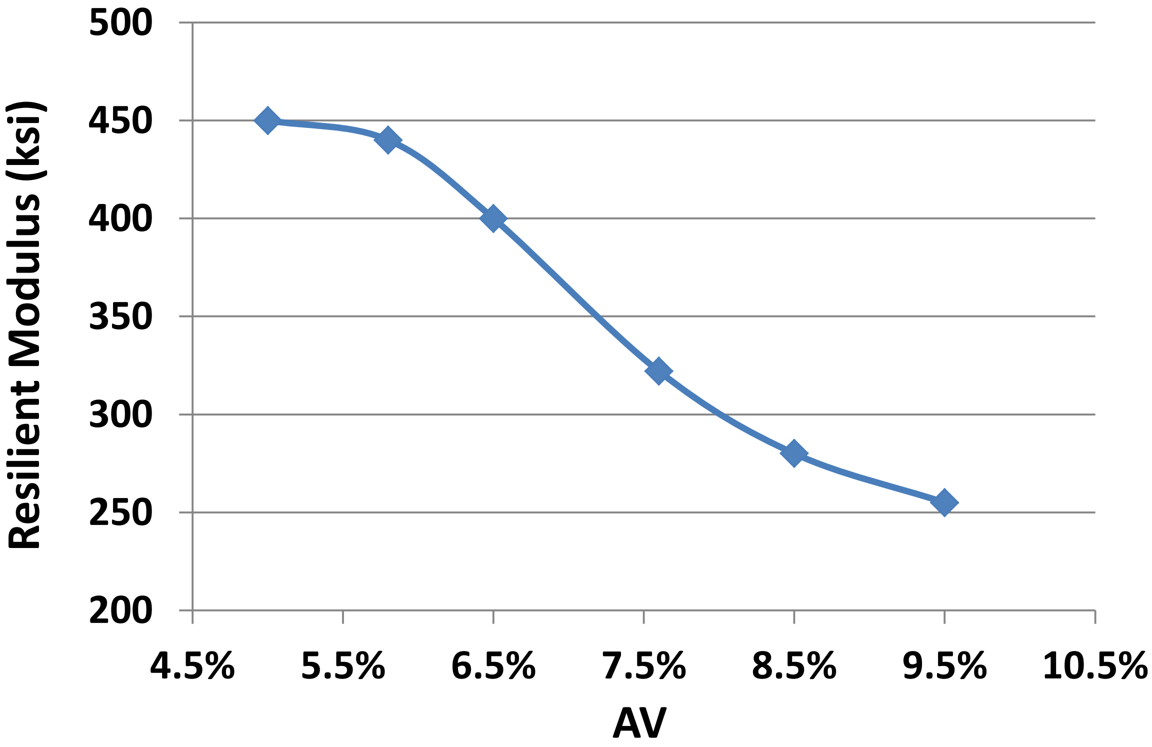
Summary – Validation of STOA Protocols

Validated laboratory STOA protocols of 2 hours at 275°F for HMA and 240°F for WMA to simulate plant aging

