Flexible Pavement Materials Characterization for the 2002 Pavement Design Guide

Ramon Bonaquist, Ph.D., P.E.
Chief Operating Officer
Advanced Asphalt Technologies, LLC

New Jersey Pavement Technology Workshop
February 25, 2003

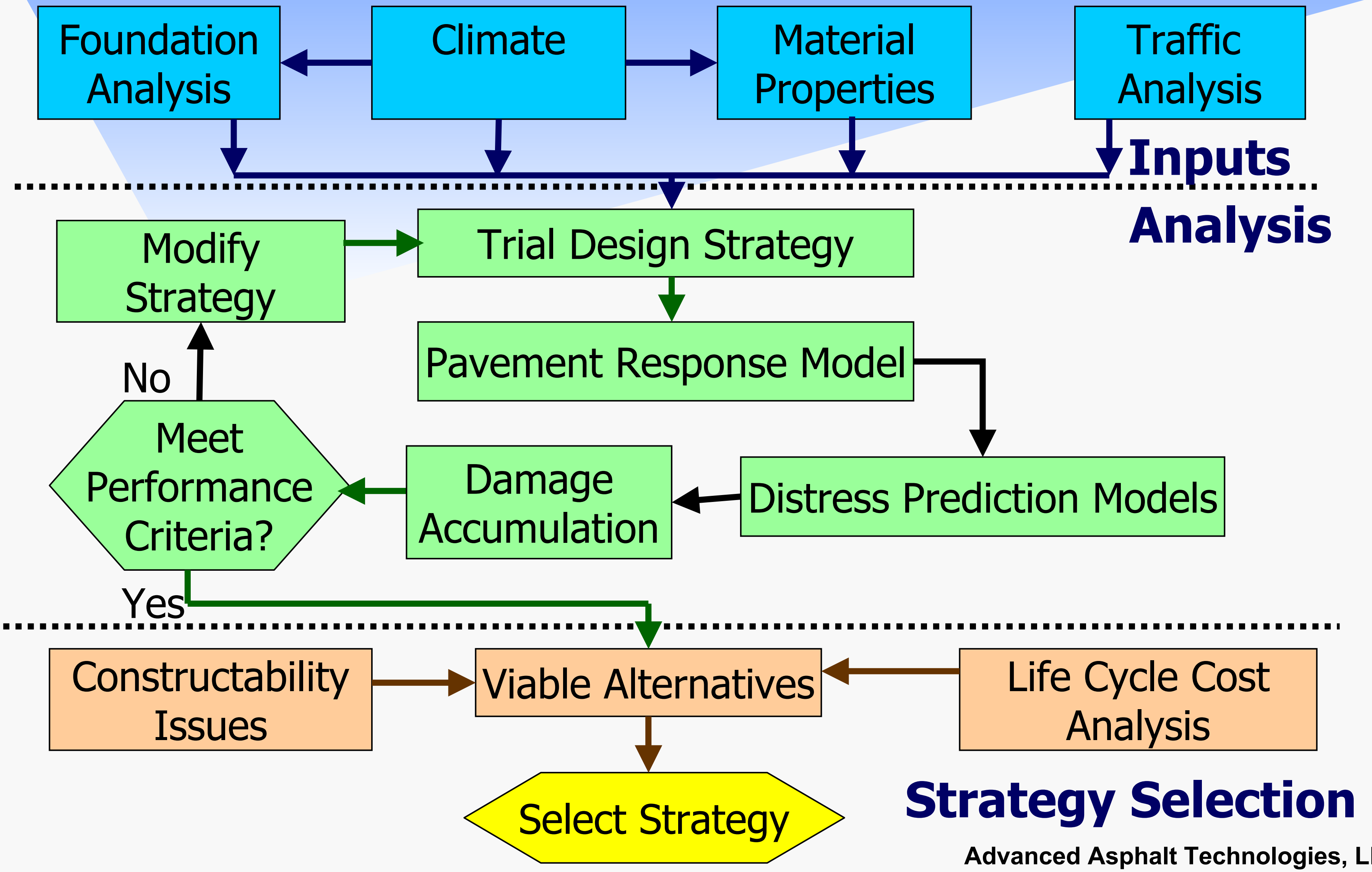
Acknowledgements

- NCHRP Project 1-37A
  - Dr. Amir Hanna
  - Project Panel
- ERES Consultants
  - Prime Contractor
- Professor Matthew W. Witczak
  - Flexible Pavement Team Leader
- Members of the Flexible Pavement Team

Outline

- Overview of 2002 Flexible Pavement Design Process
- Importance of Material Characterization
- Hierarchical Approach for Design Inputs
- Flexible Pavement Materials Characterization
  - Asphalt Concrete
  - Subgrade and Unbound Base/Subbases
- Summarize

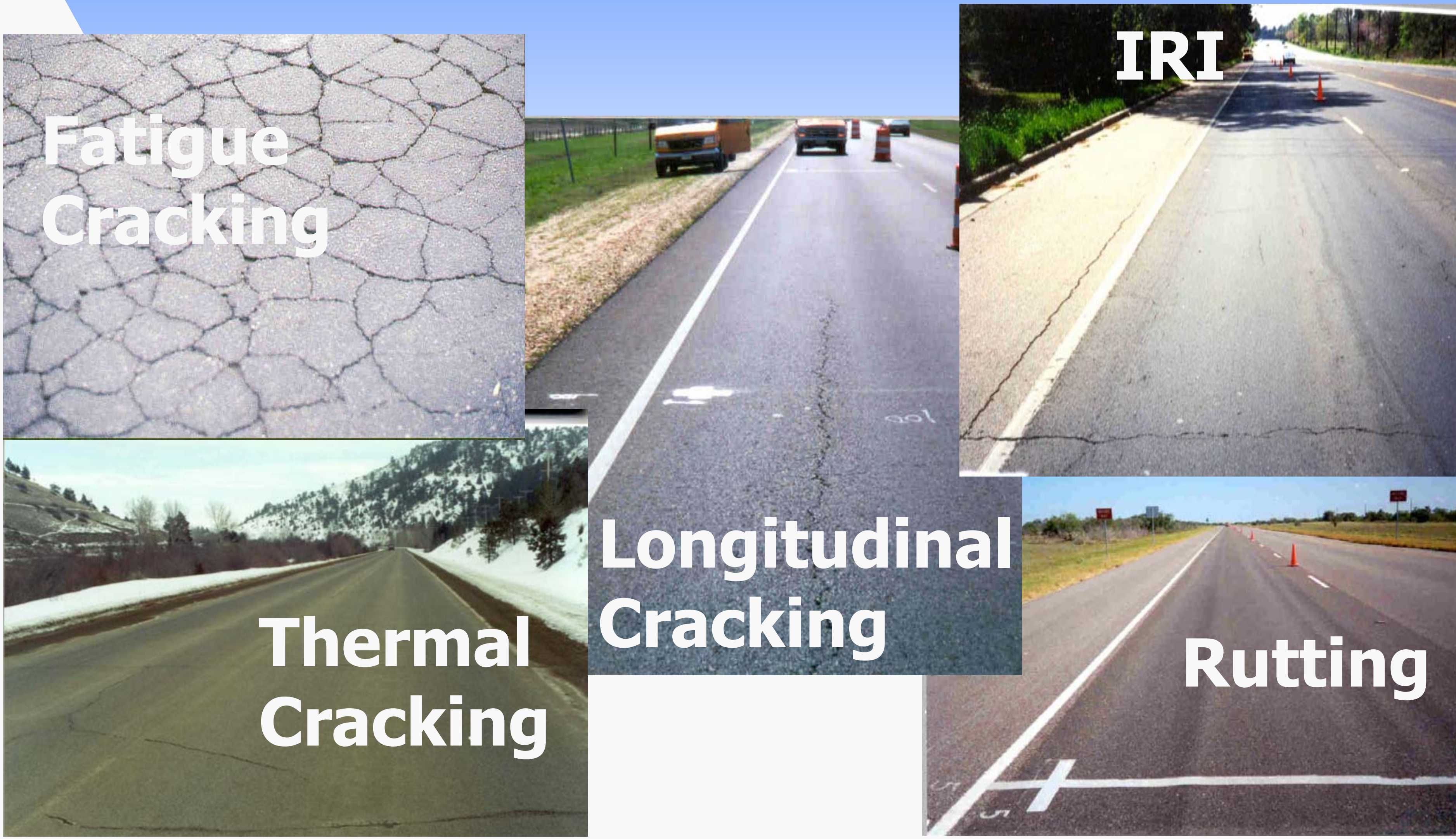
Design Process



Advanced Asphalt Technologies, LLC

"Engineering Services for the Asphalt Industry"

