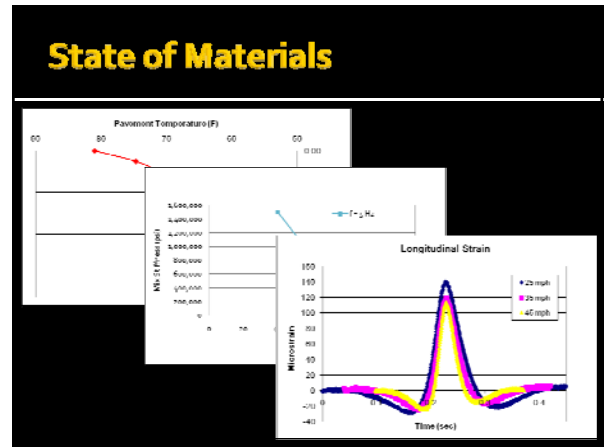
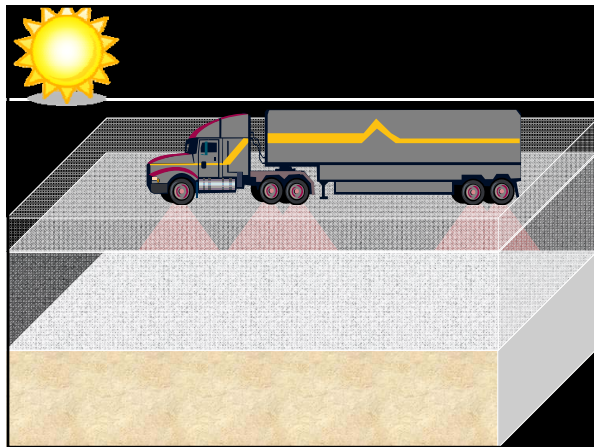


A Practical Look at E*

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National Center for Asphalt Technology
November 12, 2009

Importance of E*

- M-E Design



Importance of E*

- M-E Design

$E^* = fn(f, T)$

E* Defined

- Purely Elastic Material:

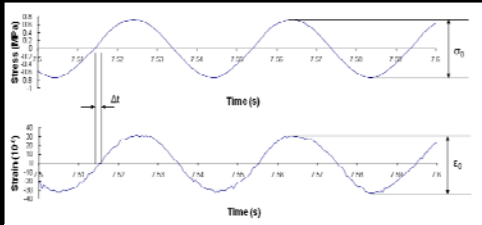
Stress: $\sigma = \frac{\text{Force}}{\text{Area}}$

Strain: $\epsilon = \frac{\text{Deformation}(\Delta L)}{\text{Unloaded Dimension}}$

Modulus: $E = \frac{\sigma}{\epsilon}$

E* Defined

Visco-Elastic Material (HMA):



Modulus: $E^* = \frac{\sigma_0}{\epsilon_0}$ Phase angle: $\phi = 2\pi f \Delta t$

How?

Models

- Van der Poel Model (1954)
- Shell Nomograph (1977)
- NCHRP 1-37A (1999)
 - $E^* = \text{fn}(p_{200r}, P_{4r}, P_{38r}, P_{34r}, V_{ar}, V_{beffr}, f, \eta)$
- Hirsch Model (2003)
 - $E^* = \text{fn}(VFA, VMA, G^*)$
- NCHRP 1-40D (2005)
 - $E^* = \text{fn}(p_{200r}, P_{4r}, P_{38r}, P_{34r}, V_{ar}, V_{beffr}, G^*)$

How?

Laboratory

- AMPT (a.k.a. SPT)



E* in the Lab

- Min. of 2 specimens
- Target Air Voids = 7% (±0.5)
 - AASHTO T 269
- Aging
 - AASHTO R30
 - Short-term
 - Long-term

E* in the Lab

AASHTO Spec.

