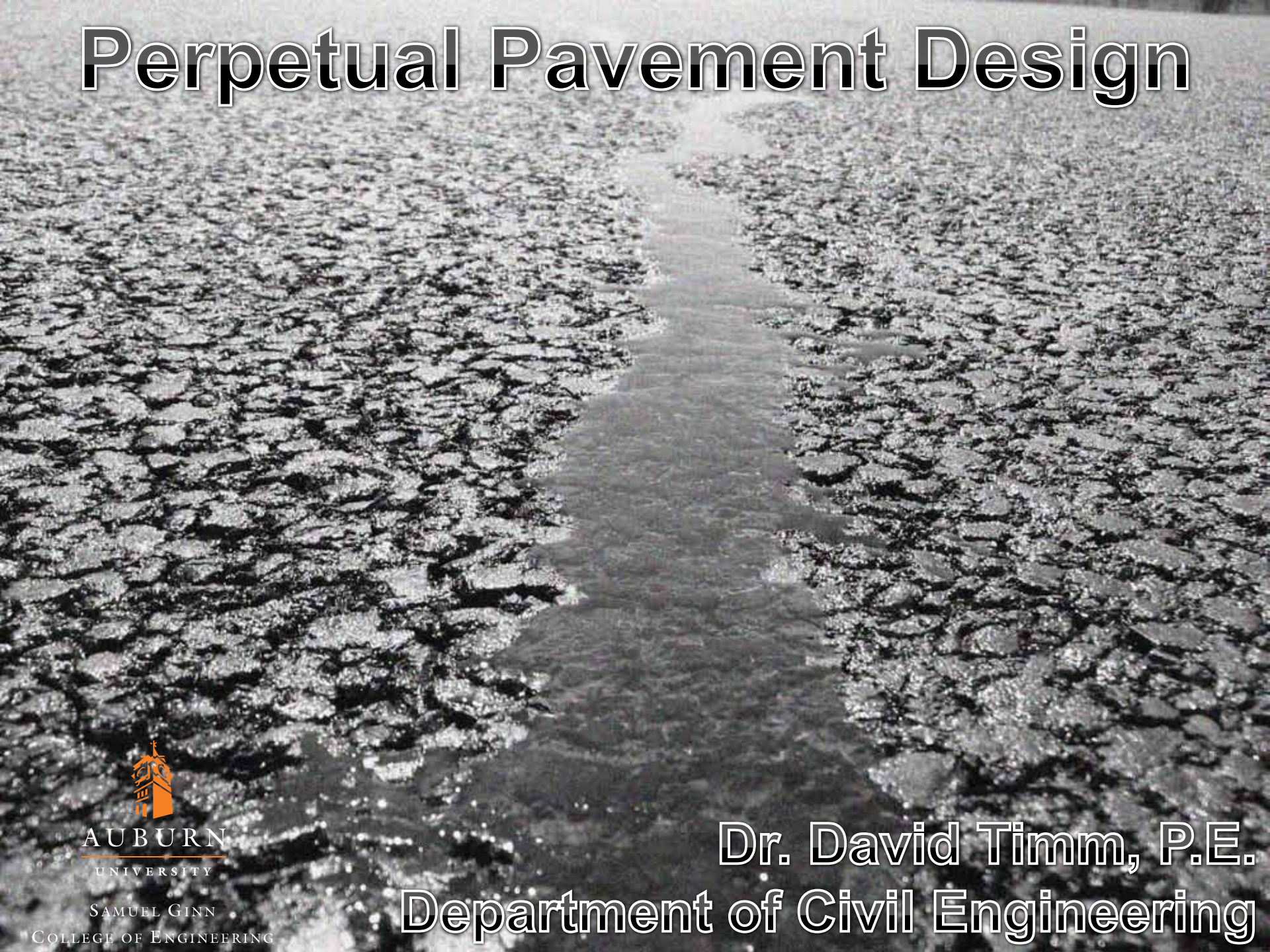
Perpetual Pavement Design



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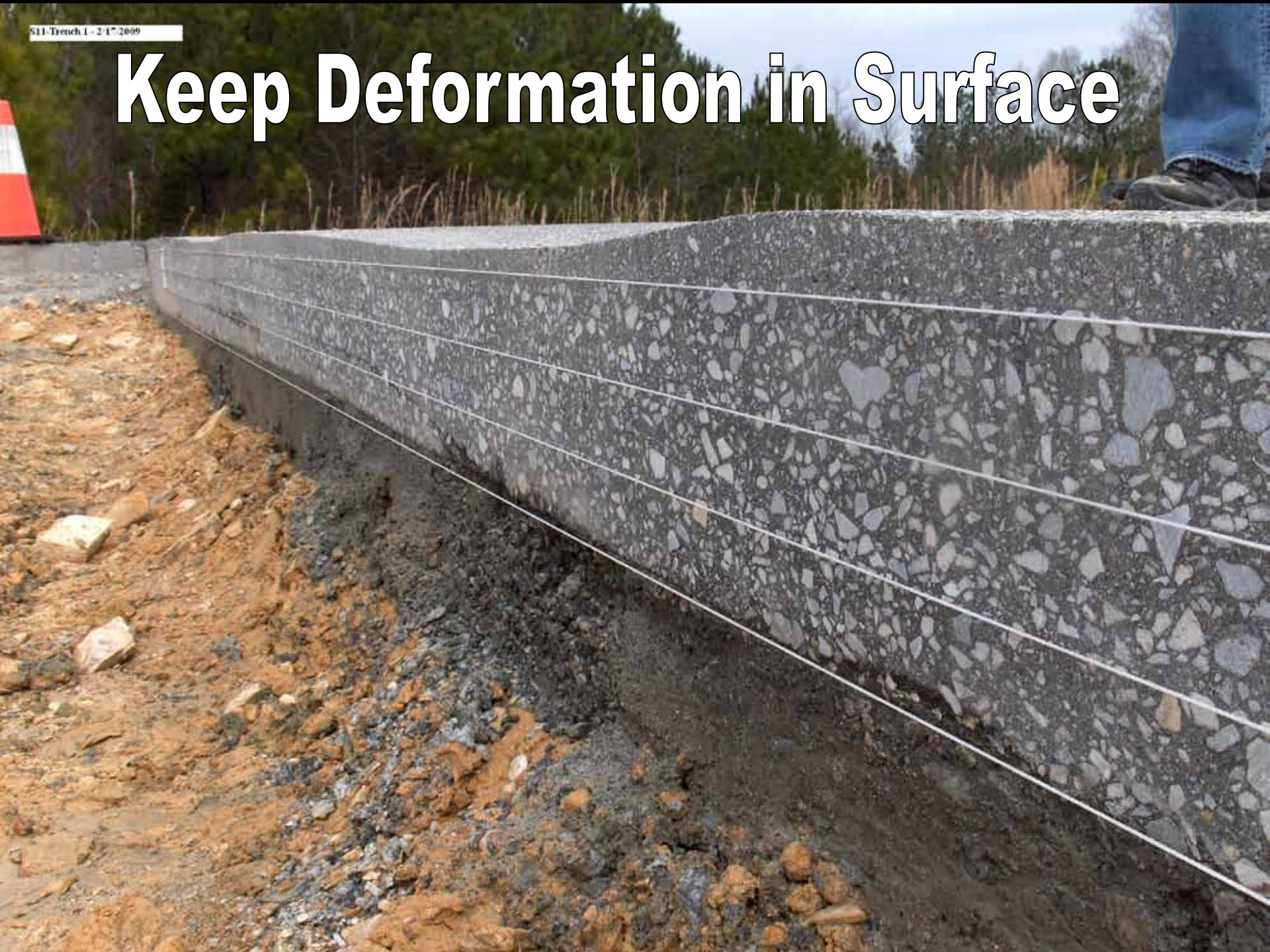
UNIVERSITY
SAMUEL GINN
COLLEGE OF ENGINEERING

Dr. David Timm, P.E.
Department of Civil Engineering

What is a Perpetual Pavement?

