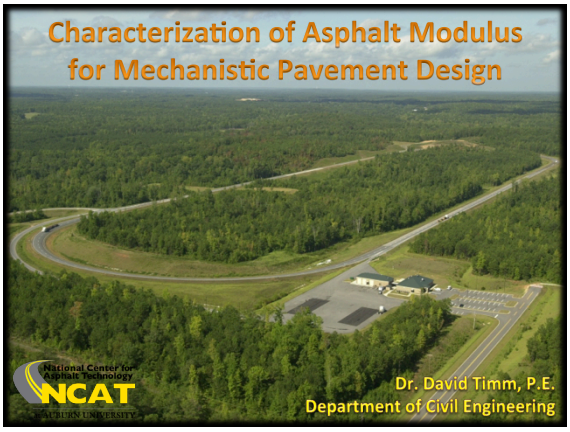
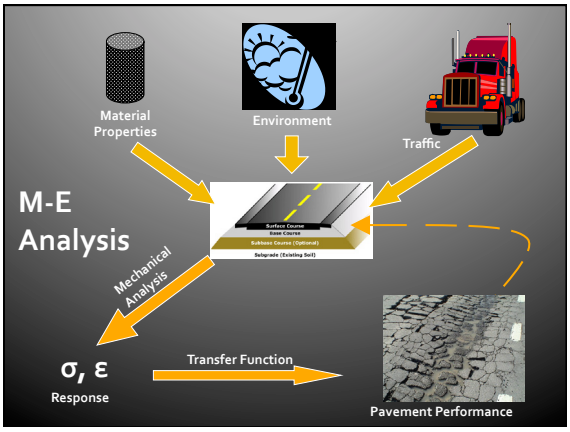
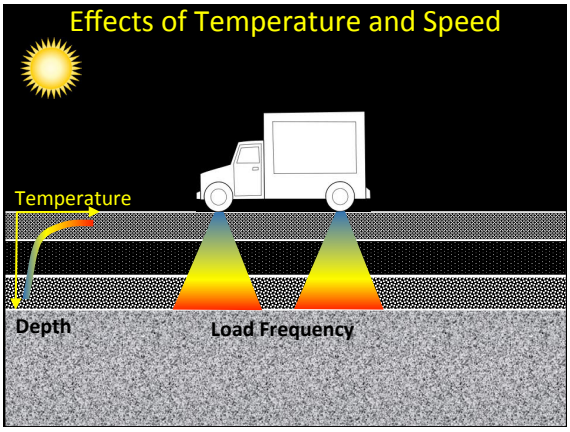
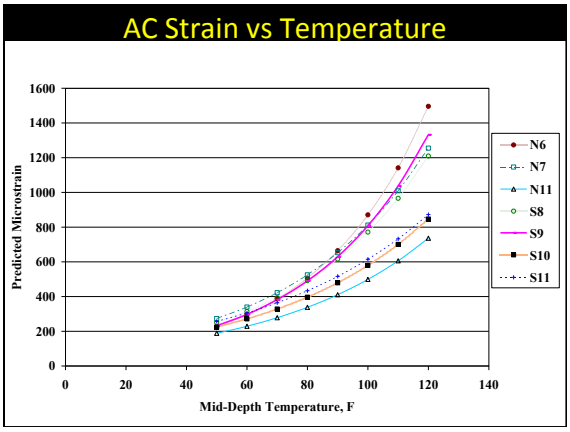
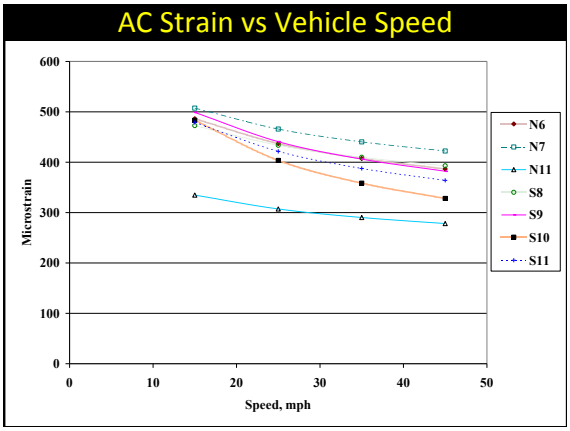
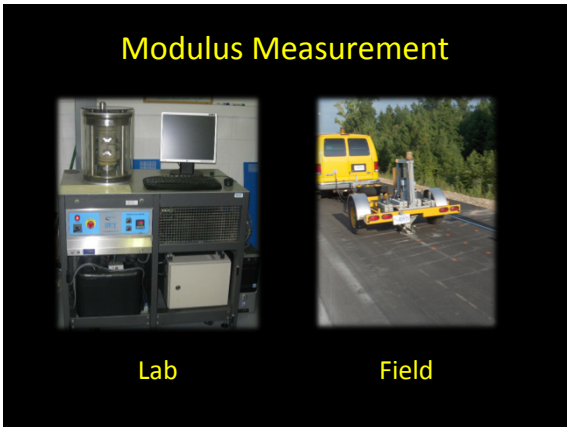