- AASHTO PP 60-09
 - Specimen Prep using SGC
 - 100 mm in diameter
 - 150 mm in height
 - End flatness ≤ 0.5 mm
 - End perpendicularity ≤ 1.0 mm



Sample Prep



Sample Prep



Testing

Sample Conditioning

Specimen Temp (°C)	Time from Room Temp 25°C (hrs)	Time from Previous Test Temp (hrs)
-10	Overnight	Overnight
4	Overnight	4 or Overnight
21	1	3
37	2	2
54	3	1

- Starting at lowest temp
 - Beginning with highest frequency

Testing

- ASTM Specification
 - ASTM D3497-79 (2003)
 - T = 41, 77, 104 °F
 - f = 1, 4, 16 Hz
- AASHTO Specifications
 - AASHTO TP 62-07
 - T = 14, 40, 70, 100, 130 °F (-10, 4.4, 21.1, 37.8, 54 °C)
 - f = 0.1, 0.5, 1.0, 5, 10, 25 Hz

Testing

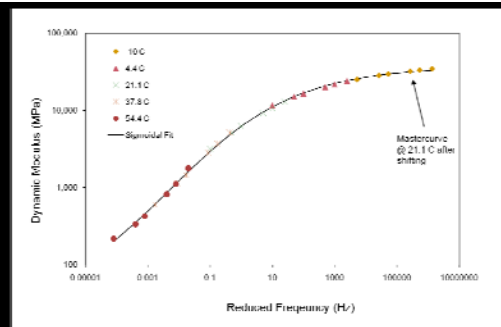
- AASHTO spec. (cont'd)
 - AASHTO TP 79-09
 - For AMPT
 - AASHTO PP 61-09
 - Recommendations on T and f for binder grades

PG 58-XX and softer		PG 64-XX and PG 70-XX		PG 76-XX and stiffer	
Temp (°C)	f (Hz)	Temp (°C)	f (Hz)	Temp (°C)	f (Hz)
4	10, 1, 0.1	4	10, 1, 0.1	4	10, 1, 0.1
20	10, 1, 0.1	20	10, 1, 0.1	20	10, 1, 0.1
35	10, 1, 0.1 and 0.01	40	10, 1, 0.1 and 0.01	45	10, 1, 0.1 and 0.01

Results

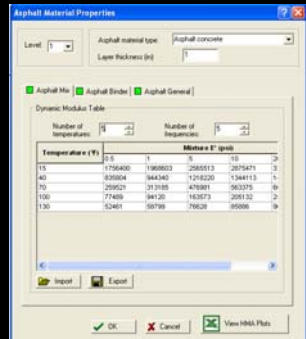
- Check Data Quality
 - Tolerances – AASHTO TP 62-07
 - Updated statistics /guidance – AASHTO TP 79-09
- Develop Master Curve
 - AASHTO TP 61-09
 - Hirsch Model
 - Microsoft Excel – solver function

Results



Use in Design

- MEPDG
 - Master Curve
 - Level 1
 - Lab Data
 - Level 2, 3
 - NCHRP 1-37A model
 - viscosity
 - NCHRP 1-40D model
 - G*



Use in Design

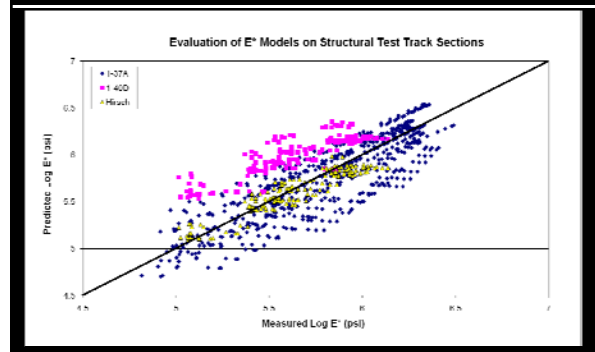
- MEPDG Level 1

Temp (°F)	Mixture E* and δ				Binder G* δ, 1-59 Hz
	0.1 Hz	1 Hz	10 Hz	25 Hz	
10	X	X	X	X	
40	X	X	X	X	X
55					X
70	X	X	X	X	X
85					X
100	X	X	X	X	X
115					X
130	X	X	X	X	X

Use in Design

- No AMPT?
 - FHWA Pooled Fund Project
 - \$60-75k
 - Utilize Models
 - Hirsch
 - NCHRP 1-37A
 - NCHRP 1-40D
 - Requires G*

Model Comparison



Summary

- E* necessary for M-E Design
- Obtained in Lab
 - AASHTO TP 62-07 and TP 79-09
 - Meets requirements for MEPDG Level 1
 - FHWA Pooled Fund Project
- Obtained thru Models
 - MEPDG Levels 2 and 3: 1-37A/ 1-40D
 - Hirsch Model most accurate

Questions?