- No deep structural distress


S11-Trench 1 - 2/17/2009
Keep Deformation in Surface

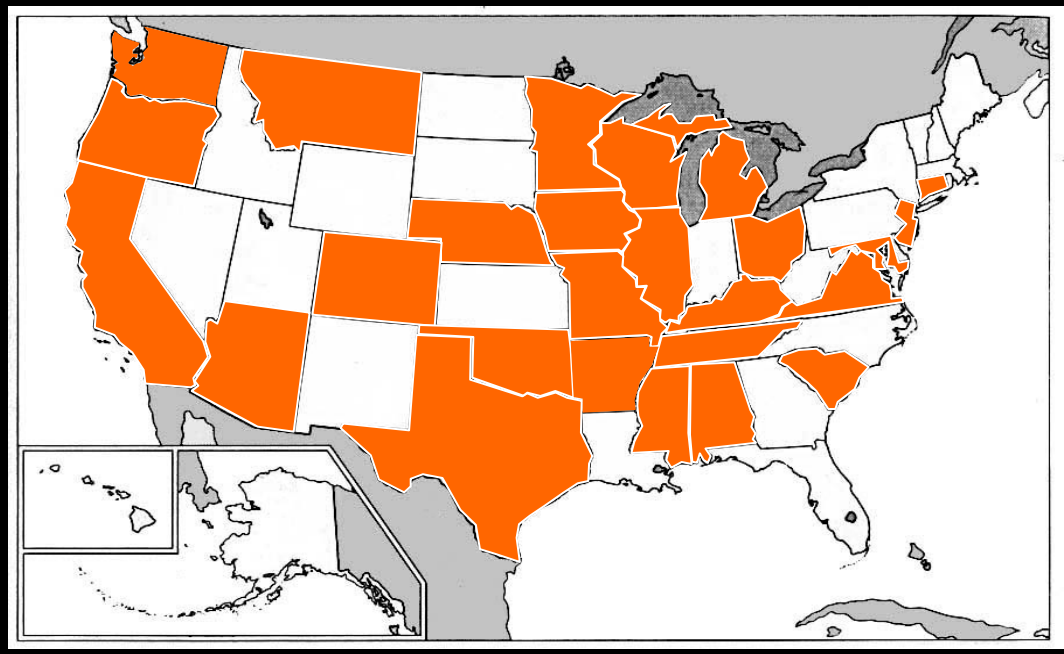
Limit Cracking to top-down

Goal of Perpetual Pavement Design

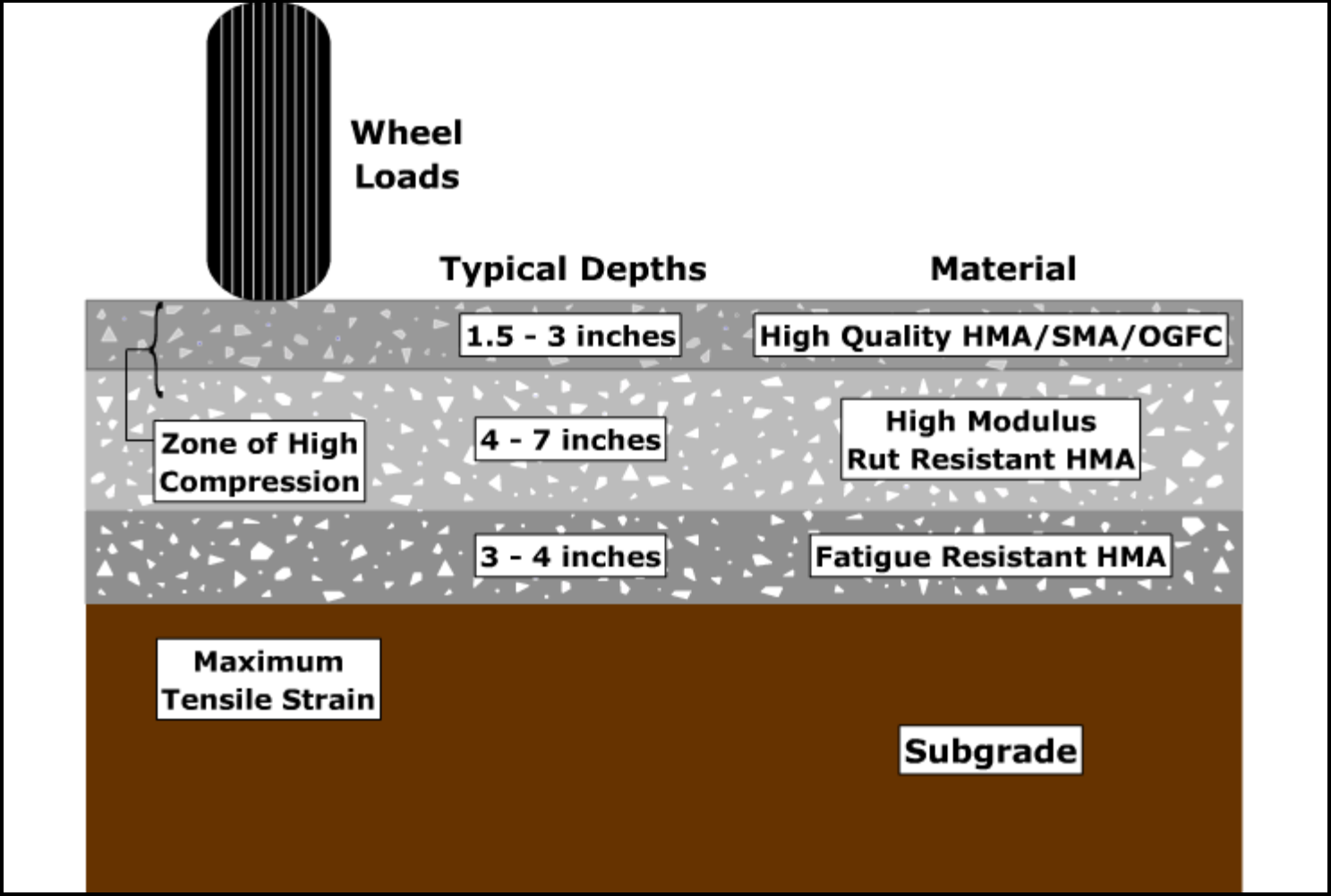
- Design so there are no deep structural distresses
  - Bottom up fatigue cracking
  - Structural rutting
- All distresses can be quickly remedied from surface
- Result in a structure with ‘Perpetual’ or ‘Long Life’

Do Perpetual Pavements Exist?