Characterization of Asphalt Modulus for Mechanistic Pavement Design
National Center for Asphalt Technology
NCAT
AUBURN UNIVERSITY
Dr. David Timm, P.E.
Department of Civil Engineering


Material Properties
Environment
Traffic
M-E Analysis
Mechanical Analysis
σ, ε
Response
Transfer Function
Pavement Performance

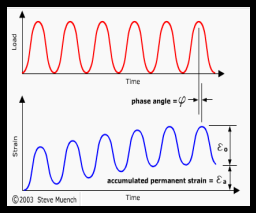

Effects of Temperature and Speed
Temperature
Depth
Load Frequency


AC Strain vs Temperature
Predicted Microstrain
Mid-Depth Temperature, F
N6
N7
N11
S8
S9
S10
S11


AC Strain vs Vehicle Speed
Microstrain
Speed, mph
N6
N7
N11
S8
S9
S10
S11


Modulus Measurement
Lab
Field

Dynamic Modulus - Lab



Modulus: $|E^*| = \frac{\sigma_0}{\varepsilon_0}$ Phase angle: $\phi = 2\pi f \Delta t$

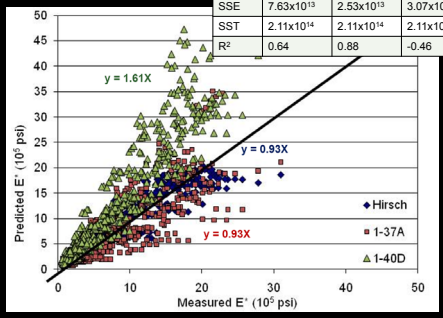
Determination of |E*|: Predictive Equations

Parameter	Witczak 1-37A	Witczak 1-40D	Hirsch
Gradation			
ρ_{200} passing	✓	✓	
ρ_4 retained	✓	✓	
ρ_{38} retained	✓	✓	
ρ_{34} retained	✓	✓	
Volumetric			
VMA			✓
V_a	✓	✓	
VFA			✓
V_{beff}	✓	✓	
Binder			
f	✓		
η	✓		
G*		✓	✓
δ_b		✓	

Robbins, 2012

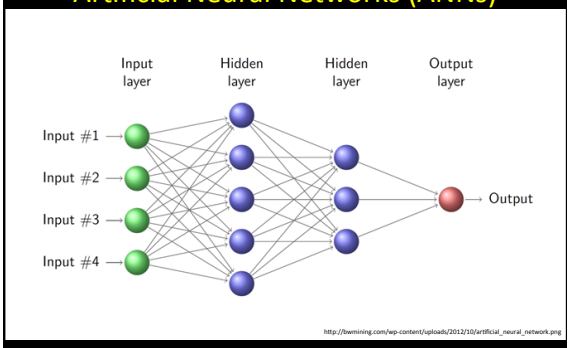
Determination of |E*|: predictive equations