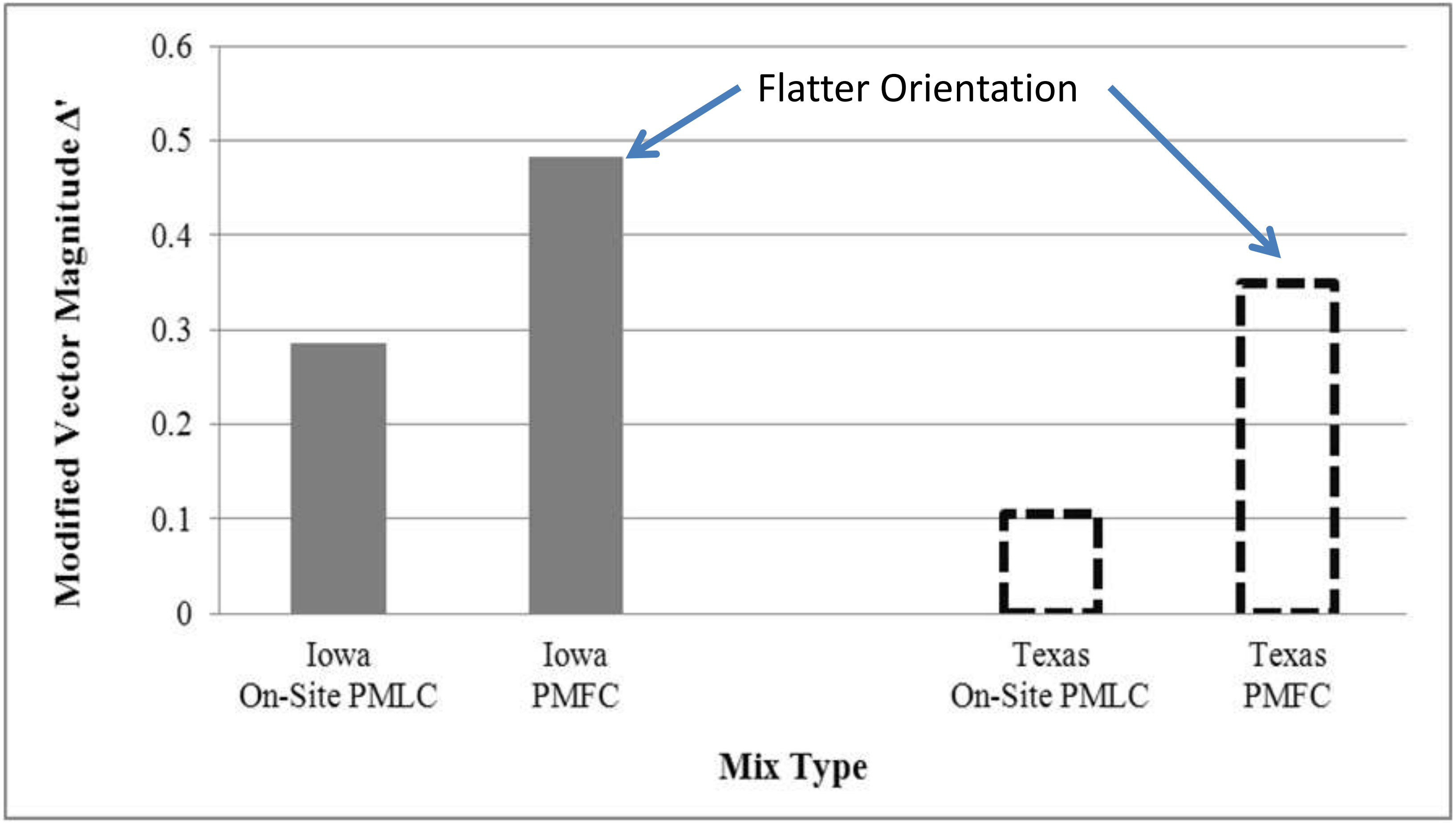
- Volumetrics: LMLC = PMPC
- E* stiffness: LMLC = PMPC
- M_R stiffness: LMLC = PMPC > construction core
- Rutting resistance: LMLC = PMPC > construction core
- Construction core vs. LMLC & PMPC
  - Higher AV (9.0% vs. 7.0%)
  - Use of plaster (degradation and debonding)

Effect of Air Voids

- Effect of AV on M_R Stiffness

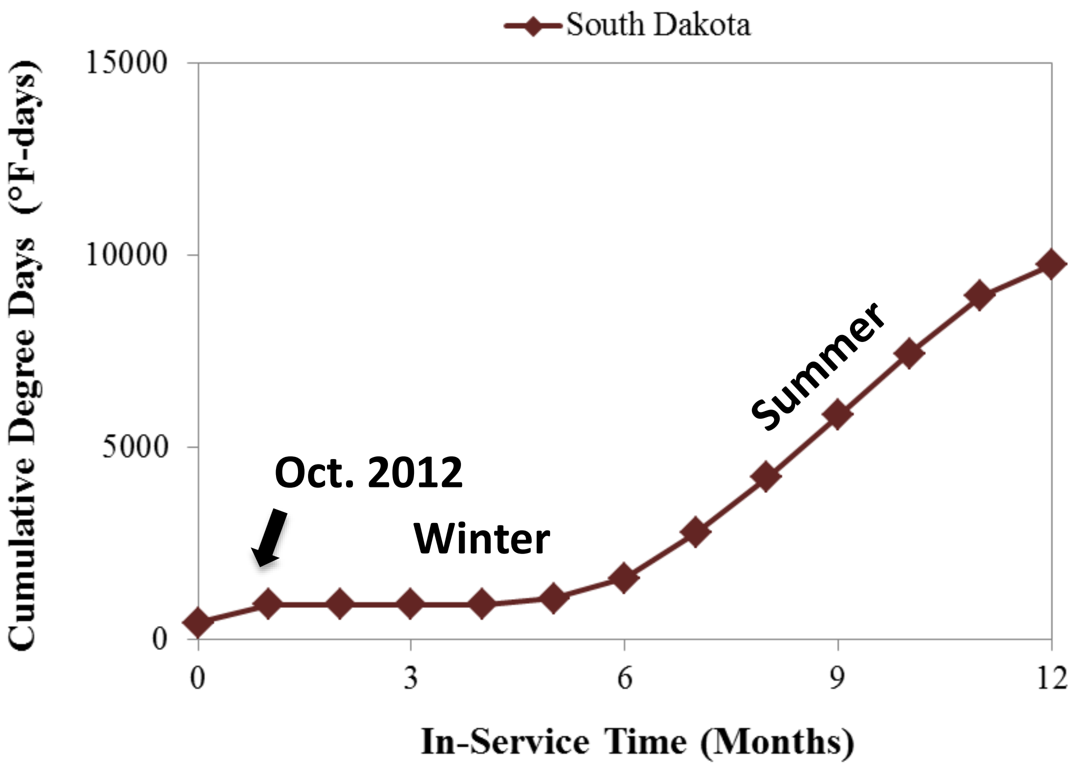


NCHRP 9-49 – Aggregate Orientation



Quantification of Field Aging

- Cumulative Degree-Days (CDD): sum of the daily high temperature above freezing for all the days from time of construction to the time of core sampling