- Perpetual Pavements are NOT a new concept
  - Full-depth
  - Mill and inlay
  - Deep strength
- Perpetual Pavement Award
  - 35+ years
  - No structural failures
  - 13+ year rehab interval

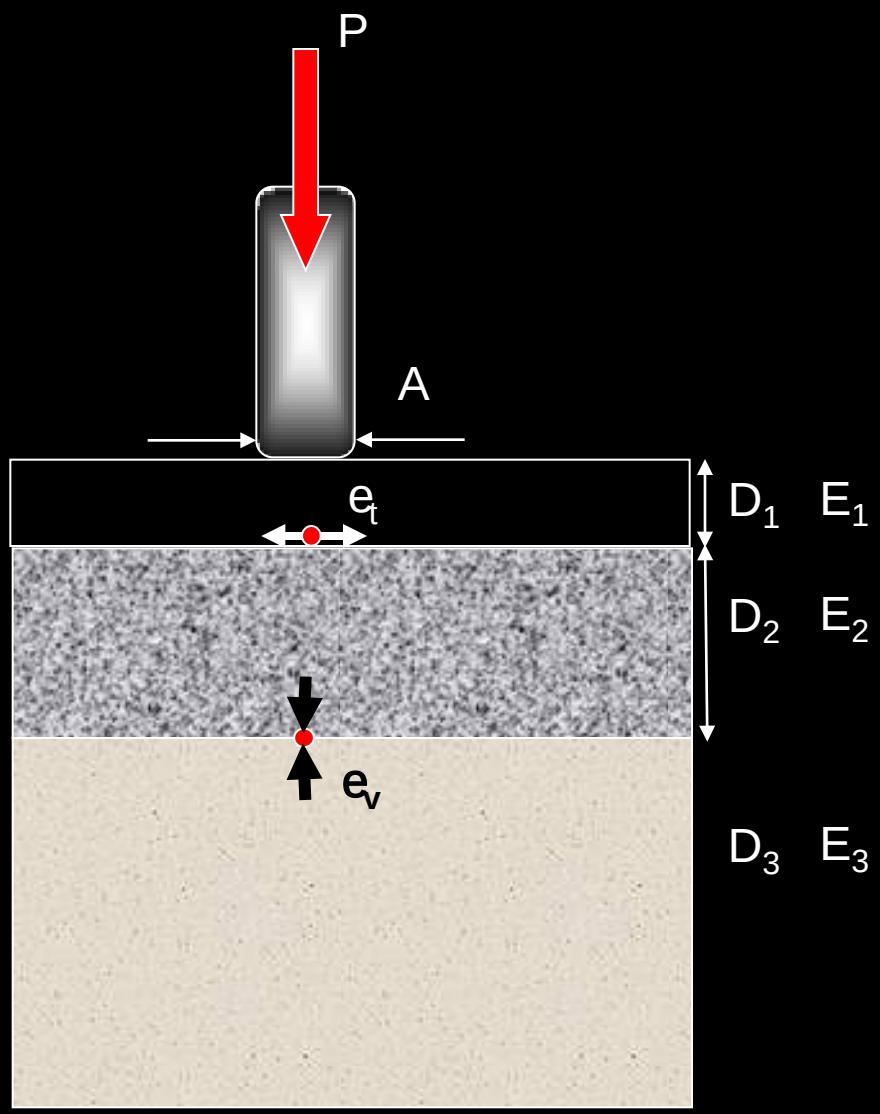


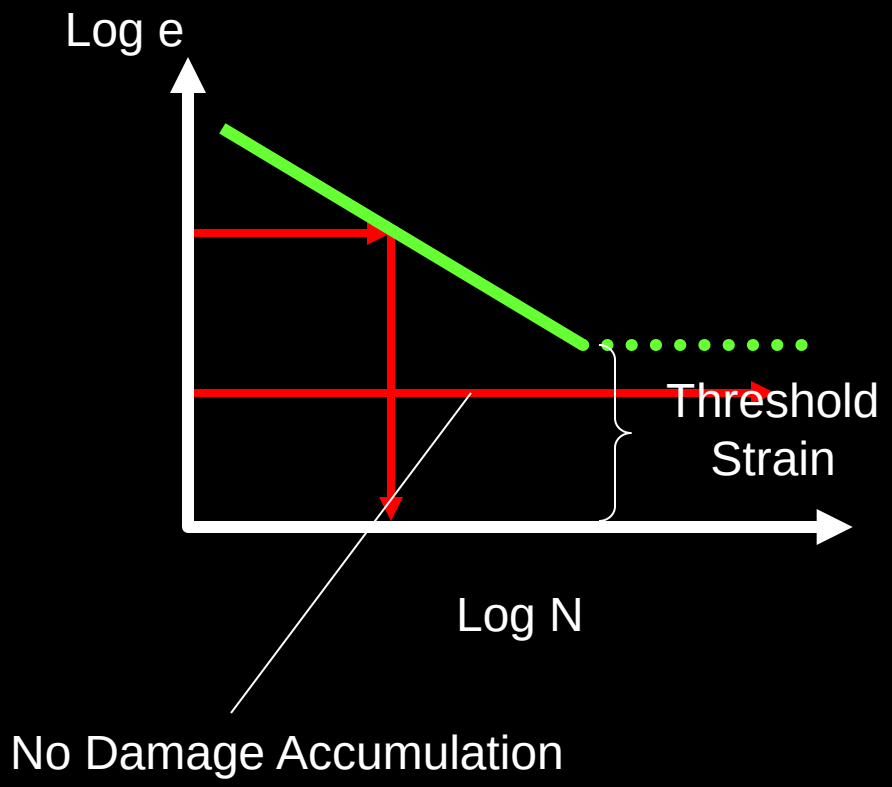
