M-E Design Inputs

Southeast Asphalt User Producer Group
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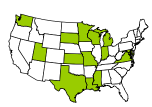
19 November 2008

Overview

- Introduction
- MEPDG – Where are we now
- MEPDG – Inputs, Outputs, and Sensitivity

Implementation Timeframe

- Some DOT's Already Underway
- Others are Awaiting Other Efforts:
  - NCHRP Projects
  - FHWA Research Projects
  - Copy Other State Approaches
  - AASHTO Adoption
  - Windfall from Gas Tax Revenues
  - Hell Freezes Over



DARWin ME Timeline

- Sunset Previous AASHTO Design Software
- Fall 2007
  - Sign intellectual property agreement with TRB
- Winter 2007/2008
  - Contract to review source code
    - Identify if modifications are needed for making software modular
    - Interface with third party software

DARWin ME Timeline (cont.)

- Summer 2008
  - Issue project solicitation proposal package for funding commitments
- Fall 2008
  - Select contractor
  - Commence development shortly thereafter (Early 2009)

Overview

- Introduction
- MEPDG – Where are we now
- MEPDG – Inputs, Outputs, and Sensitivity

Good News, Bad News

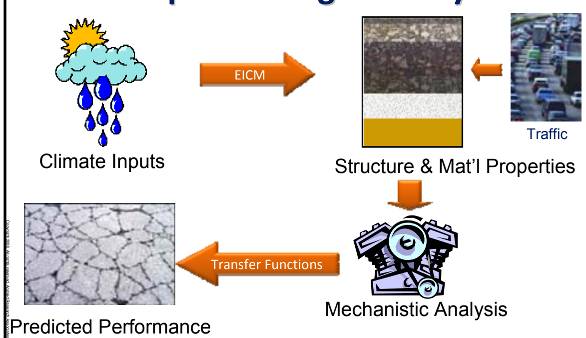
- **Bad News**
  - There's a lot going on
  - We are going to tell you about it
- **Good News**
  - MEPDG does it all for you in the background

What's New in Flexible Design?

HMA Materials

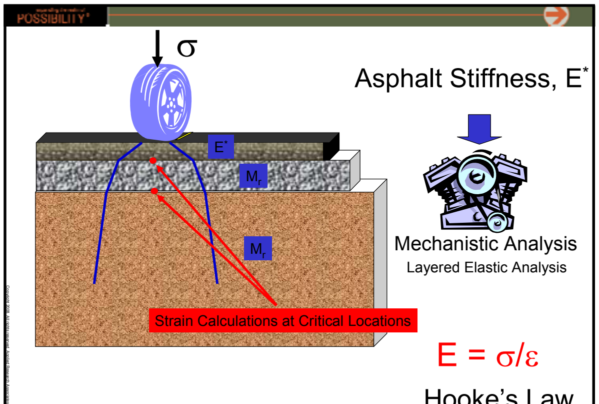
1993 Guide	M-E Guide
Layer Coefficient	Dynamic Modulus (Master curves)
Structural Number	Binder and Volumetric

Asphalt Design Theory



What's New in Flexible Design

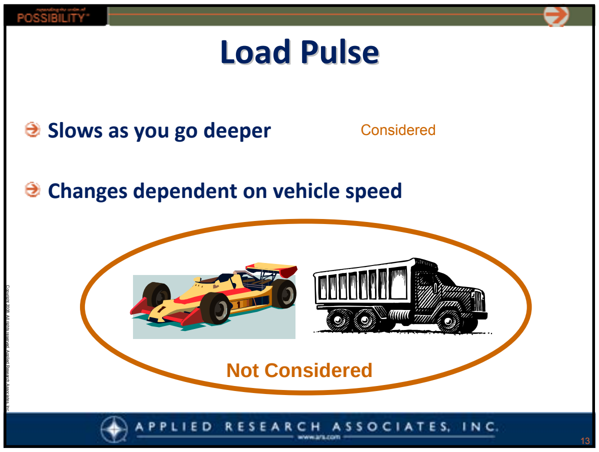
- **Analysis models – Layered Elastic**
- **Distress based on material performance**
  - Fatigue –
    - bottom up
  - Rutting
  - Thermal cracking
- **Overall performance**
  - Ride (IRI)



Asphalt Modulus is not Constant

- **Changes with Load Pulse Duration**
- **Accumulated Damage**
- **Aging**
- **Temperature**