	1-37A	Hirsch	1-40D
SSE	7.63×10^{13}	2.53×10^{13}	3.07×10^{14}
SST	2.11×10^{14}	2.11×10^{14}	2.11×10^{14}
R^2	0.64	0.88	-0.46



Robbins, 2012

Artificial Neural Networks (ANNs)



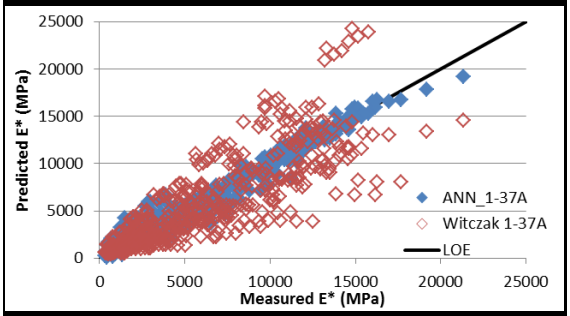
Asphalt Mixture Characteristics

- 2006 Test Track Mixtures
  - 18 different mixtures
    - PG 64-22, 67-22, 70-22, 76-22, 76-28
    - RAP
    - SMA
- 2009 Test Track Mixtures
  - 24 different mixtures
    - PG 67-22, 76-22, 76-22 with GTR, 67-28 with TLA, binder modified with 7.5% SBS
    - 50% RAP HMA
    - 50% RAP WMA
    - WMA Foam and WMA Additive
    - Coarse and fine mixtures

Lab Testing

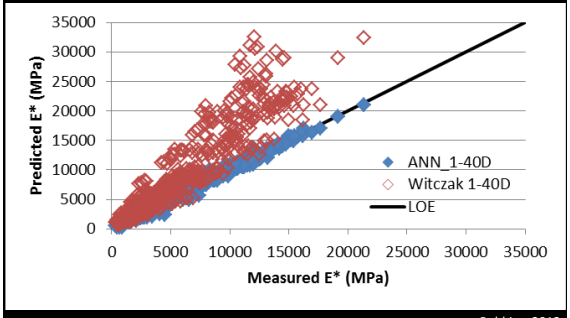
- 2006 Test Track Mixtures
  - AASHTO TP 62-07
    - 4, 21 & 37.8°C
    - 0.5, 1, 2, 5, 10, 20, 25 Hz
    - Plant produced mix compacted in laboratory with SGC
- 2009 Test Track Mixtures
  - AASHTO TP 79-09
    - 4, 20 & 40 or 45°C (depending on PG Grade)
    - 0.01 (at highest temp), 0.1, 1, 10 Hz
    - Plant produced mix compacted in laboratory with SGC
- Binder Testing
  - Viscosity: AASHTO D4402-06
  - G*: AASHTO T315-06