Designing Perpetual Pavements

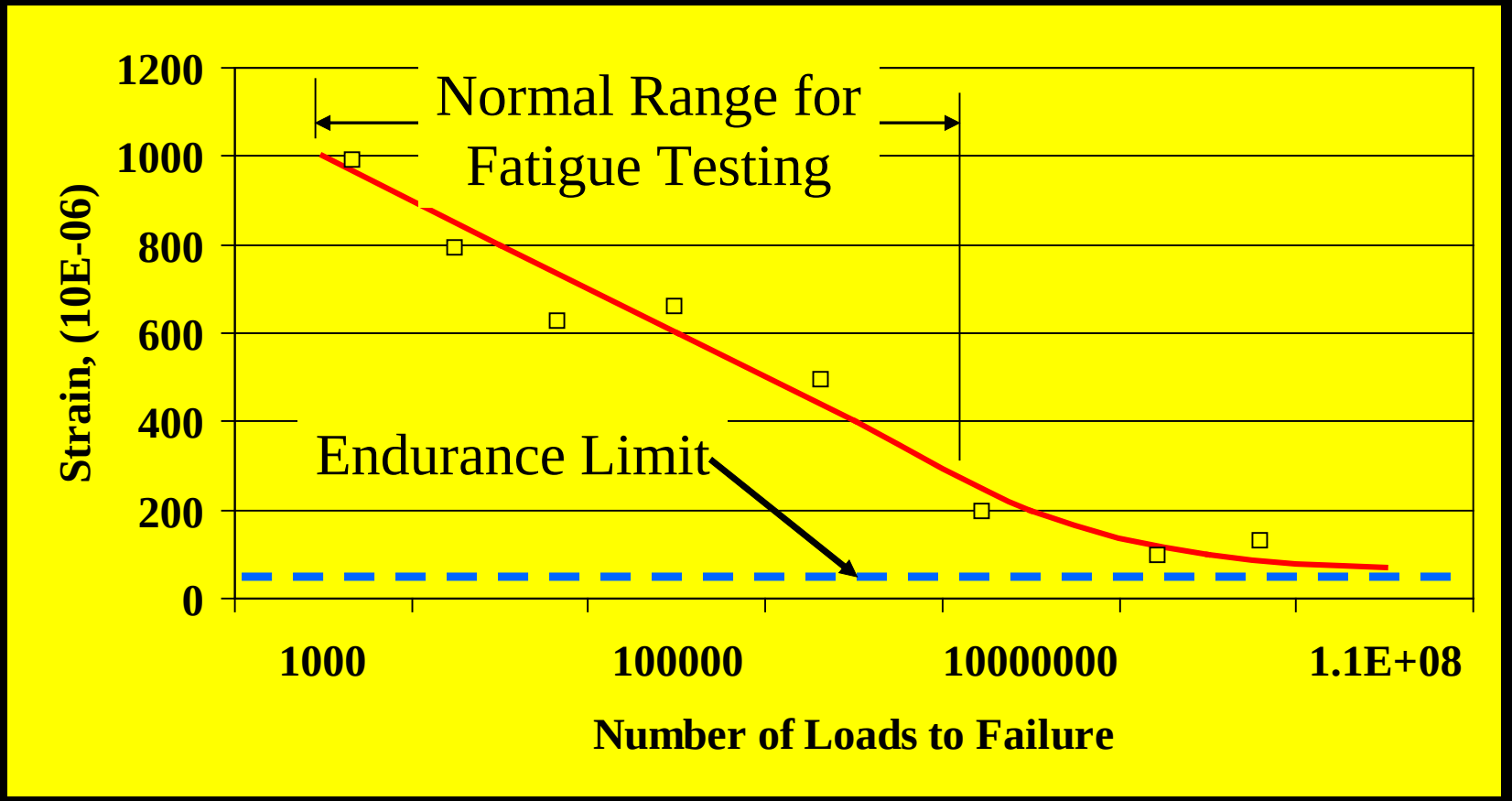


Newcomb, 2001

M-E Perpetual Pavement Design







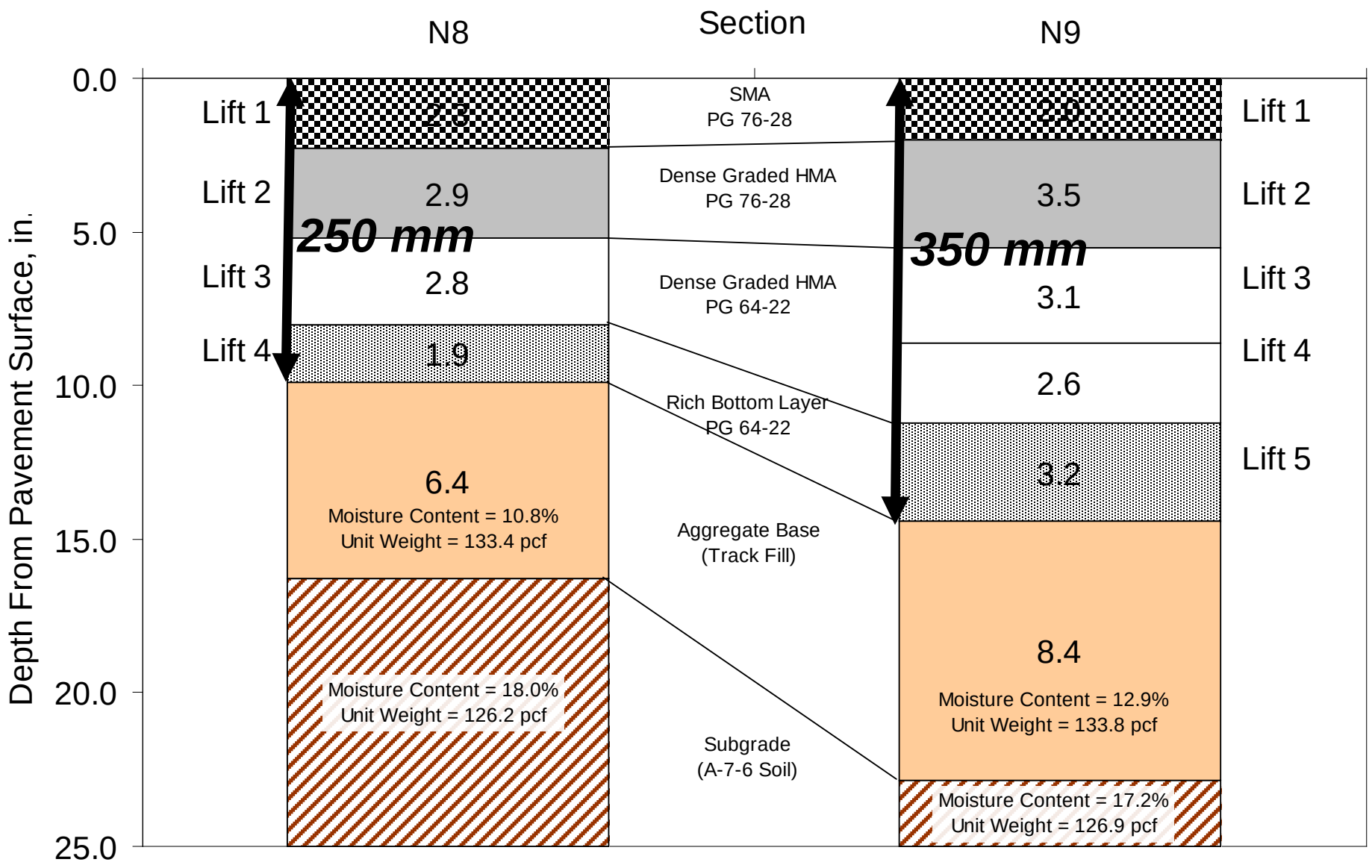
Normal Fatigue Testing Results Versus Endurance Limit Testing

What is the Endurance Limit for HMA?