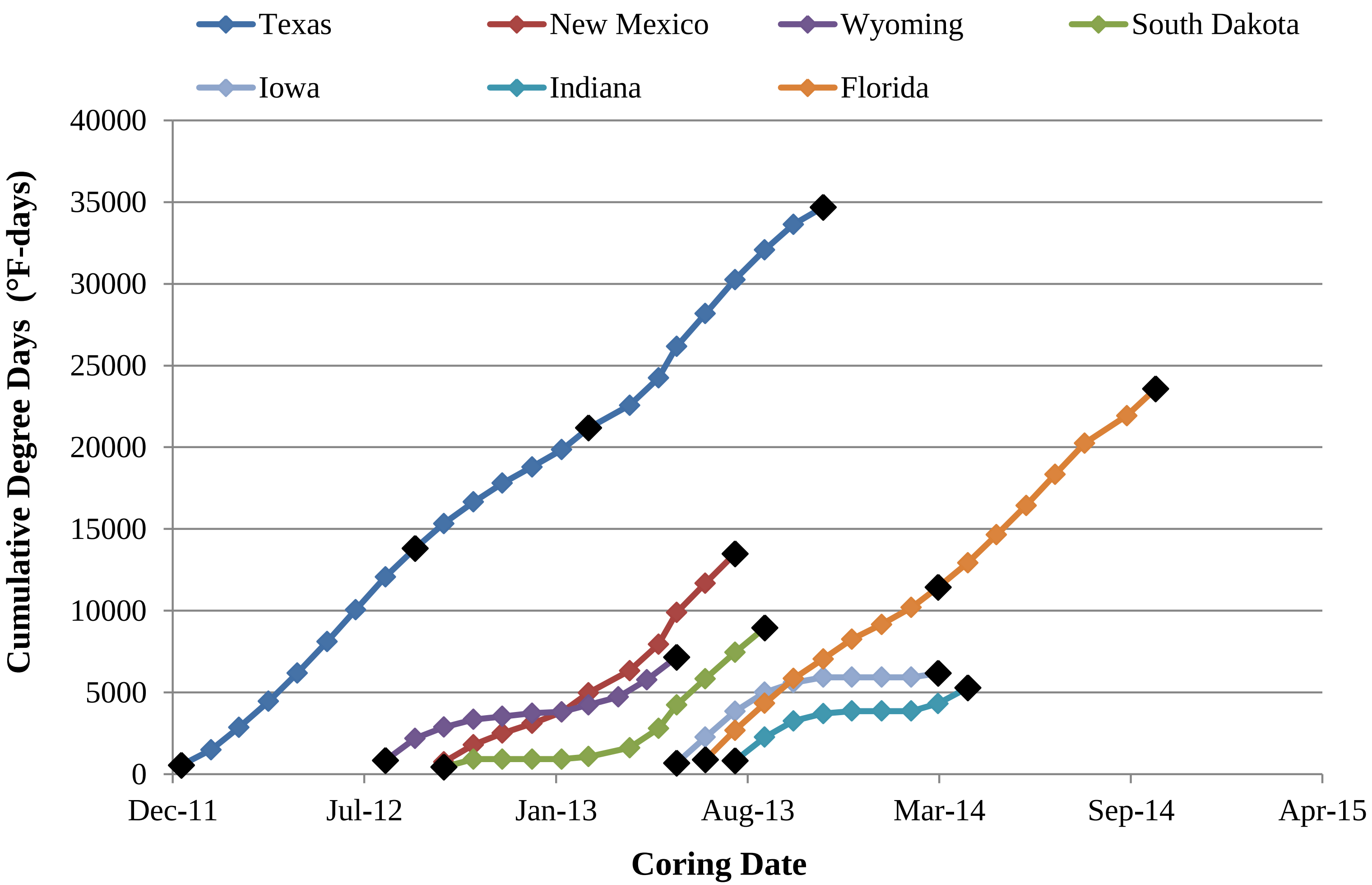


$$CDD = \sum (T_{dmax} - 32)$$

Construction Season √

Geographic Location √

CDD Curves



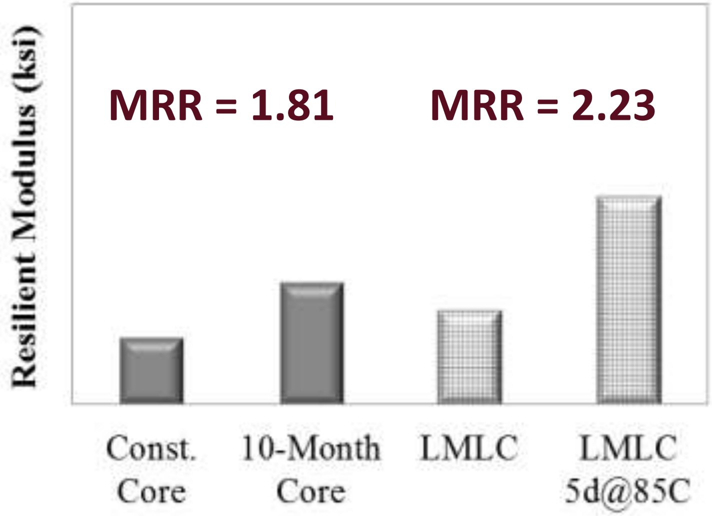
Texas
New Mexico
Wyoming
South Dakota
Iowa
Indiana
Florida
Cumulative Degree Days (°F-days)
40000
35000