1-37A Model



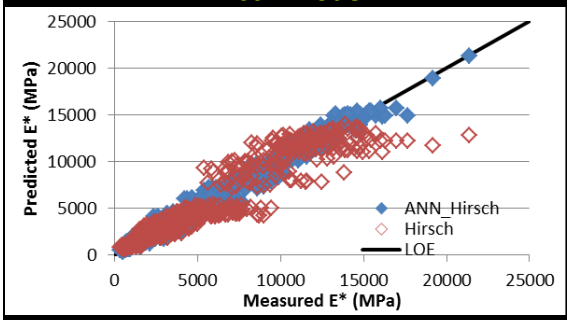
Robbins, 2012

1-40D Model



Robbins, 2012

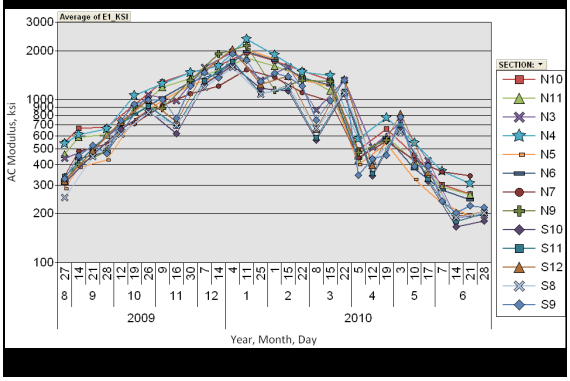
Hirsch Model



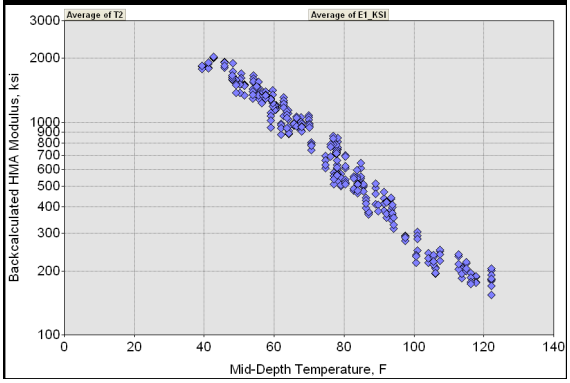
Robbins, 2012

Elastic Modulus - Field

Backcalculated Modulus vs Date

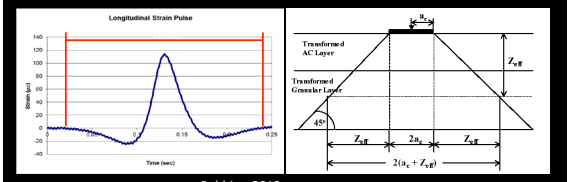


Backcalculated Modulus vs Temperature



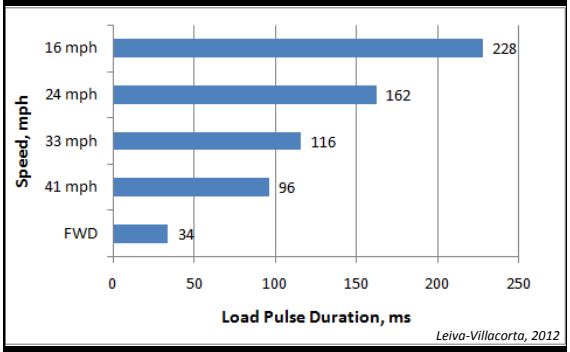
Which Best Represents Modulus Under Traffic?

- Temperatures can be matched directly
- Loading frequency is more difficult
  - Vehicle speed to load frequency conversion?