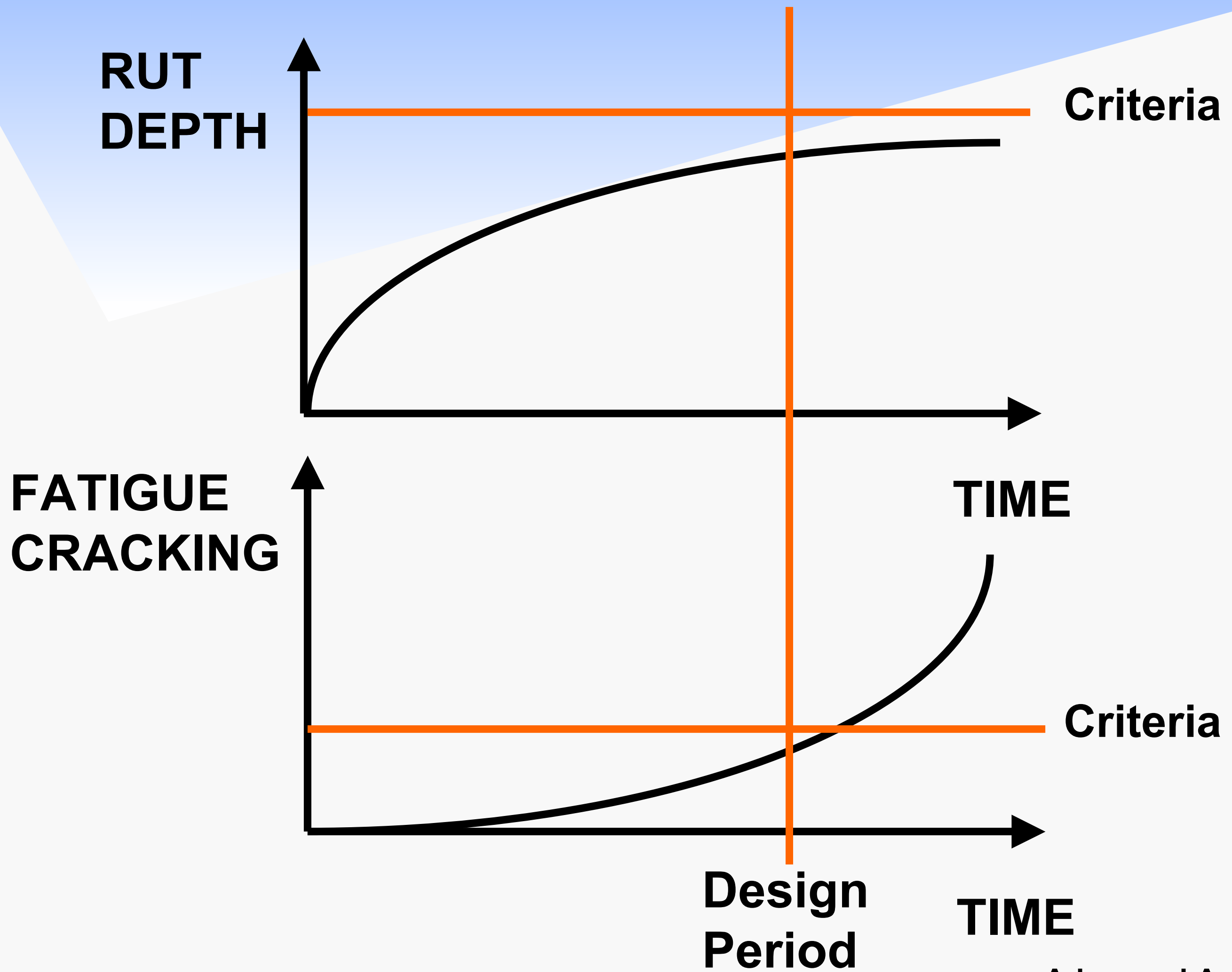
Distresses



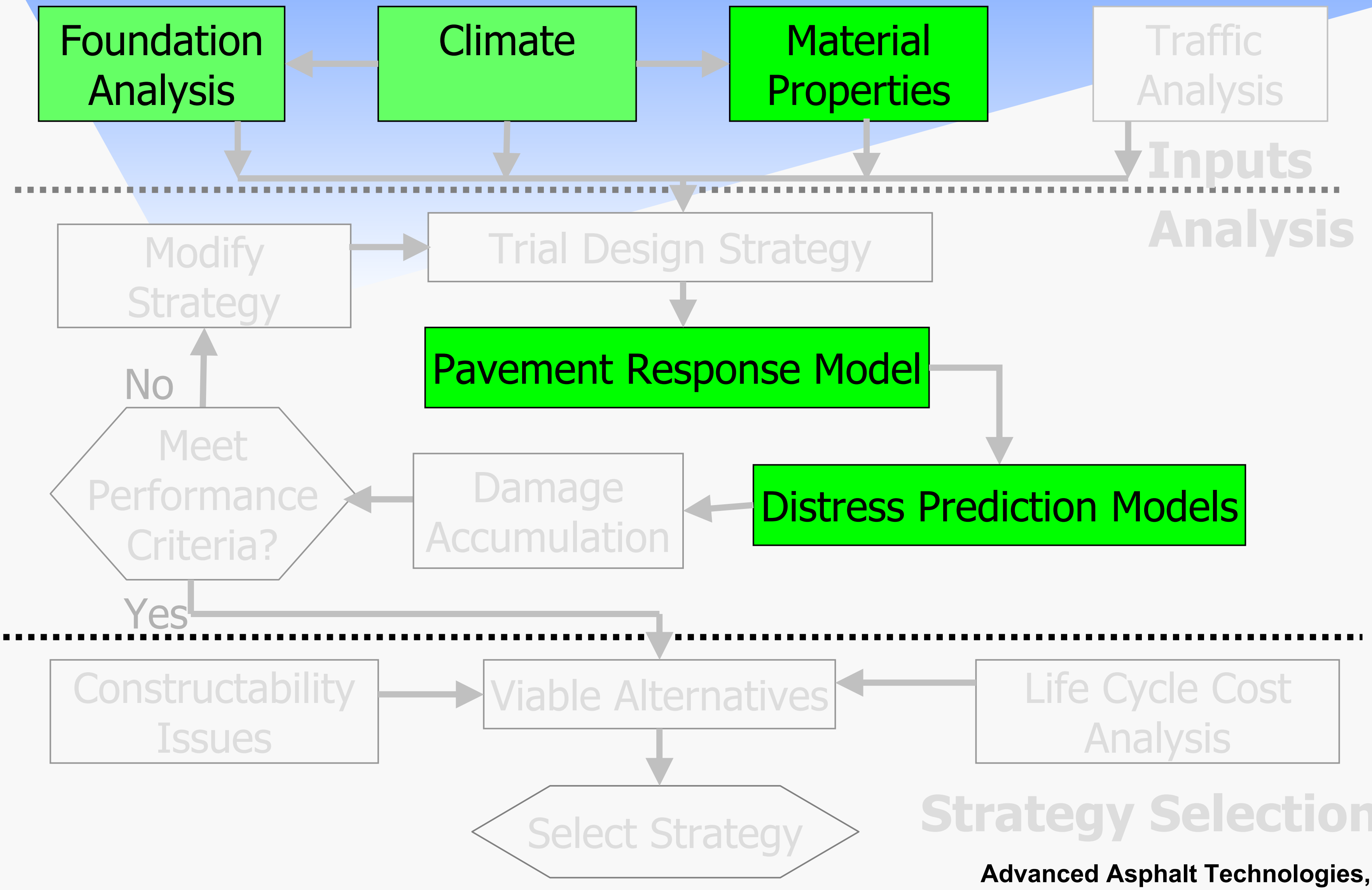
Advanced Asphalt Technologies, LLC

"Engineering Services for the Asphalt Industry"

Damage


RUT
DEPTH
Criteria
TIME
FATIGUE
CRACKING
Criteria
Design
Period
TIME

Materials in Design Process

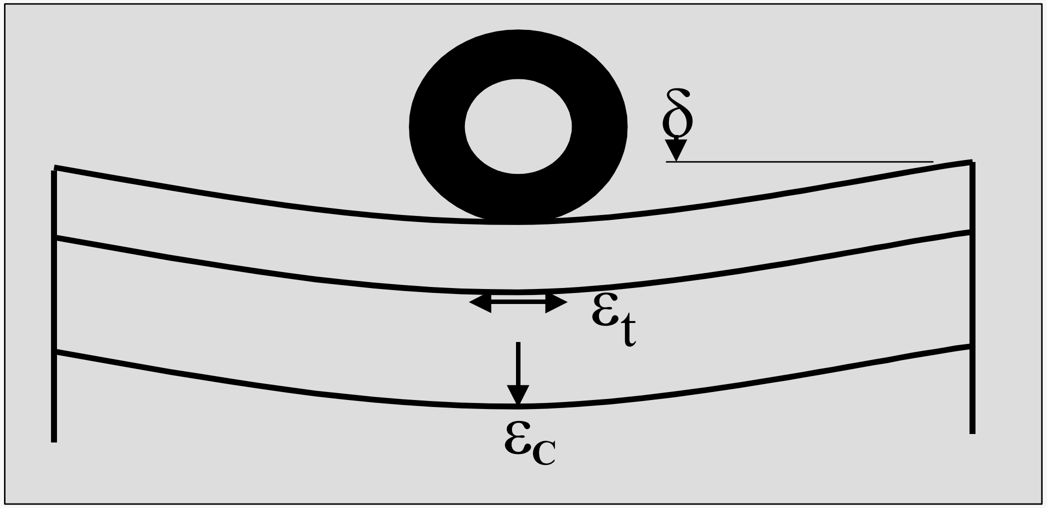


Advanced Asphalt Technologies, LLC

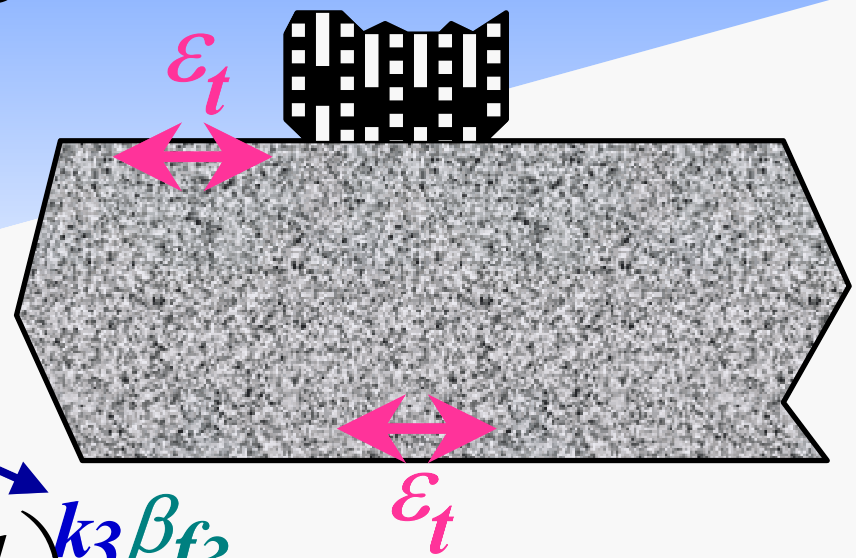
"Engineering Services for the Asphalt Industry"