30000
25000
20000
15000
10000
5000
0
Dec-11
Jul-12
Jan-13
Aug-13
Mar-14
Sep-14
Apr-15
Coring Date

Property Ratio (PR)

- To quantify effect of aging on mixture properties

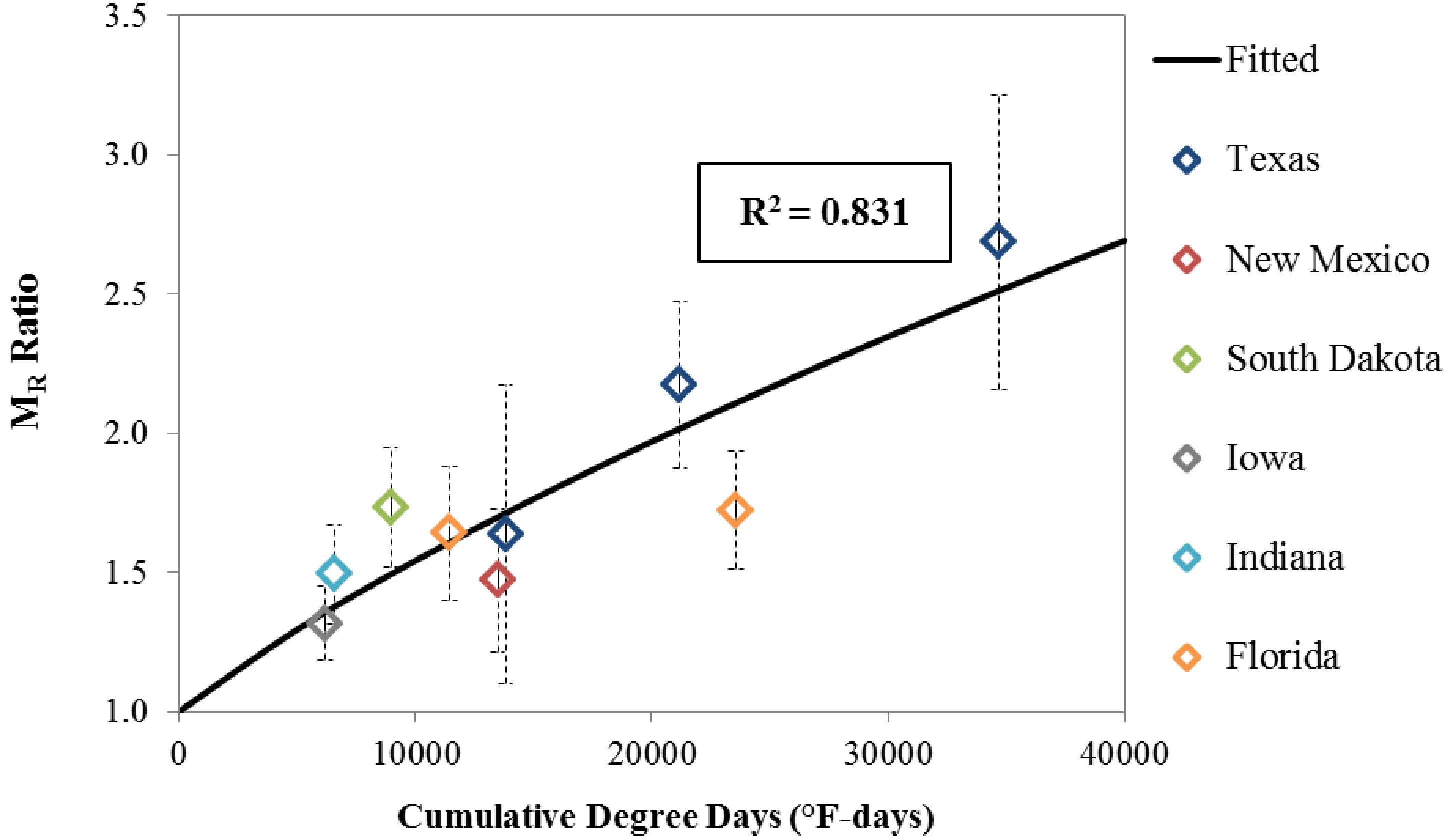
$$PR = \frac{Property\ after\ Aging}{Property\ before\ Aging}$$