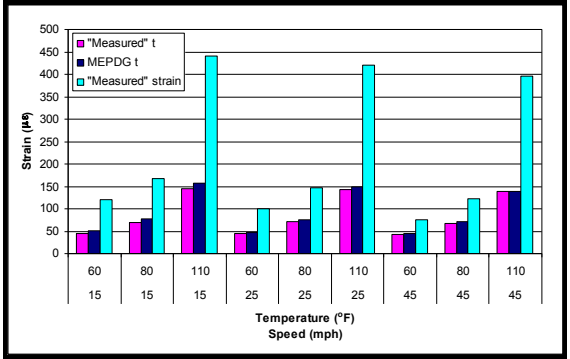
Robbins, 2012

Load Durations



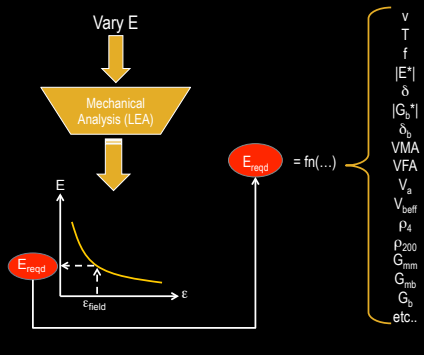
Leiva-Villacorta, 2012

Frequency = 1/t



Robbins, 2012

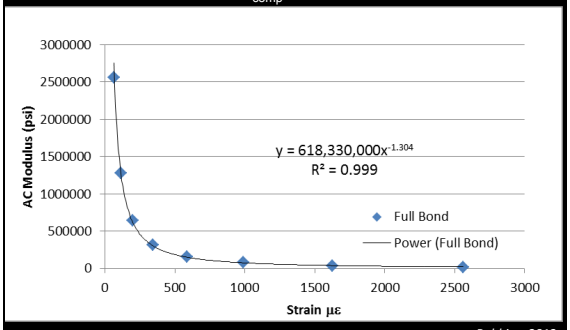
Backcalculate Modulus from Measured Strain



Robbins, 2012

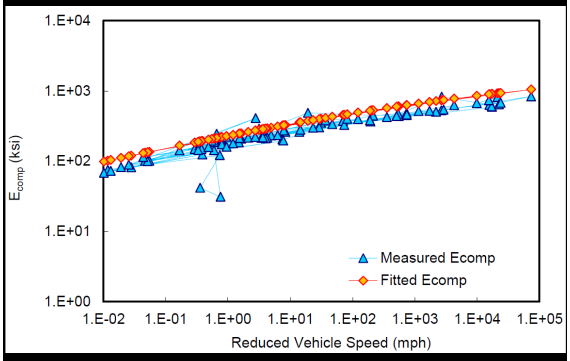
Modulus vs Strain

$E_{comp} = c\varepsilon^{d}$



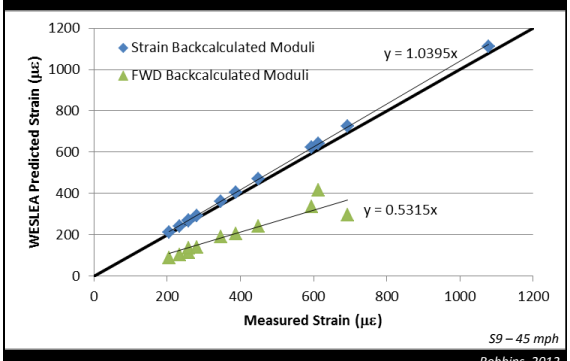
Robbins, 2012

Strain-Based Master Curves



Robbins, 2012

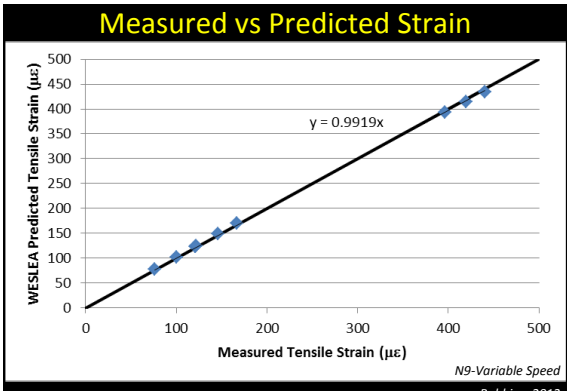
Measured vs Predicted Strains



S9 – 45 mph

Robbins, 2012

Measured vs Predicted Strain



N9-Variable Speed

Robbins, 2012

Summary

- Accurate strain prediction critical to mechanistic-based design
- Proper modulus characterization important to strain prediction
- Artificial neural networks effective in predicting AC modulus
  - Can be locally trained

Summary…continued

- Backcalculation characterizes in situ modulus effectively, but loading frequency is extremely high
- Existing models and procedures don't accurately account for visco-elastic and non-linear effects
- Strain-based backcalculation provides more accurate predictions of strain response
  - Need to expand and validate the approach