Pavement Response Model

- Multilayer Elastic Solution
  - JULEA
- Material Properties
  - Modulus
  - Poisson's Ratio



Fatigue Cracking



Modified Shell Fatigue Equation

$$N_f = \beta_{f1} k_1 \left(\frac{1}{\varepsilon_t}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$$

From Layered Elastic Analysis

Asphalt Modulus

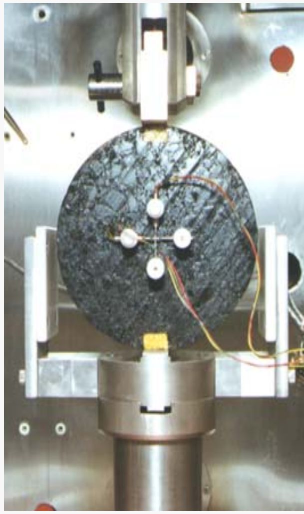
Field Calibration Factors

Hierarchical Design Inputs

Input Level	Determination of Input Values	Knowledge of Input Parameter
1	Project/Segment Specific Measurements	Good
2	Regression equations, Regional values	Fair
3	Defaults, Judgement	Poor

New Asphalt Concrete

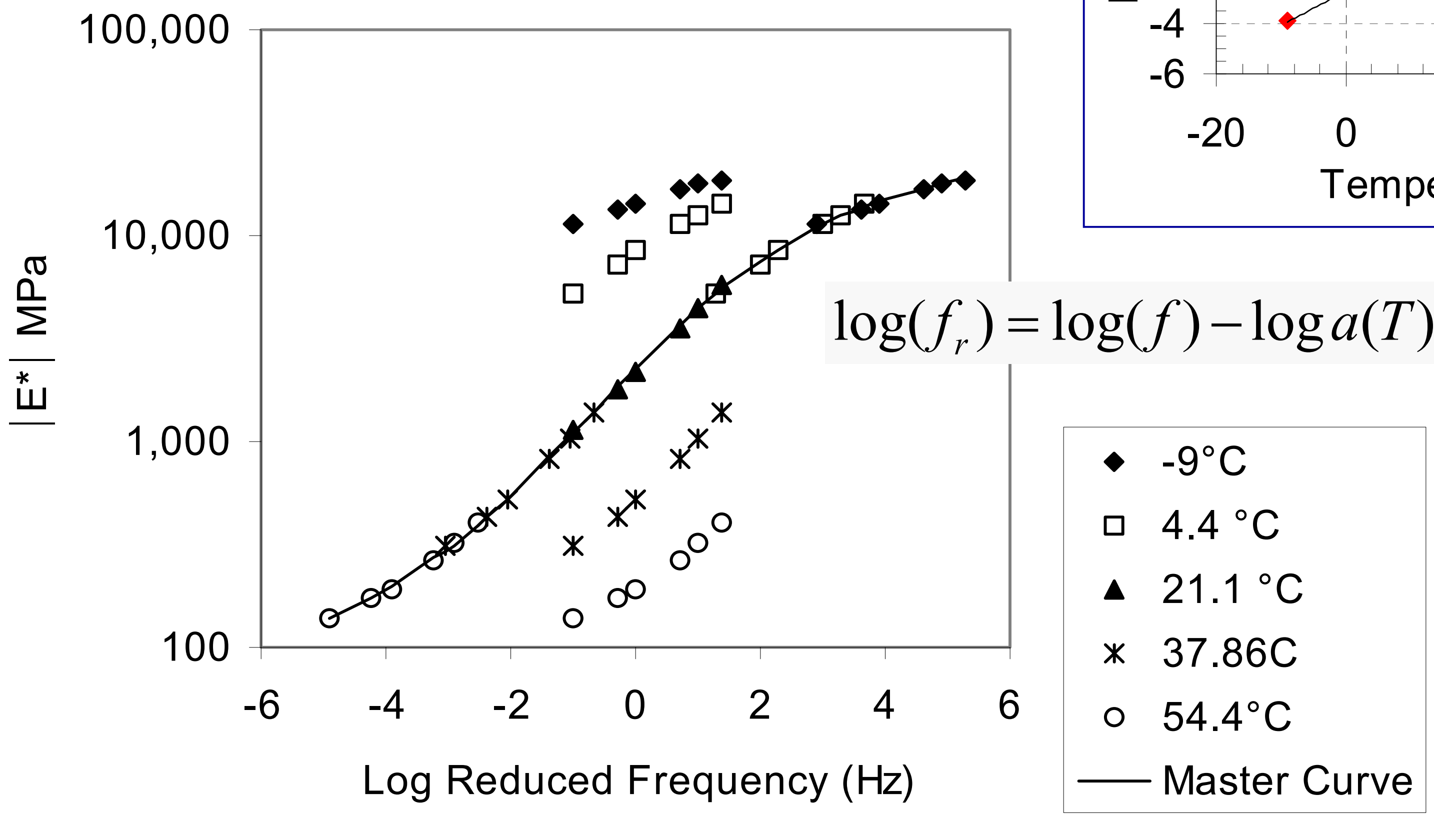
- Modulus Mastercurve
  - Structural Response
  - Rutting and Fatigue
- Low Temperature Creep Compliance and Strength
  - Thermal Cracking Analysis



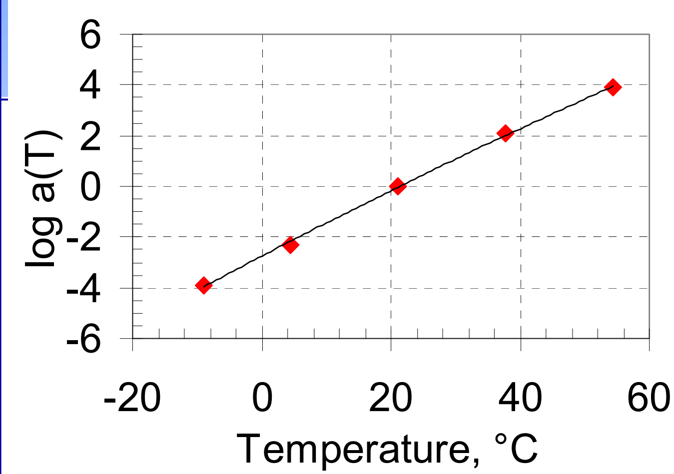
- Poisson's Ratio Predicted From Modulus

Mastercurve

Reference Temperature 21.1 °C



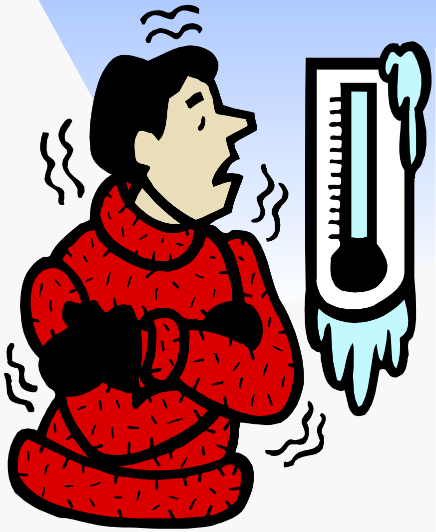
$$\log(f_r) = \log(f) - \log a(T)$$

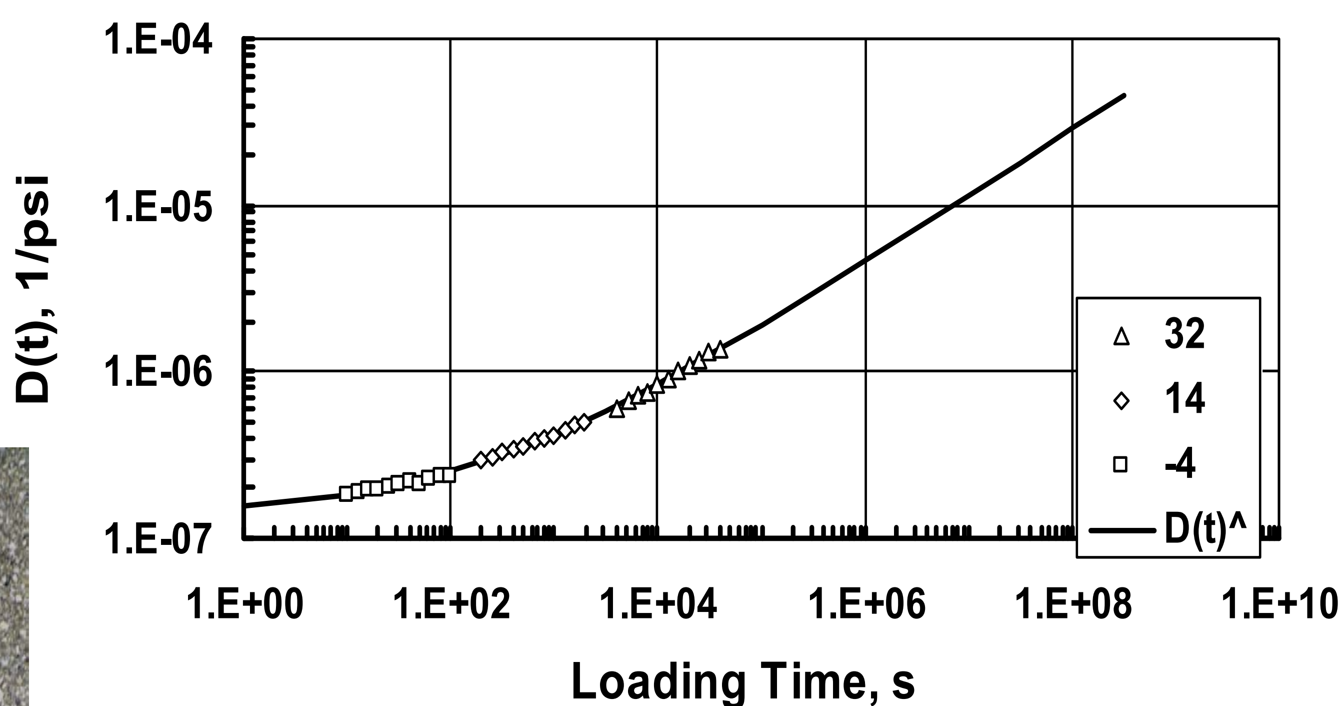


Advanced Asphalt Technologies, LLC

"Engineering Services for the Asphalt Industry"