- Samples before aging
  - Field cores at construction
  - LMLC specimens with only STOA
- Samples after aging
  - post-construction field cores
  - LMLC specimens with STOA + LTOA



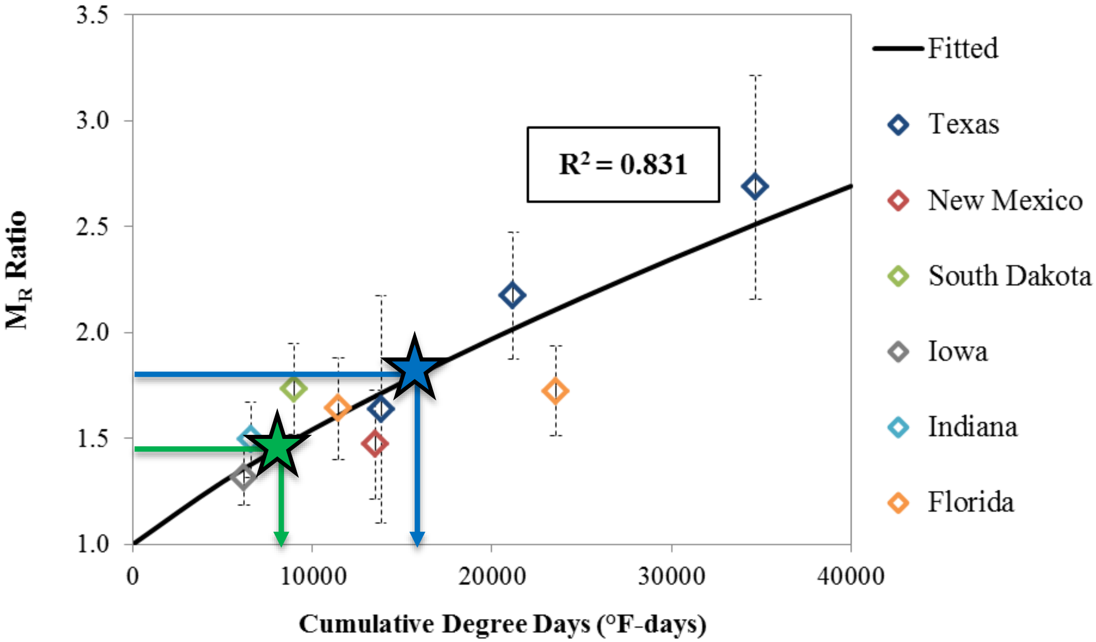
CDD vs. PR (M_R Stiffness)

$$M_R \text{ Ratio} = 1 + 2.73 * 10^5 * exp\left[-\left(\frac{1.24 * 10^{21}}{CDD}\right)^{0.065}\right]$$



Field Aging vs. Laboratory LTOA – M_R Stiffness

$$M_R \text{ Ratio} = 1 + 2.73 * 10^5 * exp\left[-\left(\frac{1.24 * 10^{21}}{CDD}\right)^{0.065}\right]$$



Field Project	2w@60C	5d@85C
Florida	1.22	1.38
Indiana	1.30	1.54
Iowa	1.32	1.65
New Mexico	1.89	2.21
South Dakota	1.58	1.95
Texas	1.60	1.94
Wyoming	1.44	1.80
Average	**1.48**	**1.78**
Stdev	**0.23**	**0.28**

2w@60C = 9,600 CDD (M_R & HWTT RRP)

5d@85C = 17,500 CDD (M_R & HWTT RRP)

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Time for WMA = HMA or HMA_o

Field site	Climate	CDD Values	
		WMA = HMA	WMA = HMA_0
Texas I	Warmer Climate	16 months	2 months
New Mexico		19 months	3 months
Florida		15 months	1 months
Average		17 months	2 months
Wyoming	Colder Climate	32 months*	2 months
South Dakota		32 months*	7 months
Iowa		28 months*	2 months
Indiana		26 months*	2 months
Average		30 months	3 months