Asphalt is Time-Temperature Dependent


POSSIBILITY
Load Pulse
Slows as you go deeper
Considered
Changes dependent on vehicle speed
Not Considered
APPLIED RESEARCH ASSOCIATES, INC.
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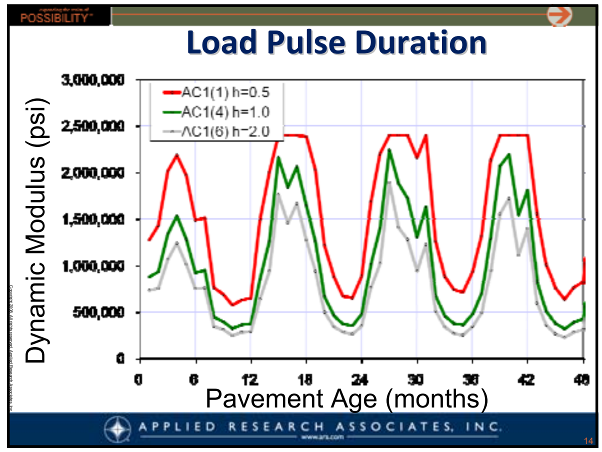
POSSIBILITY
Load Pulse Duration
Dynamic Modulus (psi)
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
AC1(1) h=0.5
AC1(4) h=1.0
AC1(6) h=2.0
0 6 12 18 24 30 36 42 48
Pavement Age (months)
APPLIED RESEARCH ASSOCIATES, INC.
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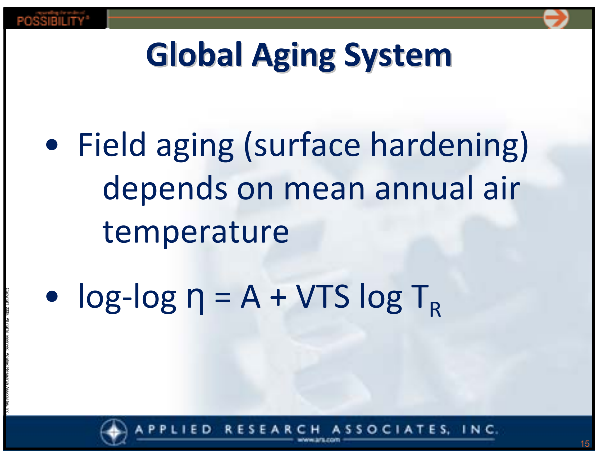
POSSIBILITY
Global Aging System
Field aging (surface hardening) depends on mean annual air temperature
log-log η = A + VTS log T_R
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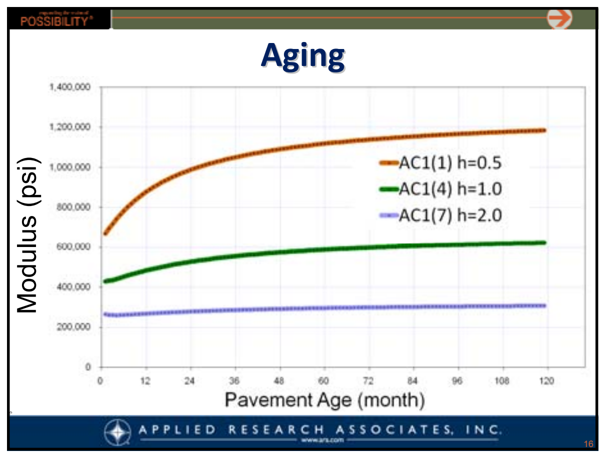
POSSIBILITY
Aging
Modulus (psi)
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
AC1(1) h=0.5
AC1(4) h=1.0
AC1(7) h=2.0
0 12 24 36 48 60 72 84 96 108 120
Pavement Age (month)
APPLIED RESEARCH ASSOCIATES, INC.
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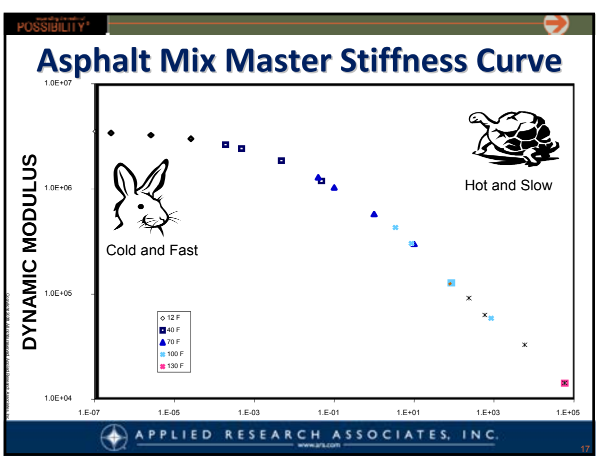
POSSIBILITY
Asphalt Mix Master Stiffness Curve
DYNAMIC MODULUS
1.0E+07
1.0E+06
1.0E+05
1.0E+04
Hot and Slow
Cold and Fast
12 F
40 F
70 F
100 F
130 F
1.E-07 1.E-05 1.E-03 1.E-01 1.E+01 1.E+03 1.E+05
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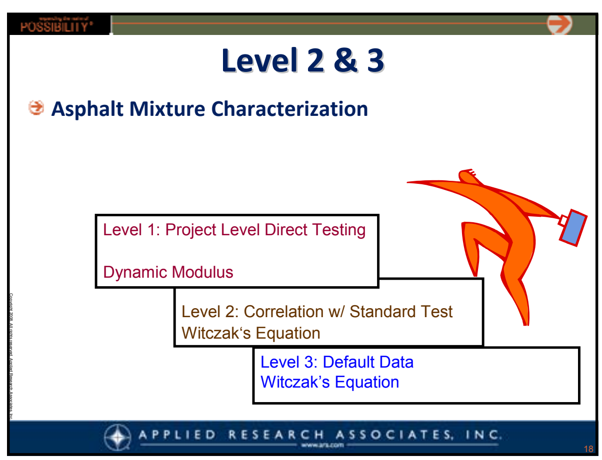
POSSIBILITY
Level 2 & 3
Asphalt Mixture Characterization
Level 1: Project Level Direct Testing
Dynamic Modulus
Level 2: Correlation w/ Standard Test
Witczak's Equation
Level 3: Default Data
Witczak's Equation
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Level 2 & 3