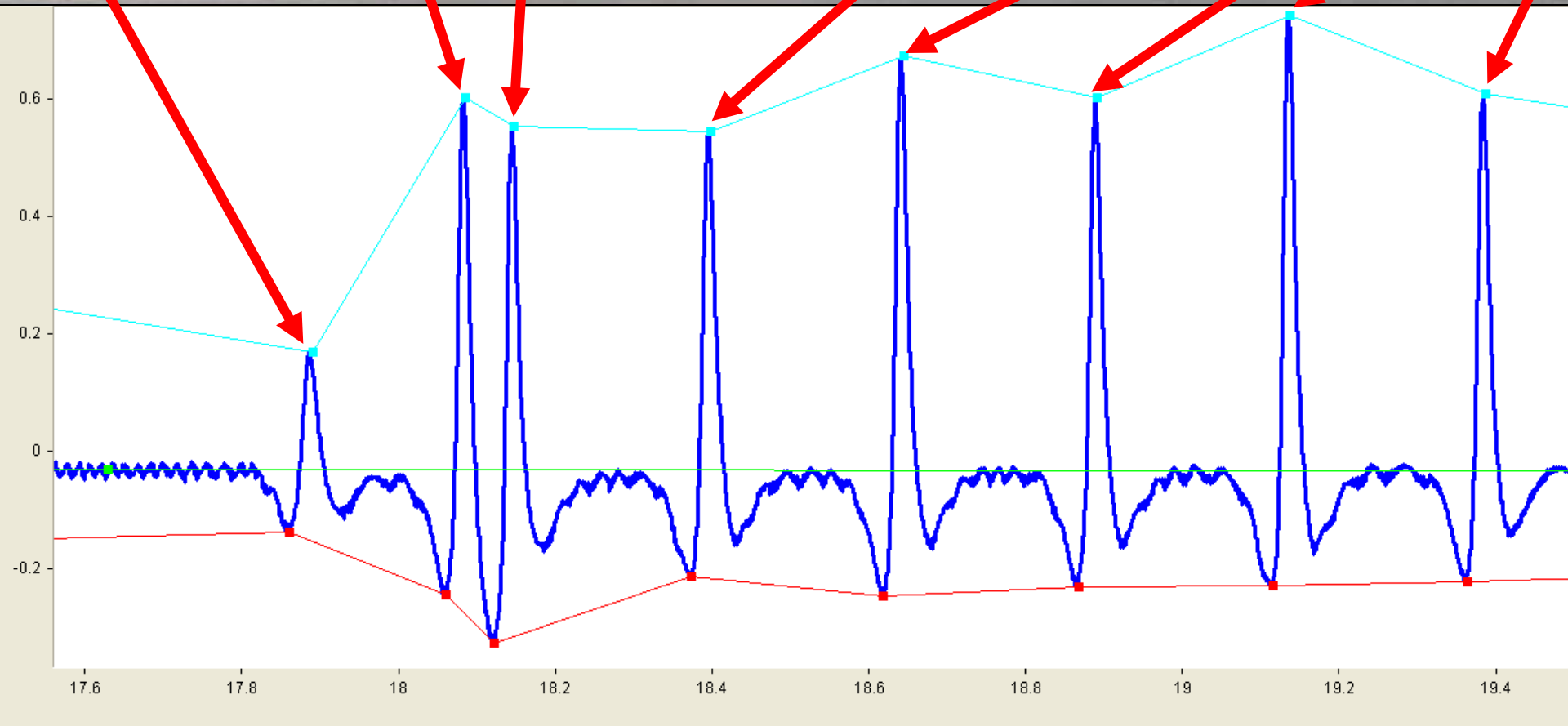
- 1972 – Monismith estimates about 70 με
- 2001 – I-710 designed at 70 με
- 2002 – 70 με used by APA
- 2007 – NCHRP 9-38 Lab Study
  - 100 με for unmod binders
  - 250 με for mod binders
  - More severe than field
- 2007 – MEPDG uses 100 to 250 με
- 2008 – Field measurements show higher strains