** predicted in-service time based on historical climatic information*

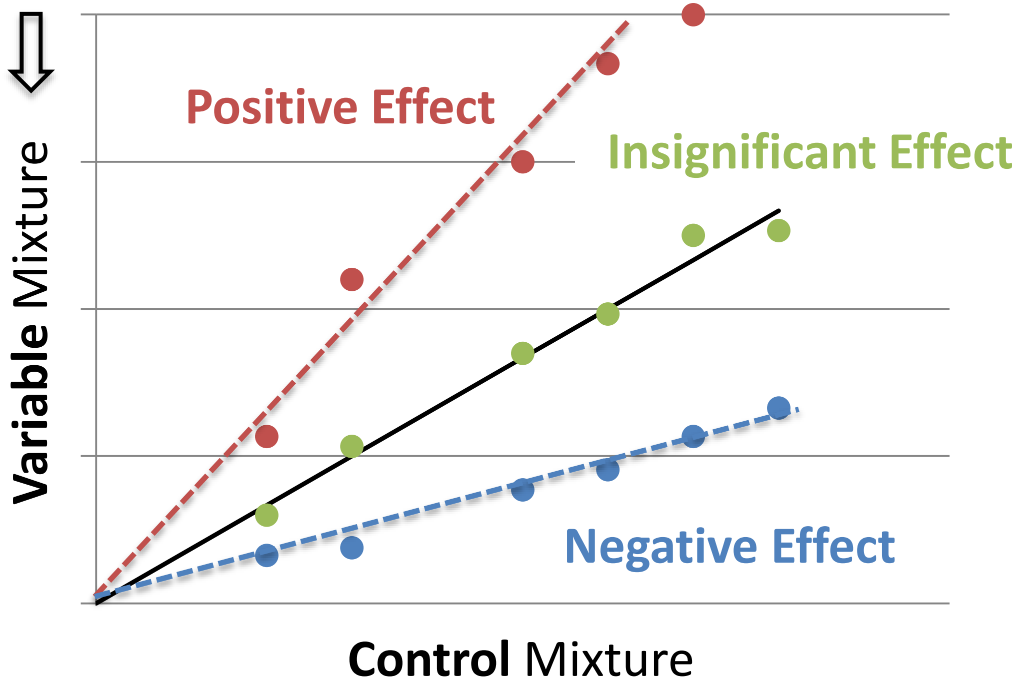
Summary – Field Aging vs. LTOA Protocols

- Proposed CDD to quantify field aging of asphalt pavements
- Proposed PR to evaluate mixture property evolution with field and laboratory aging
- Correlated field aging with laboratory LTOA protocols

LTOA Protocols	CDD	In-Service Time	
		Warmer Climates	Colder Climates
2 weeks at 140°F	9,600	7 months	12 months
5 days at 185°F	17,500	12 months	23 months