Compliance

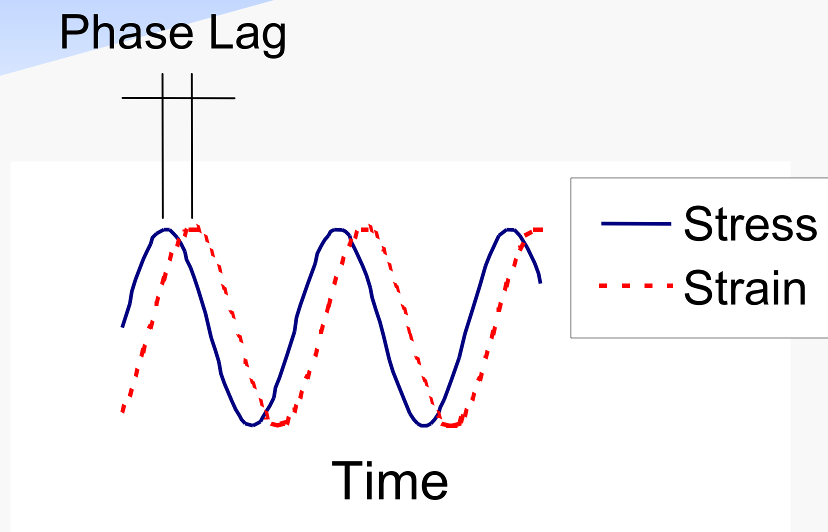


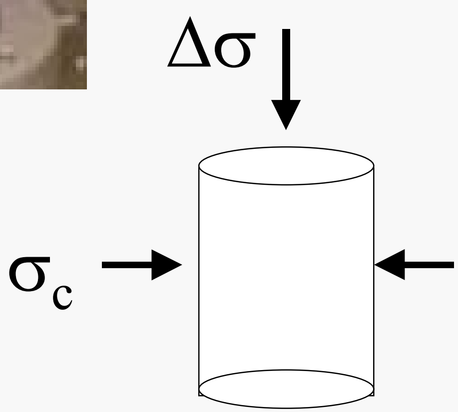

1.E-04
1.E-05
1.E-06
1.E-07
D(t), 1/psi
1.E+00
1.E+02
1.E+04
1.E+06
1.E+08
1.E+10
Loading Time, s
32
14
-4
D(t)^

New Asphalt Concrete

Input Level	Property	Characterization Method
1	Modulus	Dynamic Modulus |E*| Test ASTM D3496
	Creep/Strength	Indirect Tensile Creep/Strength AASHTO TP9
2	Modulus	Predicted From Volumetrics and Binder Properties
	Creep/Strength	Extrapolated From limited Creep/Strength Tests
3	Modulus	Predicted From Volumetrics and Binder Grade
	Creep/Strength	Predicted From Binder Grade

Dynamic Modulus Test Level 1





$$\left|E^*\right| = \frac{\sigma}{\varepsilon}$$

(ASTM D3496, NCHRP 9-19)

Advanced Asphalt Technologies, LLC

"Engineering Services for the Asphalt Industry"

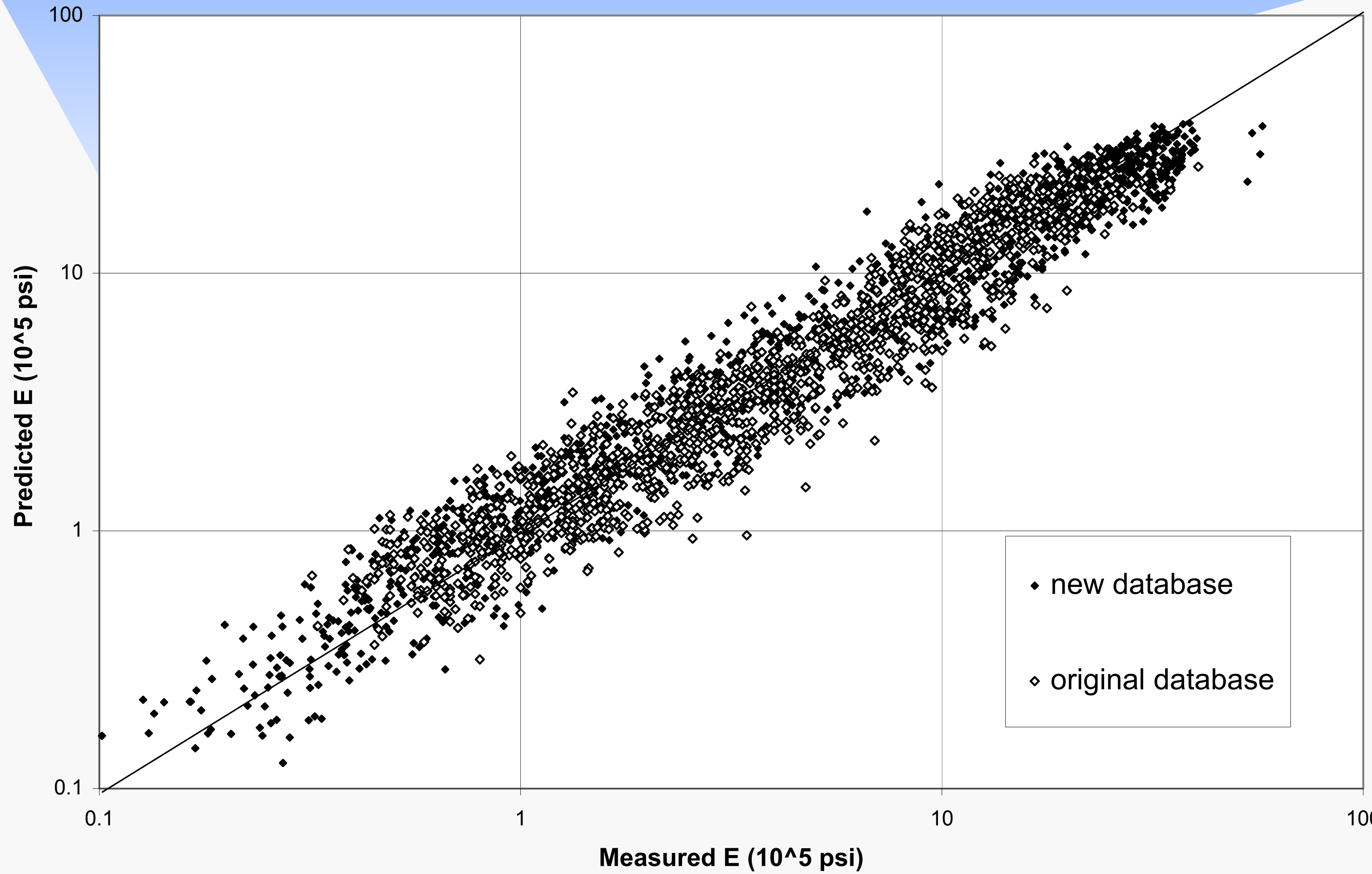
Witczak Predictive Equation Levels 2 and 3

$$\log E = -1.249937 + 0.29232\,\rho_{200} - 0.001767(\rho_{200})^2 - 0.002841\,\rho_4 - 0.058097V_a$$
$$-0.802208\left(\frac{V_{beff}}{V_{beff} + V_a}\right) + \frac{3.871977 - 0.0021\,\rho_4 + 0.003958\,\rho_{38} - 0.000017(\rho_{38})^2 + 0.005470\,\rho_{34}}{1 + e^{(-0.603313 - 0.313351\log(f) - 0.393532\log(\eta))}} \quad (2.3)$$

where:

E	=	Dynamic modulus, 10^5 psi
η	=	Bitumen viscosity, 10^6 Poise
f	=	Loading frequency, Hz
V_a	=	Air void content, %
V_{beff}	=	Effective bitumen content, % by volume
ρ_{34}	=	Cumulative % retained on the 19-mm sieve
ρ_{38}	=	Cumulative % retained on the 9.5-mm sieve
ρ_4	=	Cumulative % retained on the 4.76-mm sieve
ρ_{200}	=	% passing the 0.075-mm sieve