Field Strain - NCAT Test Track

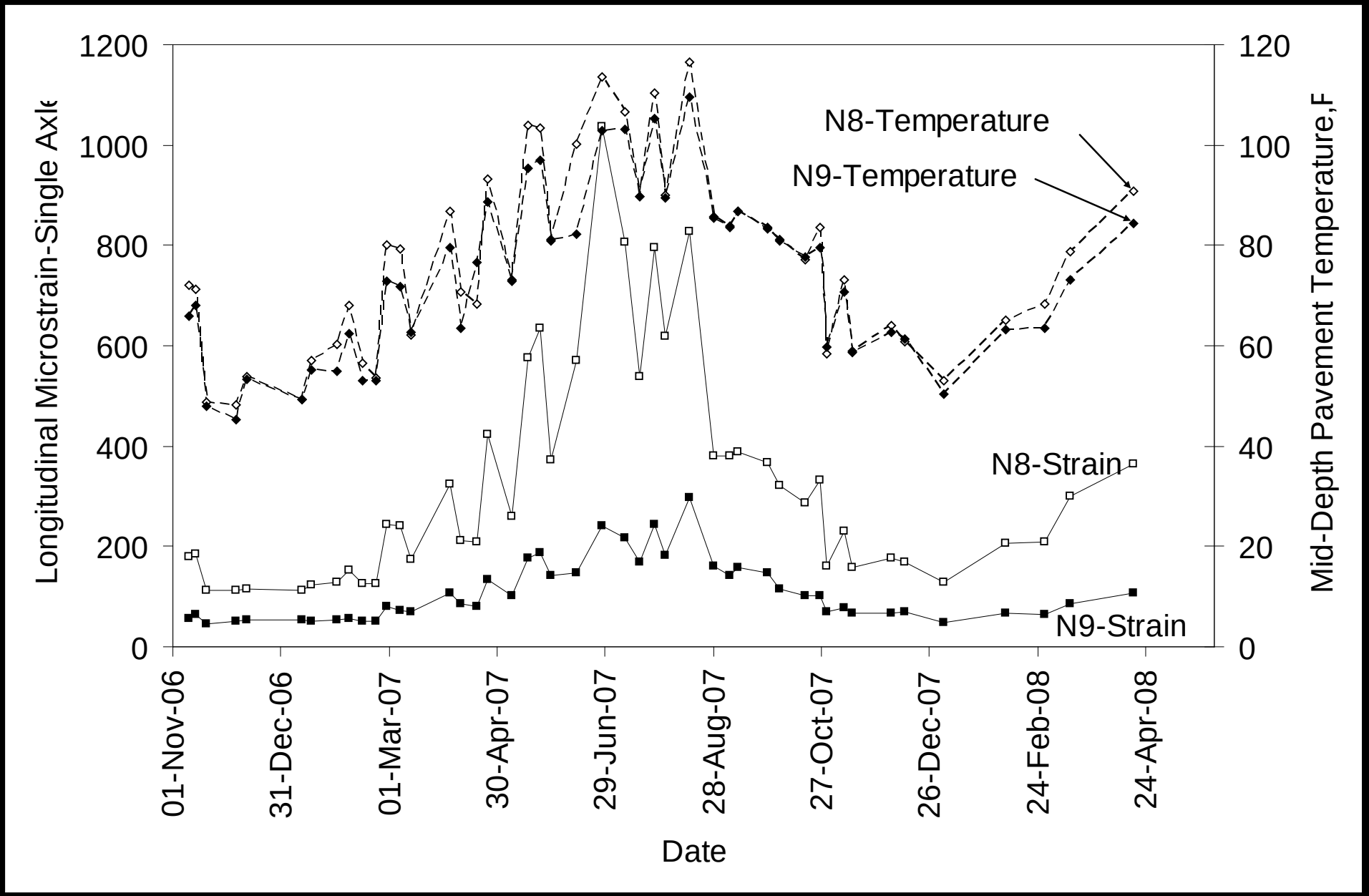
N8 and N9


N8
Section
N9
Depth From Pavement Surface, in.
0.0
5.0
10.0
15.0
20.0
25.0
Lift 1
Lift 2
Lift 3
Lift 4
Lift 5
2.3
2.9
2.8
1.9
6.4
Moisture Content = 10.8%
Unit Weight = 133.4 pcf
Moisture Content = 18.0%
Unit Weight = 126.2 pcf
250 mm
SMA
PG 76-28
Dense Graded HMA
PG 76-28
Dense Graded HMA
PG 64-22
Rich Bottom Layer
PG 64-22
Aggregate Base
(Track Fill)
Subgrade
(A-7-6 Soil)
2.6
3.5
3.1
2.6
3.2
8.4
Moisture Content = 12.9%
Unit Weight = 133.8 pcf
Moisture Content = 17.2%
Unit Weight = 126.9 pcf
350 mm