- Correlate AC Modulus (E*) with Binder properties and Mixture Volumetrics
- Compatible with SuperPave Mixture and Binder Testing

Witczak Equation for Computing E*

f (Gradation, Volumetric, and Binder Properties)

Level 2 & 3

$$\log E^* = 3.75 + 0.029\,\rho_{200} - 0.0018(\rho_{200})^2 - 0.0028\rho_4 - 0.058\,V_a - 0.8022\left(\frac{V_{beff}}{V_{beff}+V_a}\right) + \frac{3.872 - 0.002\,\rho_4 + 0.004\,\rho_{38} - 0.00002(\rho_{38})^2 + 0.0055\,\rho_{34}}{1+e^{(-0.603-0.313\log(f)-0.393\log(\eta))}}$$

Has been replaced by G^* and sin δ in version 1.0

Binder properties used in:

- Aging model
- Dynamic Modulus Shift factors
- Witczak Equation
- Thermal cracking model

Conventional Binder Tests can be used In-place of Performance Grading

ASPHALT MATERIAL PROPERTY AND DESIGN INPUTS

Categories of Inputs for HMA

Input	Used to predict
Asphalt Mix Properties	➢Stiffness of the Mix ➢Mechanistic response
Asphalt Binder Properties	➢Fatigue Cracking ➢Creep Compliance/ Thermal Cracking
General Properties	

Asphalt Mix Properties

- **Laboratory Determined Dynamic Modulus of the Mix (E*)**
  - Definition: Ratio of Cyclic Stress to Elastic Strain under sinusoidal compression loading, controlled temperature/frequency conditions
  - Enter values of laboratory determined dynamic modulus at different test temperatures and frequencies
  - Test Protocol: ASTM D 3497
  - Typical value: 600 ksi

Input Level	1	2	3
	√		

Asphalt Mix Properties, Cont'd

- **Aggregate Gradation**
  - Definition: Cumulative percentages from the grain size distribution curve:
    - % retained on 3/4 in. Sieve
    - % retained on 3/8 in. Sieve
    - % retained on No. 4 Sieve
    - % passing No. 200 Sieve
  - Test Protocol: ASTM C 136

Input Level	1	2	3
		√	√

Asphalt Binder Properties

- **Option 1: Superpave Binder Test Data - Laboratory Determined Complex Shear Modulus (G*) of the Binder**
  - Definition: Ratio of shear stress to shear strain under sinusoidal shear loading, controlled temperature/frequency conditions
  - Enter values of laboratory determined shear modulus and phase angle at different test temperatures and 10 rad/sec. angular frequency
  - Test Protocol: AASHTO PP1

Input Level	1	2	3
	√	√	

Asphalt Binder Properties, Cont'd

- **Option 2: Conventional Binder Test Data**
  - Enter values for:
    - Softening Point (P)
    - Absolute Viscosity (P, @ 140 F)
    - Kinematic Viscosity (CS, @ 275 F)
    - Specific Gravity
    - Penetrations (number of entries, value (0.1 mm), temperature (F))
    - Brookfield Viscosities (number of entries, value (CP), temperature (F))
  - Test Protocols: AASHTO T49-93, T53-92, TP48