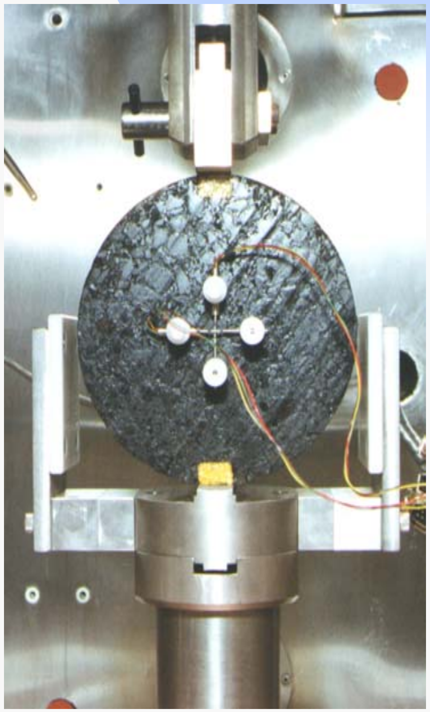
Witczak Predictive Equation



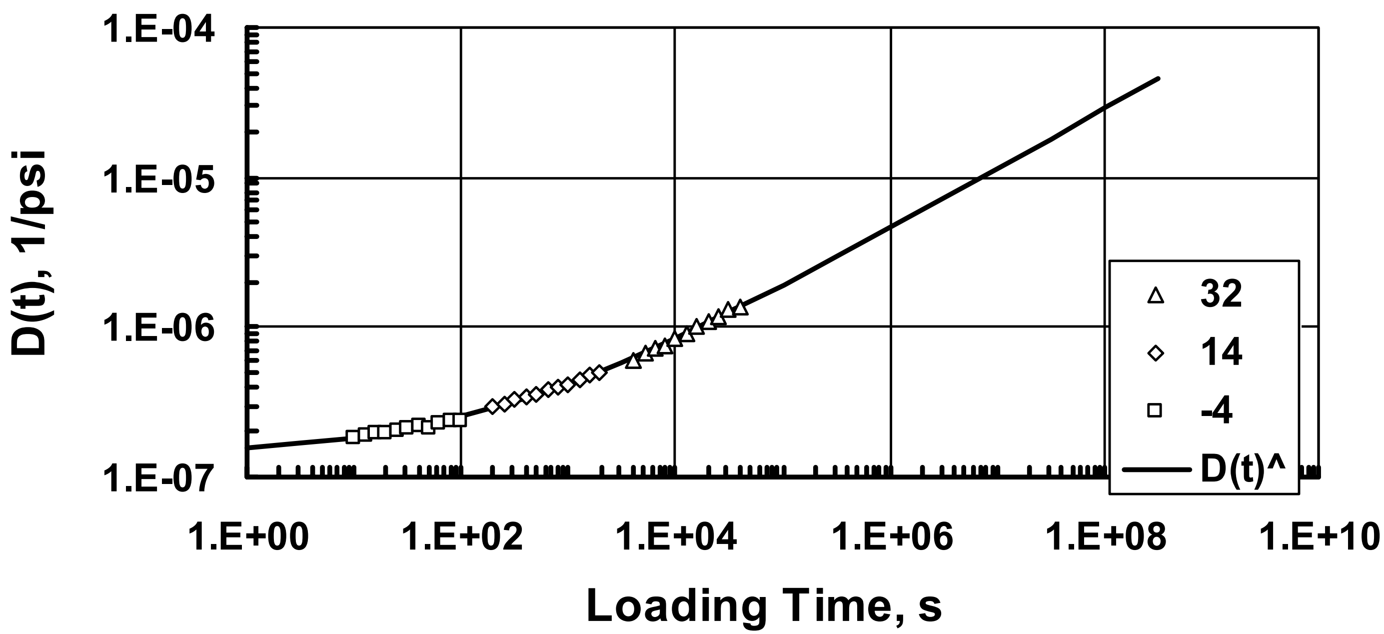
Advanced Asphalt Technologies, LLC

"Engineering Services for the Asphalt Industry"

Creep and Strength Level 1



AASHTO TP9



Advanced Asphalt Technologies, LLC

"Engineering Services for the Asphalt Industry"

Creep and Strength Levels 2 and 3

Function of Material Characteristics

$$D(t) = D_0 + D_1 \left\{ \frac{t}{10^{C_2 (T_r - T)}} \right\}^m$$

D(t) = Compliance
t = time
T = Temperature
T_r = Reference Temperature

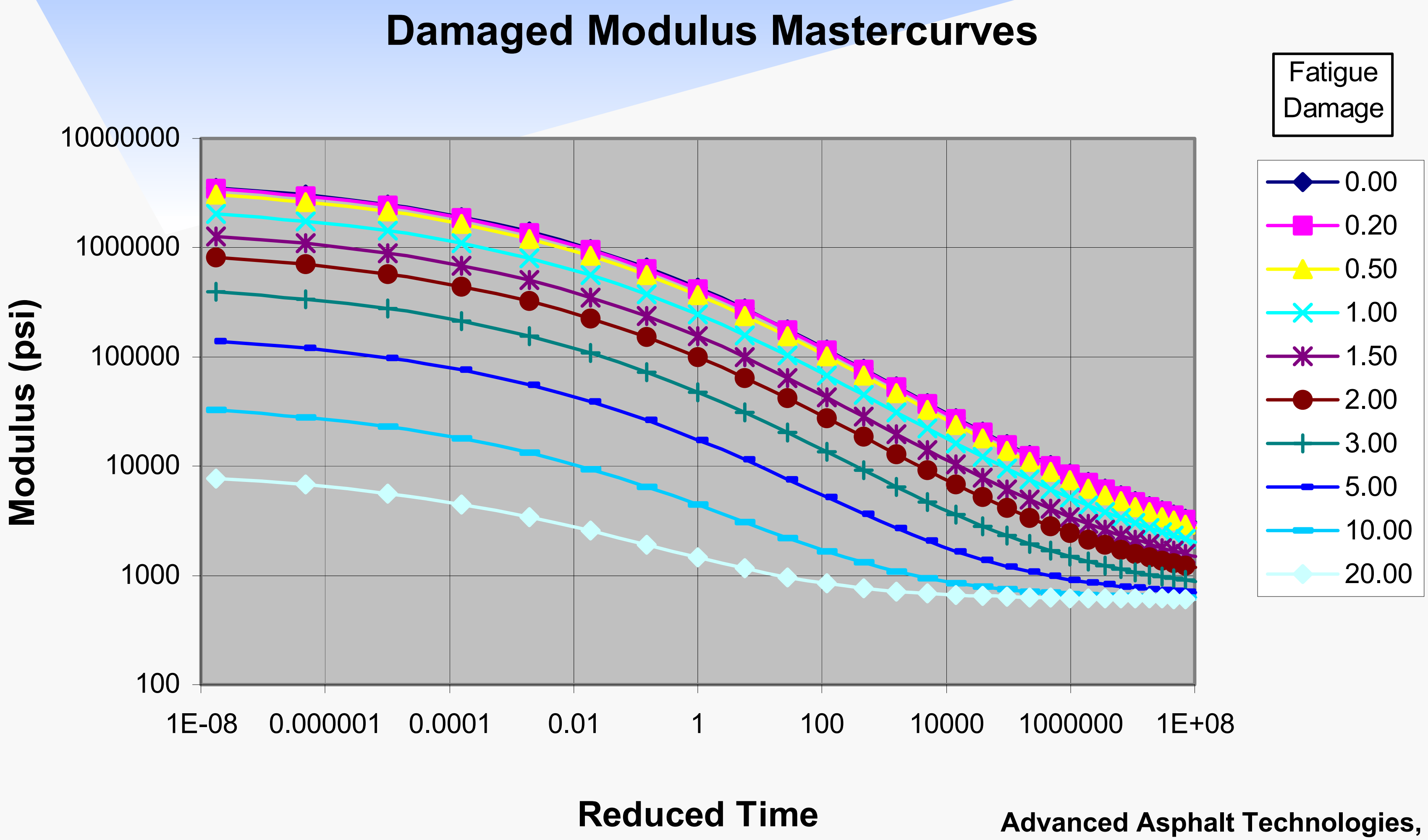
Existing Asphalt Concrete

- Damaged Modulus
  - Structural Response
  - Rutting and Fatigue
- Poisson’s Ratio Predicted From Modulus

Advanced Asphalt Technologies, LLC

“Engineering Services for the Asphalt Industry”