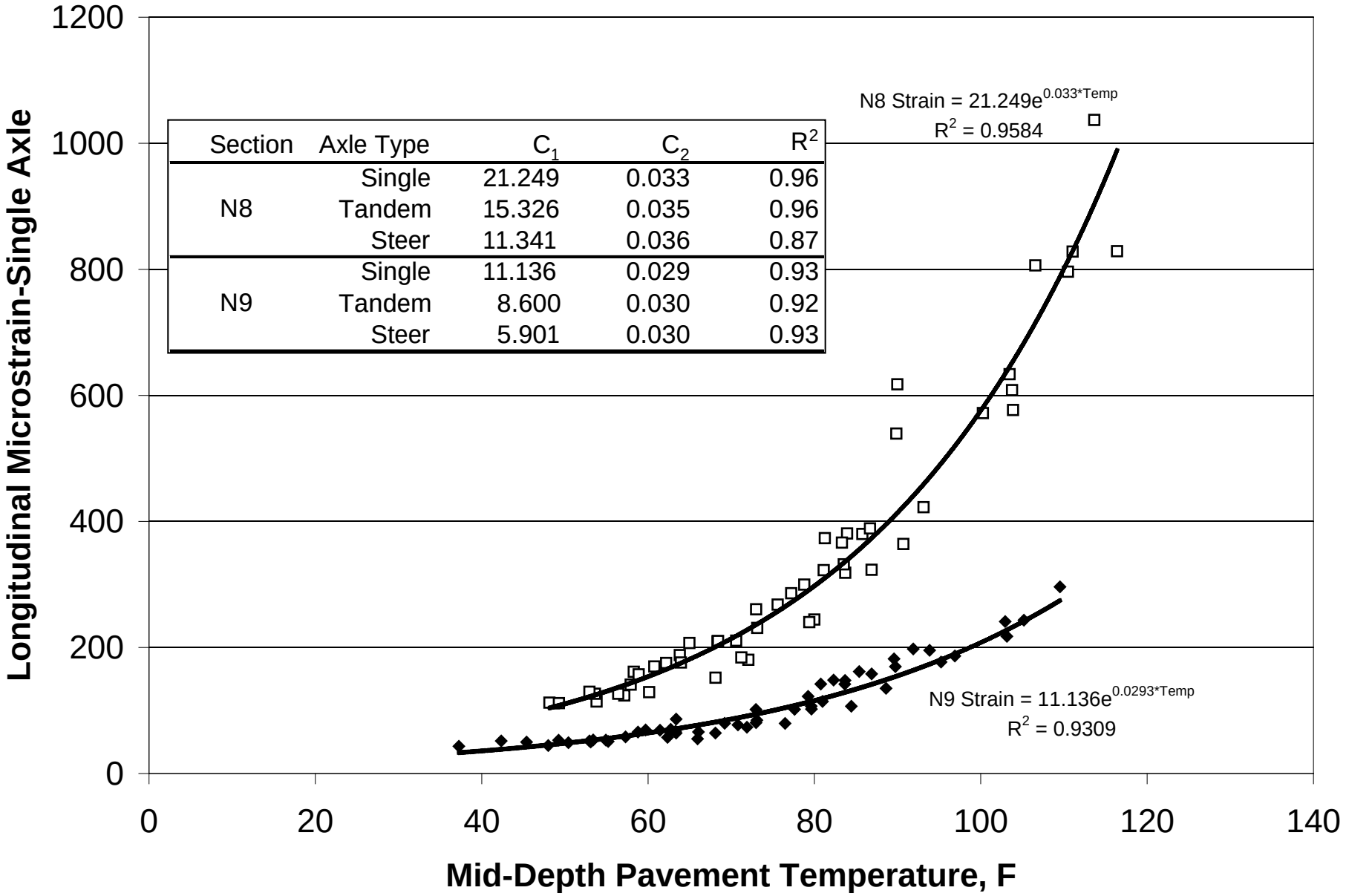
Strain Measurements



Strain and Temperature

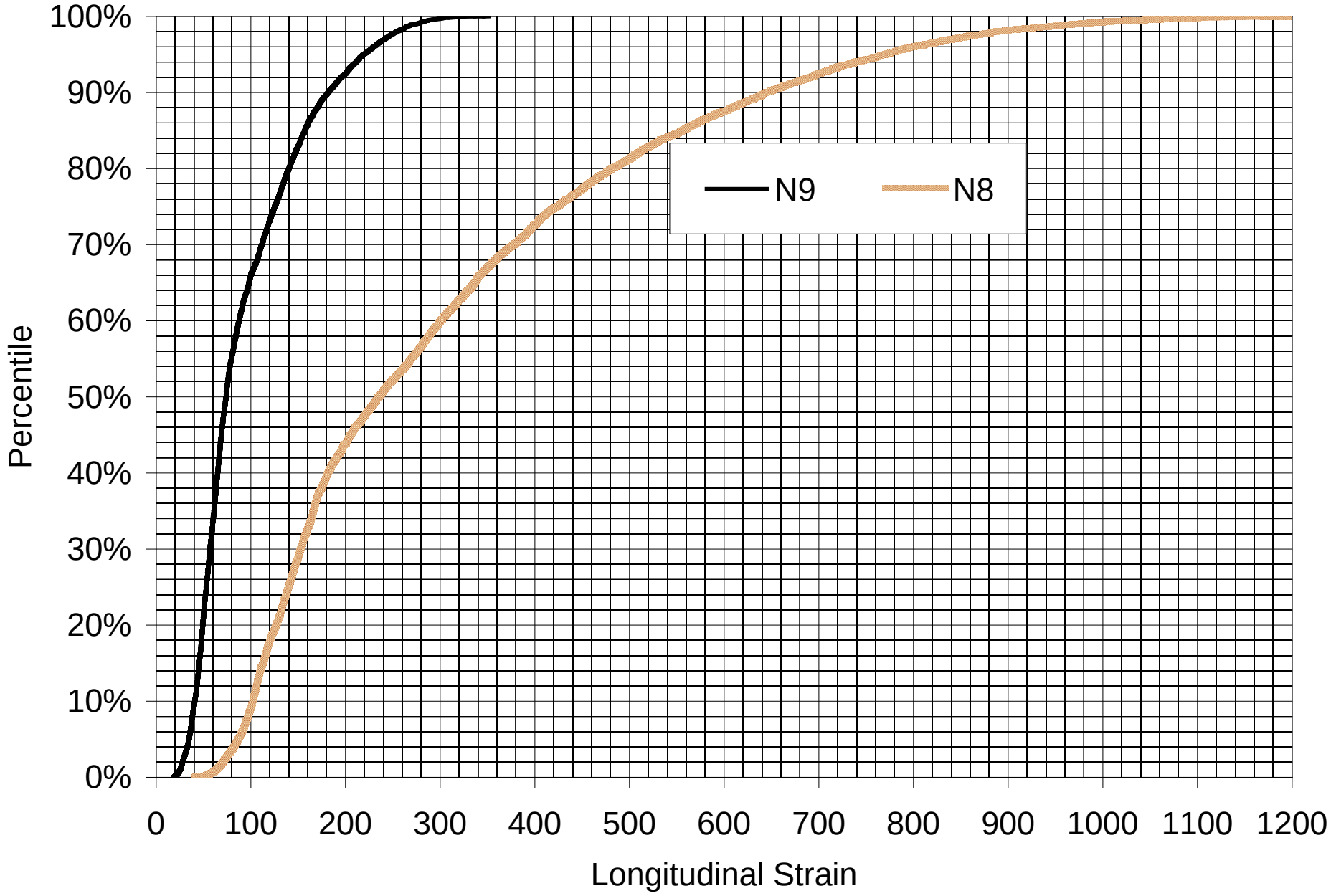


Strain vs. Temperature



Section	Axle Type	C_1	C_2	R^2
N8	Single	21.249	0.033	0.96
	Tandem	15.326	0.035	0.96
	Steer	11.341	0.036	0.87
N9	Single	11.136	0.029	0.93
	Tandem	8.600	0.030	0.92
	Steer	5.901	0.030	0.93