Factor Analysis*

Short-term: mixture property
Long-term: mixture property ratio



WMA Technology

Production Temperature

Plant Type

Recycled Materials

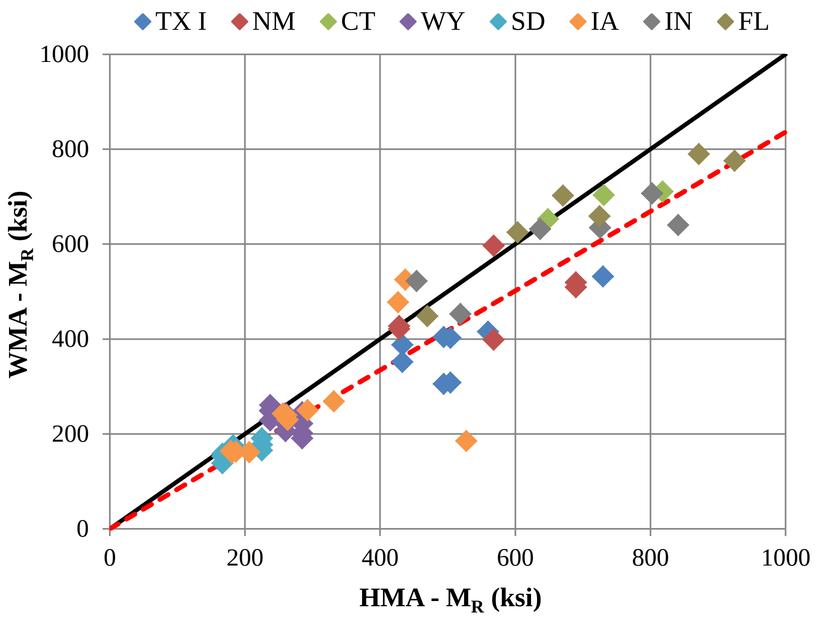
Aggregate Absorption

Binder Source

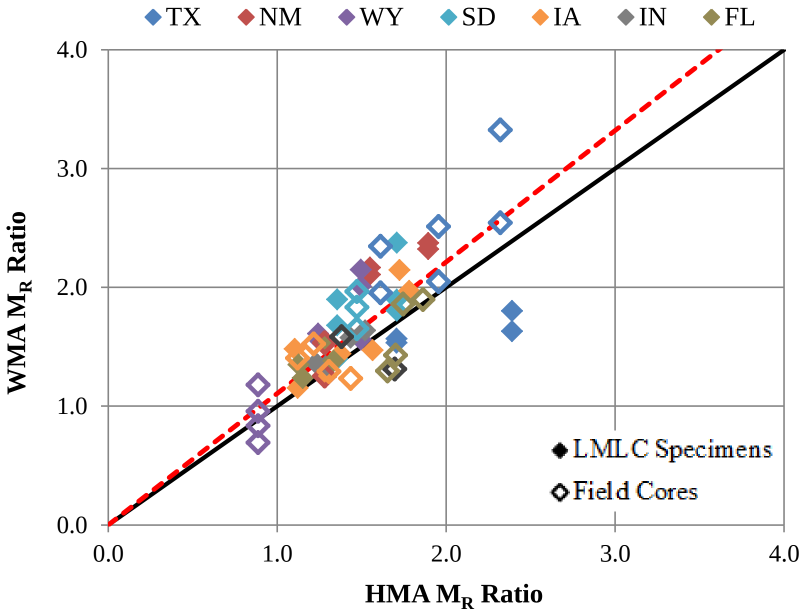
*STAT Validation by ANOVA Analysis

Factor – WMA Technology

Short-Term: M_R Stiffness

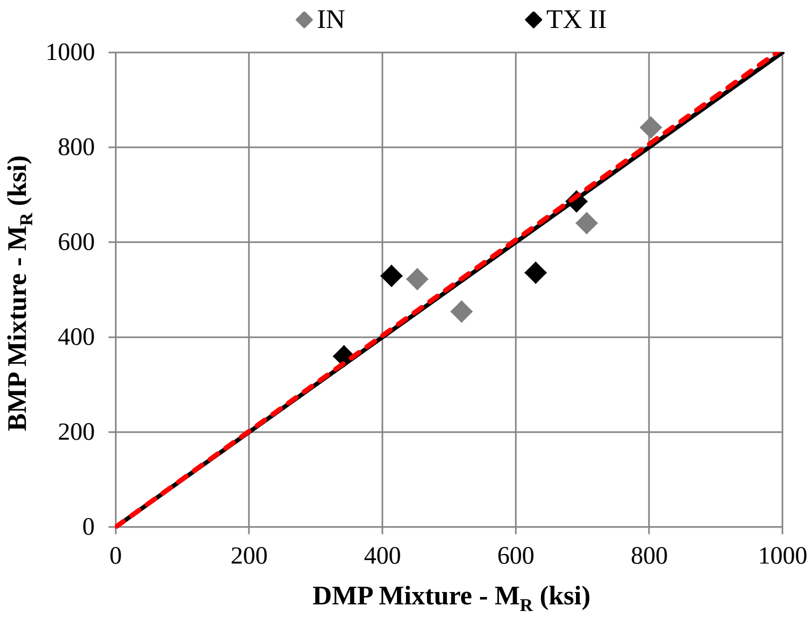


Long-Term: M_R Stiffness Ratio

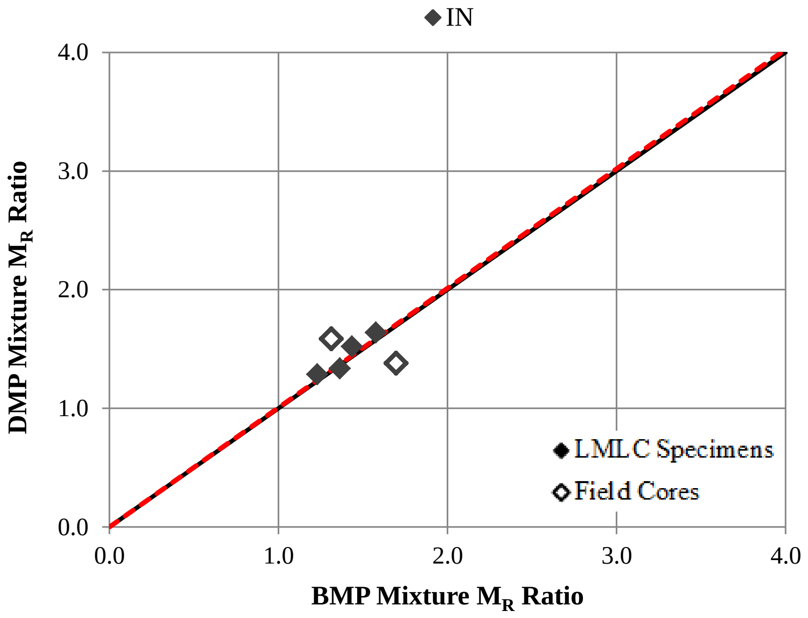


Factor – Plant Type

Short-Term: M_R Stiffness



Long-Term: M_R Stiffness Ratio



FACTOR ANALYSIS SUMMARY

Factors	Significant? ST*	Significant? LT*	Trends	Explanations
WMA Technology	Yes	Yes	WMA vs. HMA ST: worse properties LT: faster aging	• Reduced production temperatures • WMA additives