Damaged Modulus Mastercurve



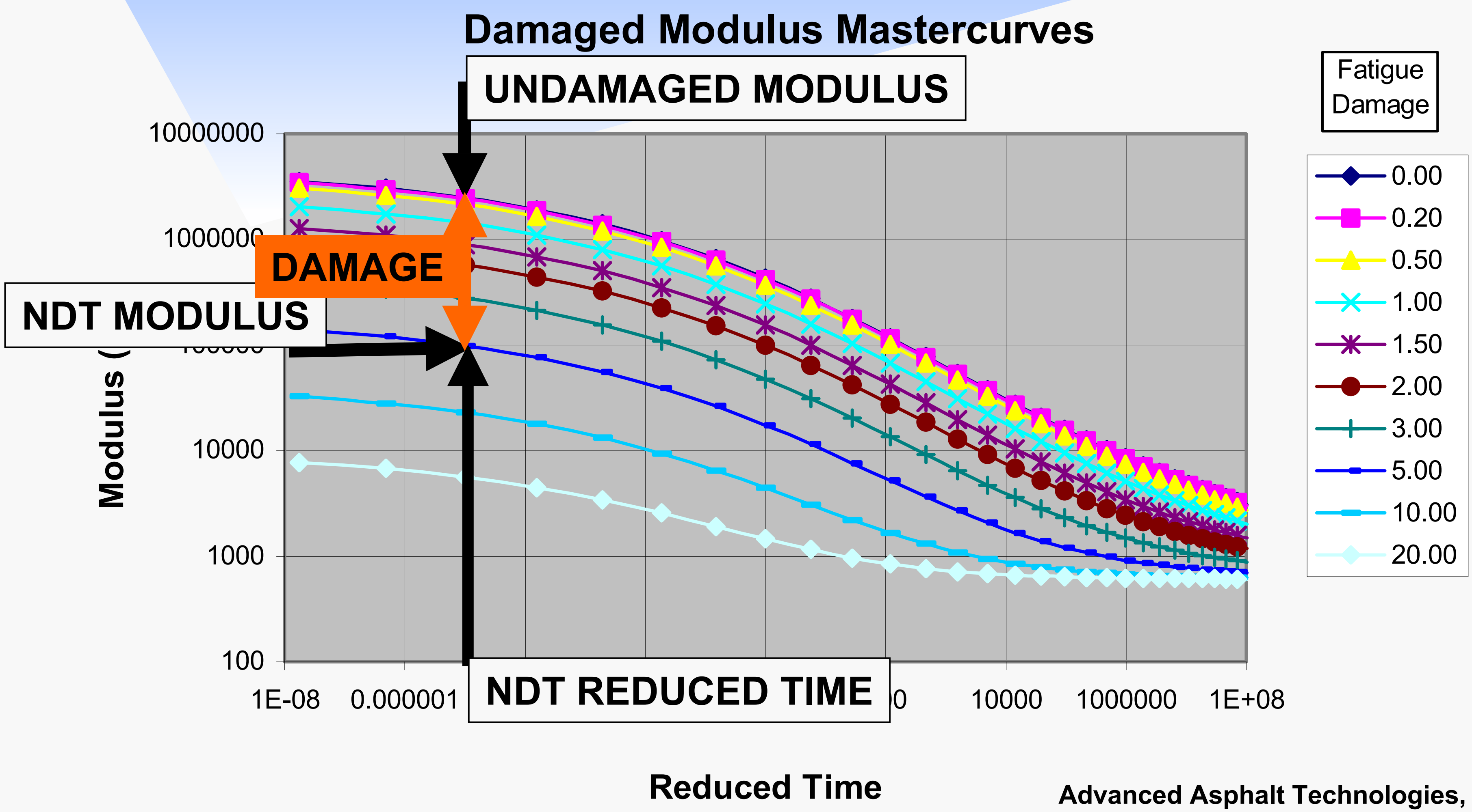
Advanced Asphalt Technologies, LLC

"Engineering Services for the Asphalt Industry"

Existing Asphalt Concrete

Input Level	Modulus	Characterization Method
1	Damaged	Backcalculated from NDT
	Undamaged	Predicted From Volumetrics & Binder Properties From Cores
2	Damaged	From Extent of Fatigue Cracking
	Undamaged	Predicted From Volumetrics & Binder Properties From Cores
3	Modulus	From Condition Rating
	Undamaged	Predicted From Volumetrics and Binder Grade

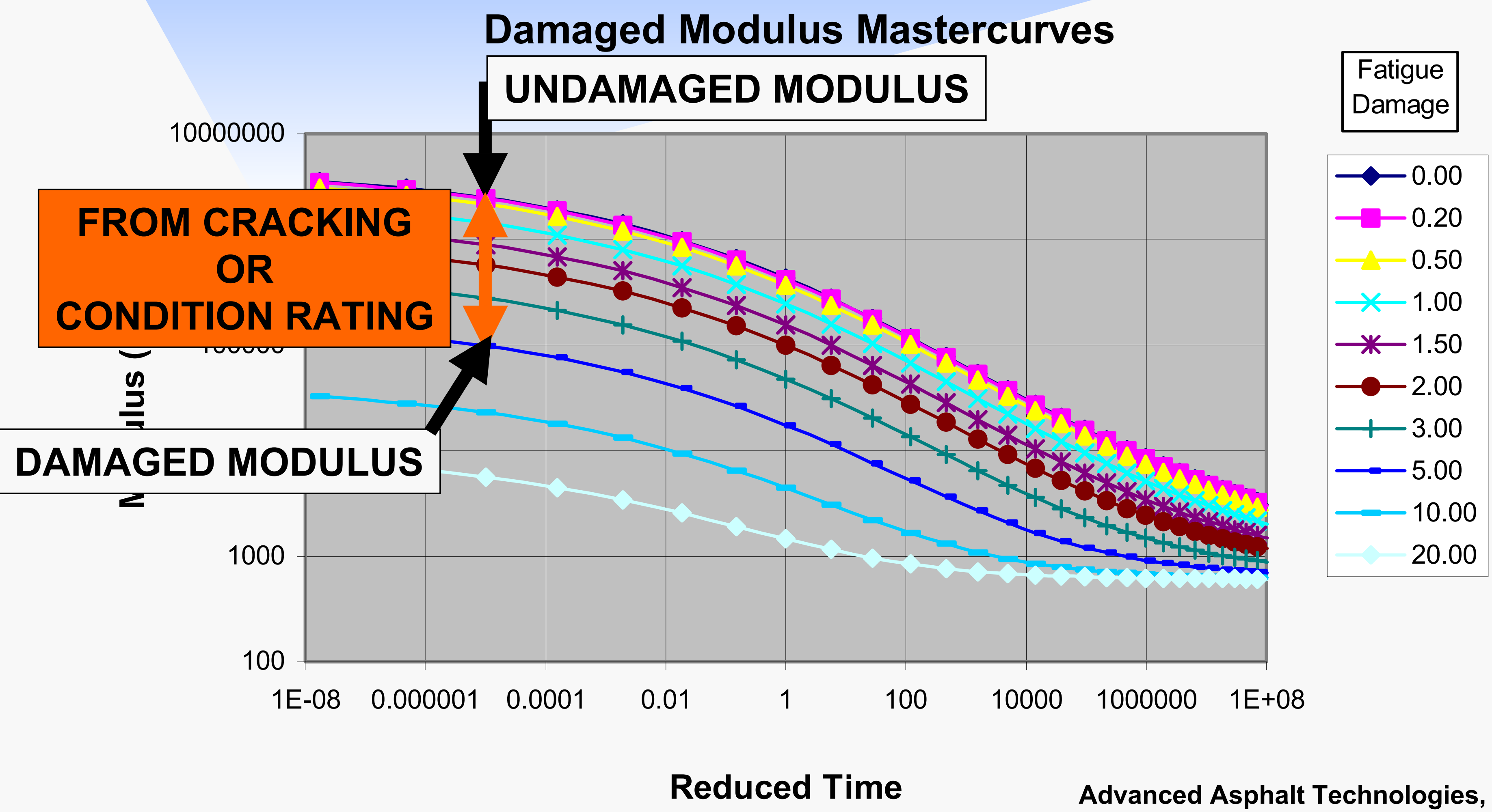
Existing Asphalt Concrete Level 1



Advanced Asphalt Technologies, LLC

"Engineering Services for the Asphalt Industry"

Existing Asphalt Concrete Level 2 and 3

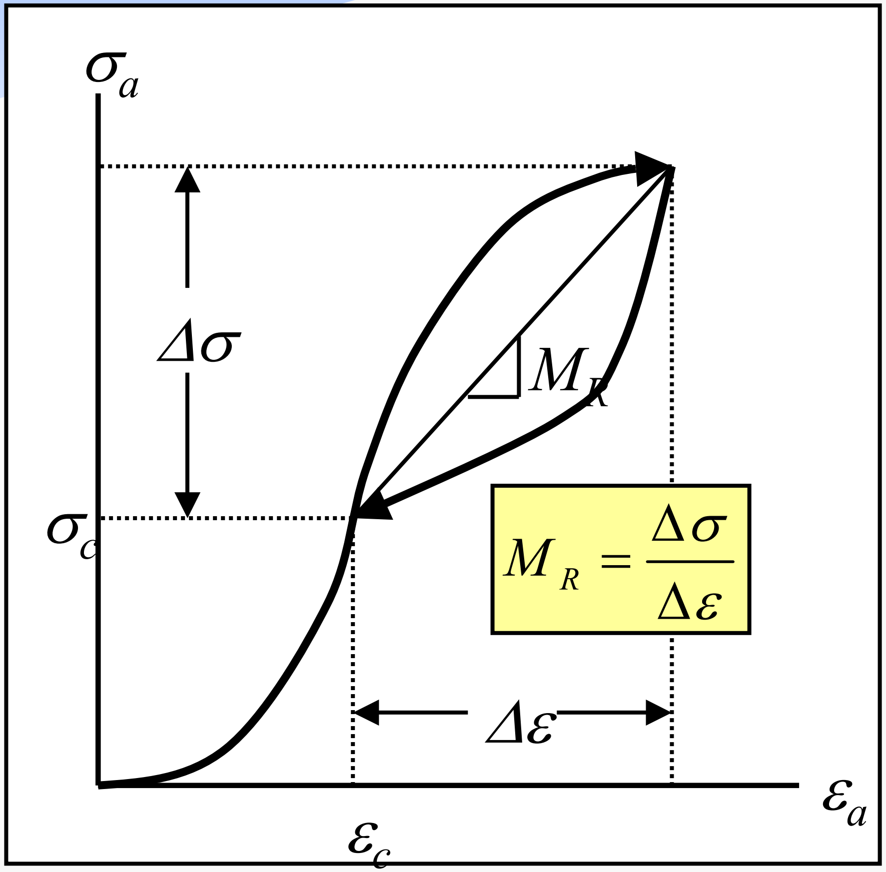


Advanced Asphalt Technologies, LLC

"Engineering Services for the Asphalt Industry"

Unbound Materials

- Resilient Modulus
  - Structural Response
  - Rutting
- Poisson's Ratio Estimated From Modulus



Stress Dependence of M_R

$$M_R = k_1 p_a \left(\frac{\theta}{p_a} \right)^{k_2} \left(\frac{\tau_{oct}}{p_a} + 1 \right)^{k_3}$$

(NCHRP 1-28A)

Bulk (Confining) Stress

- Stiffening term ($k_2 \geq 0$)
- Dominates for coarse granular soils (base, subbase)