Input Level	1	2	3
	√	√	

Asphalt Binder Properties, Cont'd

- **Option 1: Superpave Binder Grading**
  - Select from table of performance gradings as a function of the minimum pavement design temperature ("low") and the average seven-day maximum pavement design temperature ("high")
  - AASHTO MP1-93

Input Level	1	2	3
			√

Asphalt Binder Properties, Cont'd

- **Option 2: Conventional Viscosity Grade**
  - Select grade from available options:
    - AC 2.5
    - AC 5
    - AC 10
    - AC 20
    - AC 30
    - AC 40
  - ASTM D 3381

Input Level	1	2	3
			√

Asphalt Binder Properties, Cont'd

- **Option 3: Conventional Penetration Grade**
  - Select grade from available options:
    - Pen 40 - 50
    - Pen 60 - 70
    - Pen 85 - 100
    - Pen 120 - 150
    - Pen 200 – 300
  - ASTM D 946

Input Level	1	2	3
			√

Asphalt Concrete General Properties

- **Reference Temperature – used to build "mastercurves" of dynamic modulus as a function of load frequency and temperature; default 70 F**
- **Volumetric Properties (at time of construction)**
  - Effective Binder Content (%): The percent by mass of binder in a total mixture which is not absorbed into aggregate
  - Air Voids (%): The percent by volume of air in the mixture
  - Total Unit Weight (pcf): The ratio of total weight by total volume of the mixture

Input	1	2	3
Level	√	√	√

Asphalt Concrete General Properties

- **Poisson's Ratio: Ratio of horizontal to vertical elastic strain**
  - Option 1: Enter value (default 0.35)
  - Option 2: Enter predictive model parameters a and b
- **Thermal Conductivity: A measure of the uniform flow of heat through a unit thickness, when two faces of unit area are subjected to a unit temperature differential**
  - Used to predict temperature profile in AC layer
  - Calculated: ASTM E 1952 (default value 0.67 BTU /hr-ft deg F)

Input	1	2	3
Level	√	√	√

Asphalt Concrete General Properties

- **Heat Capacity: Heat required to raise the temperature of a unit mass of material by unit temperature**
  - Used to predict temperature profile in AC layer
  - Calculated: ASTM D 2766
  - Default value 0.23 BTU /lb-ft

Input	1	2	3
Level	√	√	√

Thermal Cracking Inputs

- **Average Tensile Strength at 14 F : Maximum stress that a material is capable of resisting under axial tensile loading from the indirect tensile strength test.**
- **Creep Test Duration: select either 100 or 1000 sec.**
- **Mix Coefficient of Thermal Contraction (in/in/oC) – Change in linear dimension per unit length or change in volume per unit volume per degree of temperature change. Either enter value or compute from:**
  - Mixture VMA (voids in mineral aggregate)
  - Aggregate Coefficient of Thermal Contraction

Input	1	2	3
Level	√	√	√

Thermal Cracking Inputs, Cont'd

- **Creep Compliance: ratio of strain over stress in the static creep test (psi –1)**
  - Either import file with creep compliance data or enter values in table as a function of temperature and loading time (only one temperature 14 F used in Level 2)

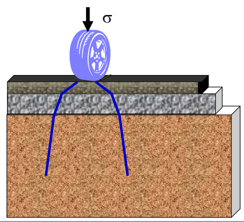
MEPDG Calculations

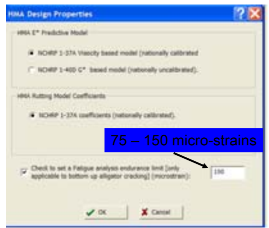
- **Temperatures:**
  - computed every six minutes
  - Up to Seven Asphalt Sub-layers
- **Traffic:**
  - Assume normal distribution divided into five sub-seasons (quintiles) to represent temperature conditions when 20% of the traffic is applied.

POSSIBILITY

Endurance Limit - Perpetual Pavement

- **Theory: Very low strain levels at the bottom of an asphalt pavement do not contribute to the fatigue damage and can be neglected.**





POSSIBILITY

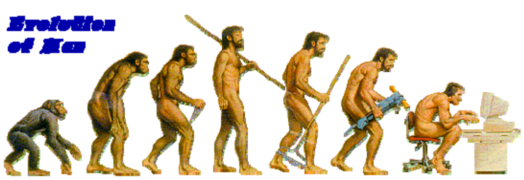
Things to remember

- **All pavement design systems need:**
  - Quality Materials Characterization
  - Recognizes Climate with Design
  - Quality Traffic Data
  - Calibrated to local conditions
- **The MEPDG has raised the bar for each of these criteria……**

POSSIBILITY

Evolution

- **The MEPDG is not perfect…..BUT;**
- **The MEPDG provides a reasonable and structured platform for continuous improvement.**



POSSIBILITY

Thank You!