Recycled Materials	Yes	Yes	RAP/RAS vs. control ST: better properties LT: slower aging	• Over aged binders • Less virgin binders available for aging
Aggregate Absorption	Yes	Yes	High vs. low abs. ST: worse properties LT: faster aging	• More effective binders available for aging
Binder Source	Yes	N/A	Same PG ≠ same properties	• Different oxidation kinetics
Production Temperature	No	No	Equivalent mixture properties	
Plant Type	No	No		

** ST = short-term; LT = long-term*

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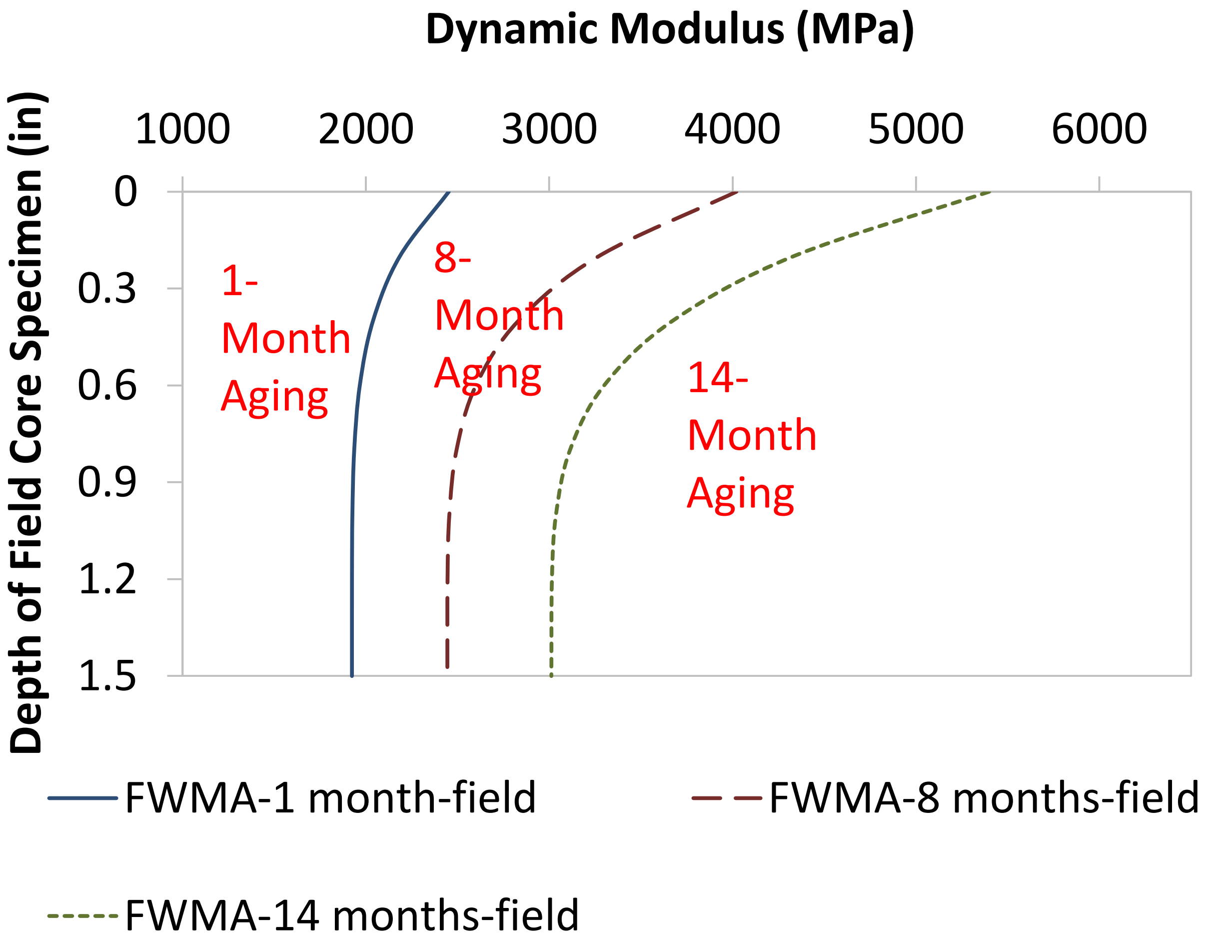
Effect of Aging on Field Stiffness Gradient



Effect of Aging on Fracture (Damage Density)