Shear (Deviatoric) Stress

- Softening Term ($k_3 \leq 0$)
- Dominates for fine-grained soils (subgrade)

Moisture Effects on M_R

$$M_R = F_{env} M_{Ropt}$$

$$F_{env} = 10^{\left\{ a + \frac{b-a}{1+\exp\left[\ln\left(-\frac{b}{a} \right) + k_m \left(S - S_{opt} \right) \right]} \right\}}$$

S = degree of saturation

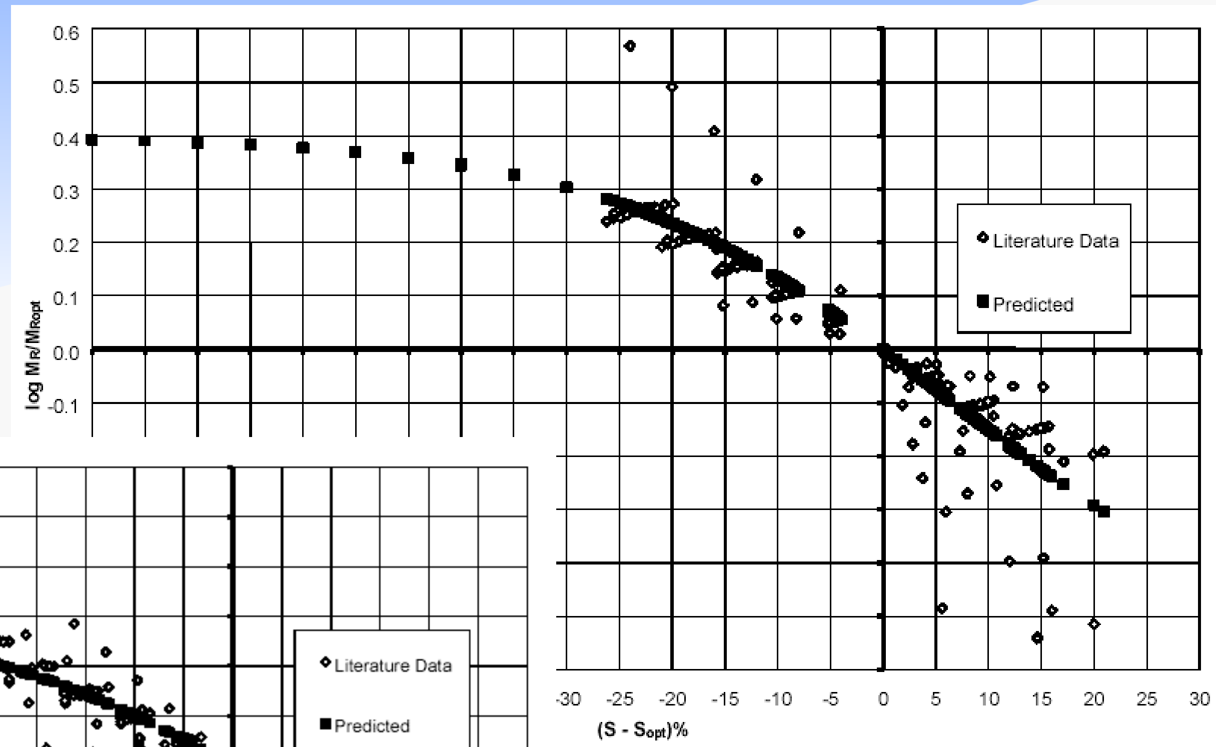
S = saturation at OMC

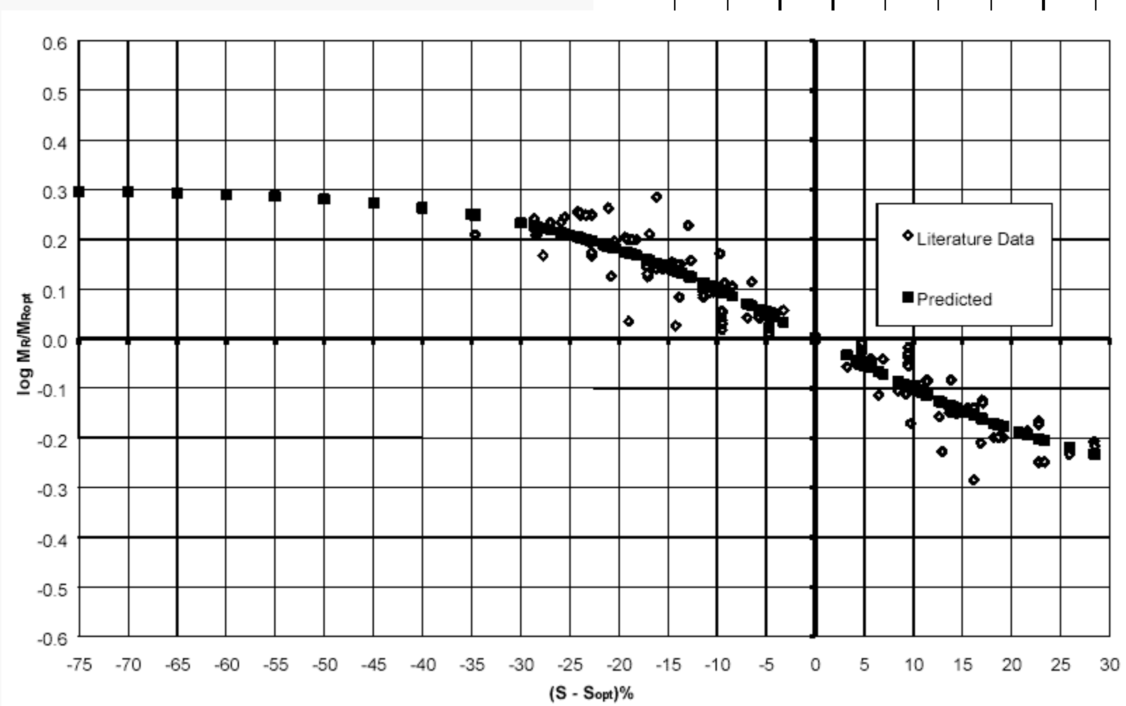
k_m = regression coefficient

a,b = constants (function of soil type)

Moisture Effects on M_R

Fine Grained



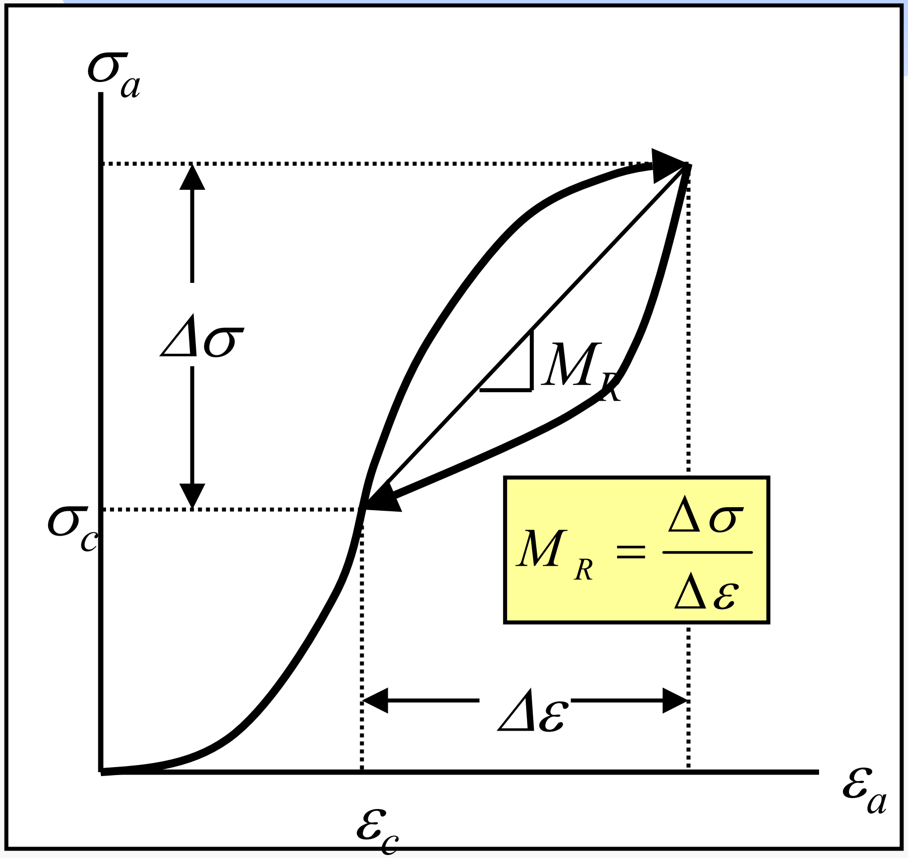


Coarse Grained

Unbound Materials

Input Level	Design Type	Characterization Method
1	New	Laboratory Resilient Modulus (M_R) test
	Rehab	NDT backcalculated M_R
2	New	M_R = f (other properties)
	Rehab	M_R = f (other properties)
3	New	M_R = f (soil classification)
	Rehab	M_R = f (soil classification)

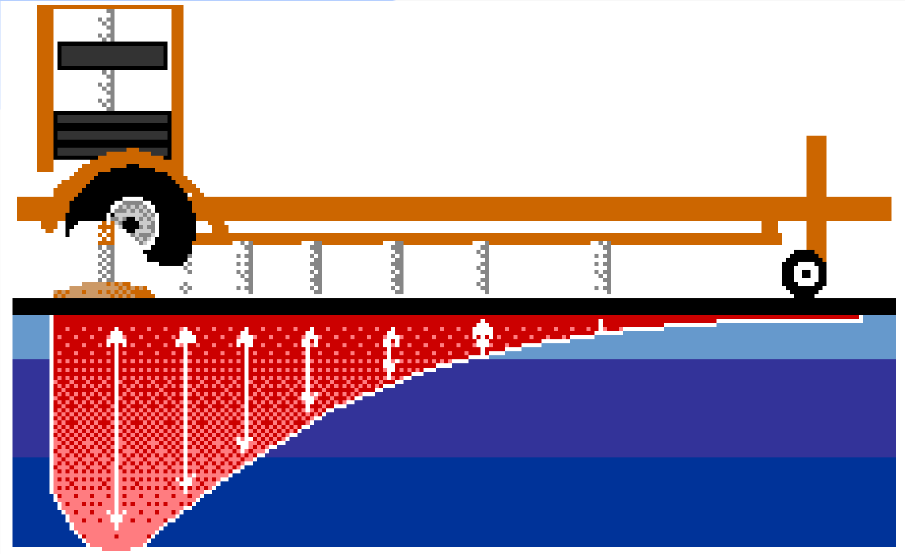
Unbound M_R: Level 1 New



LTPP P-46/AASHTO T307

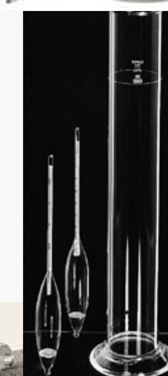
Unbound M_R: Level 1 Rehab

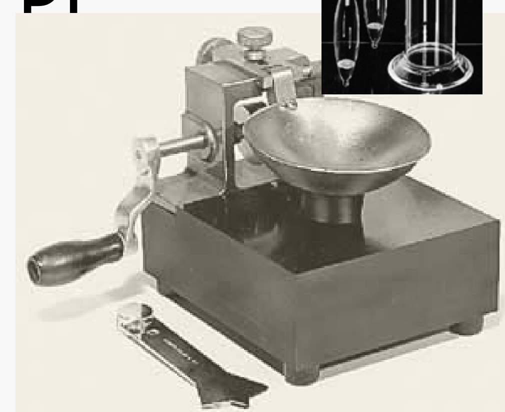
- Backcalculate From FWD
- $E_{DESIGN} = C_F(E_{FWD})$
  - C_F = user defined



Typical values: C_F = 0.40 for subgrade, 0.67 for base/subbase

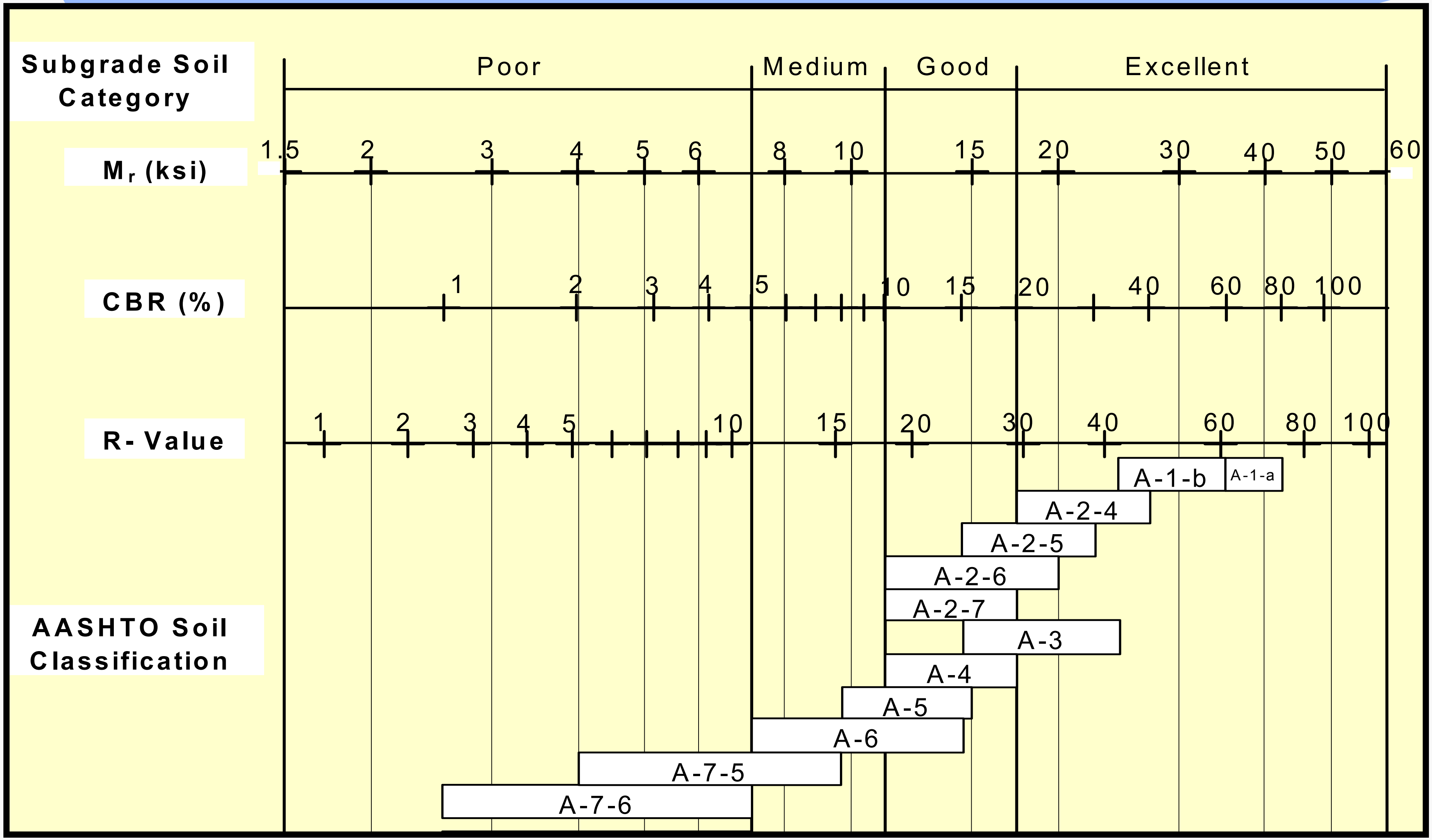
Unbound M_R: Level 2





- Correlations to Other Tests
  - DCP $CBR=(292/PR)^{1.12}$
  - CBR $M_R=2555(CBR)^{0.64}$ psi
  - R-value $M_R = 1155+555(R)$ psi
- Correlations Using Gradation and PI
- Conversion of Layer Coefficient
  - $M_R=30000(a_i/0.14)^3$ psi

Unbound M_R: Level 3

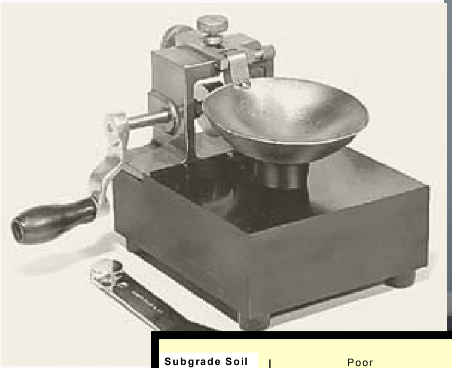


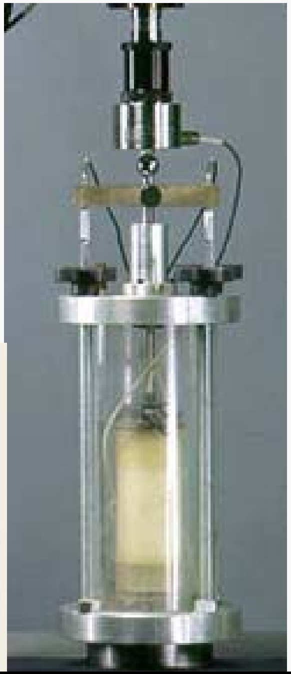
Other Materials

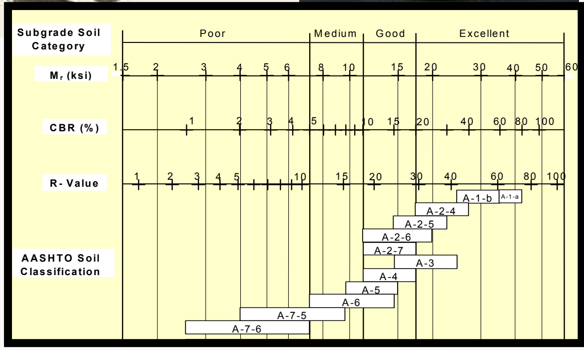
- Portland Cement Concrete
- Cementitiously Stabilized Materials
  - CTB
  - Soil Cement
- PCC Slabs
  - Intact
  - Rubbilized

Summary

- Modulus is Key Material Input Parameter
- Hierarchical Input Levels
  - Level 1: Measured
  - Level 2: Correlations
  - Level 3: Defaults
- Agency Choice



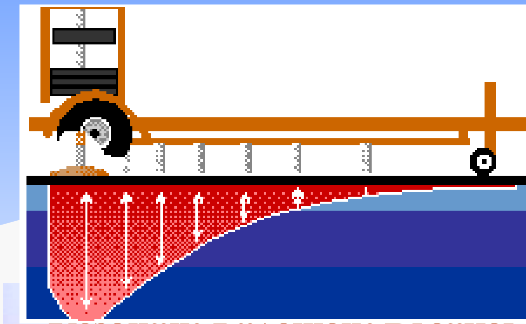




Advanced Asphalt Technologies, LLC

"Engineering Services for the Asphalt Industry"

Summary



- New and Rehabilitation
- Load Influences Addressed
  - Rate for AC
  - Stress State for Unbound
- Environmental Influences Addressed
  - Temperature in AC
  - Moisture in Unbound

"Engineering Services for the Asphalt Industry"

Questions?

Advanced Asphalt Technologies, LLC

"Engineering Services for the Asphalt Industry"