Strain Distributions

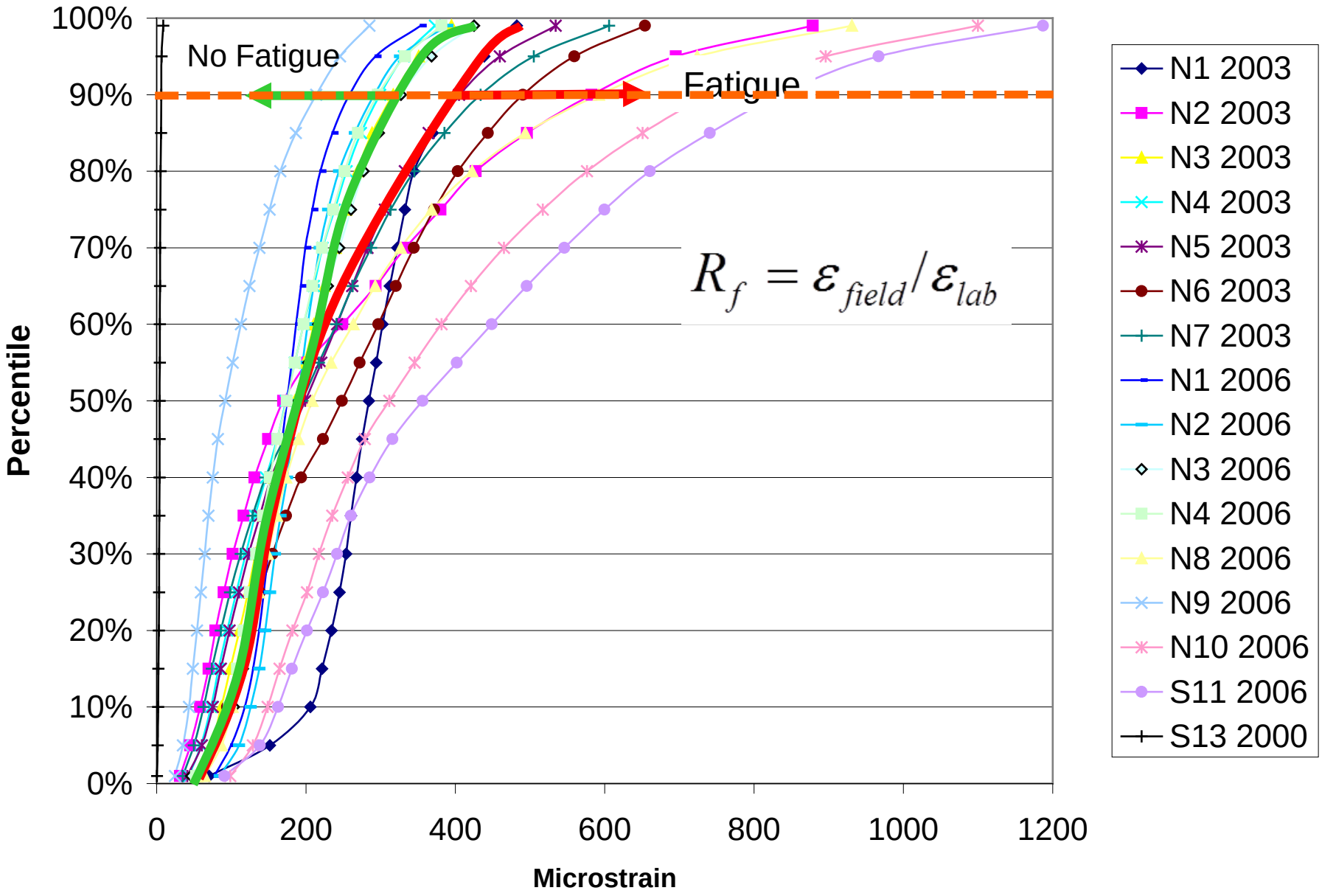


End Result

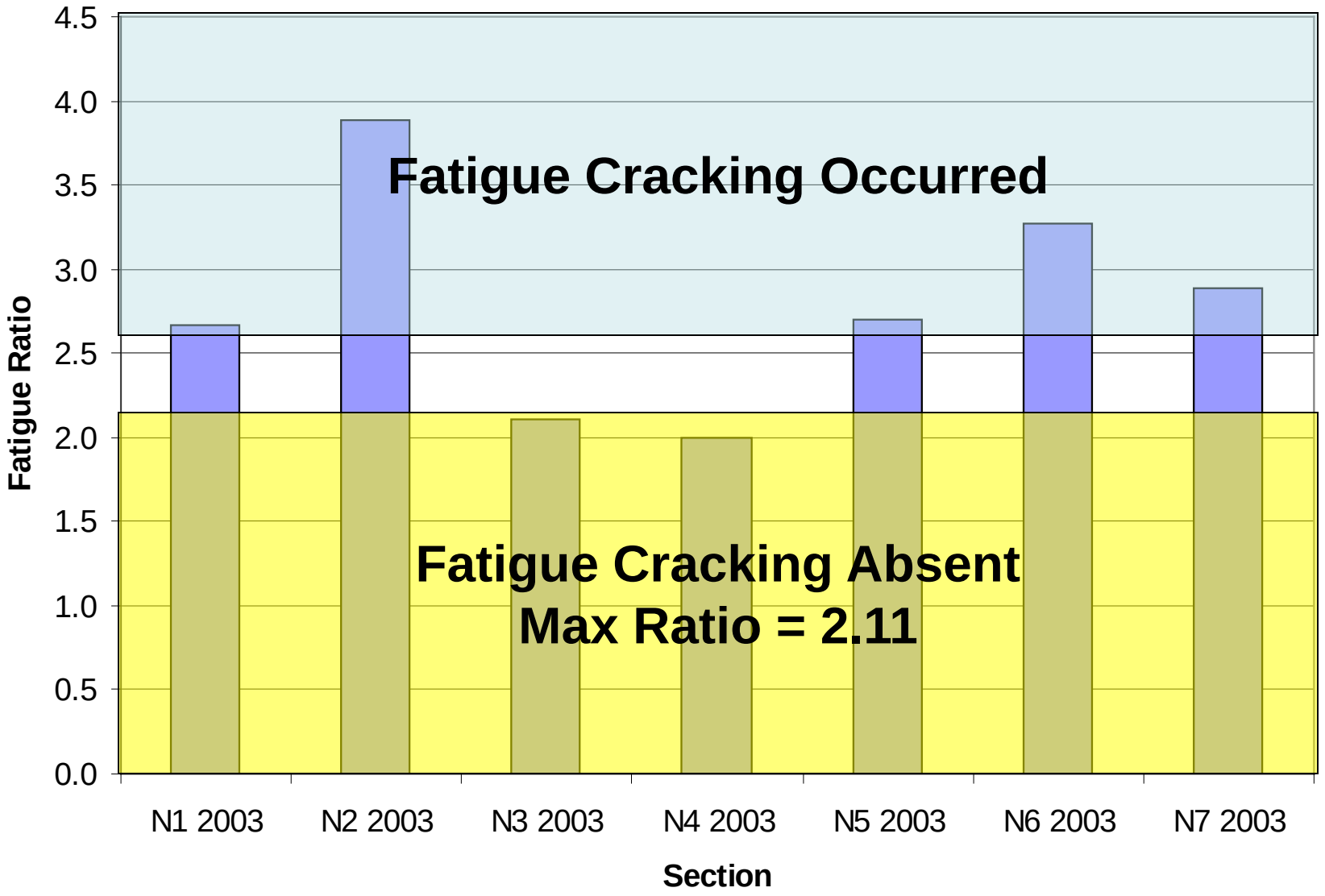

TEST SECTION
NUMBER N-9
OKLAHOMA

TEST SECTION
NUMBER N-8
OKLAHOMA

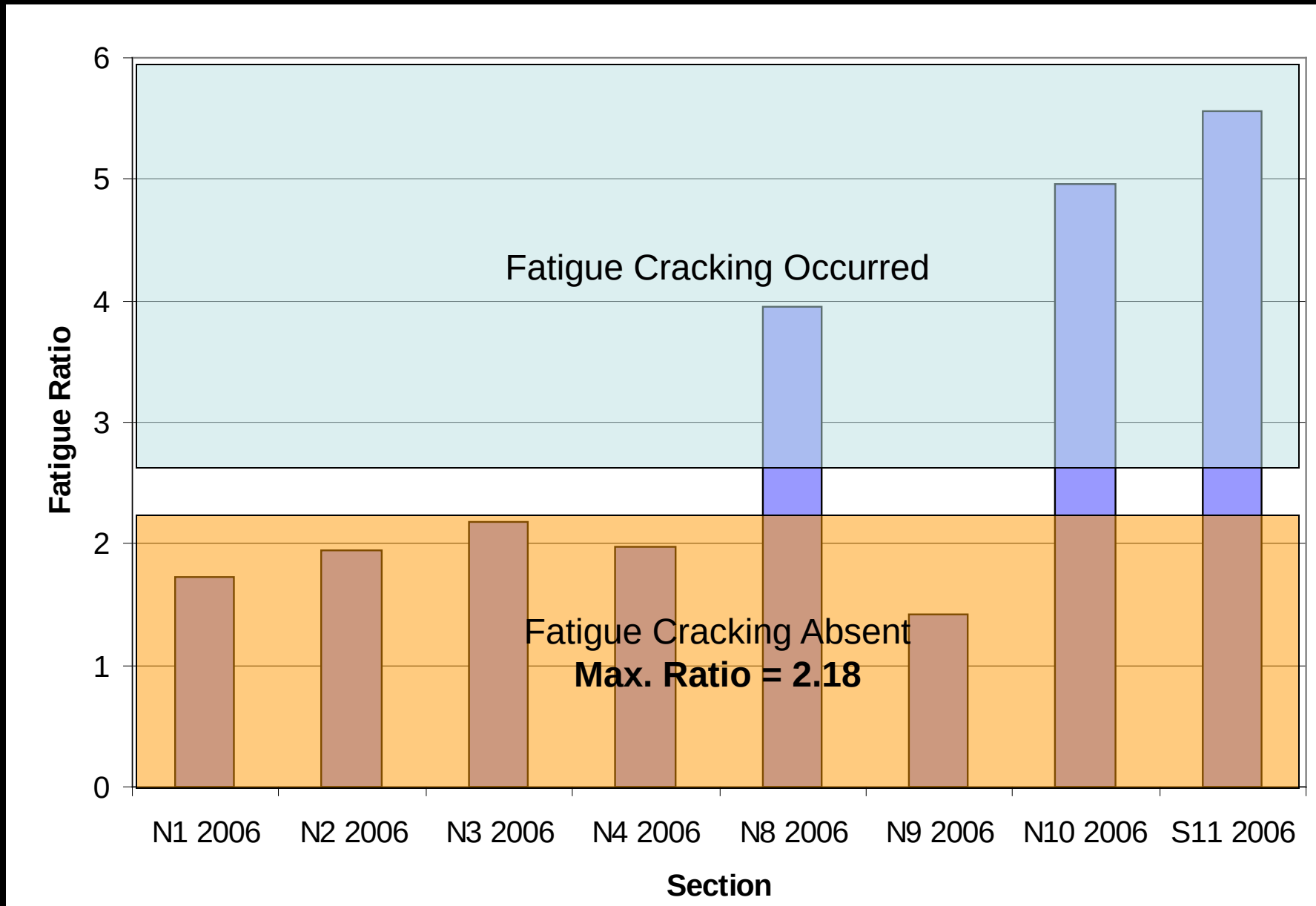
NCAT Test Track Results



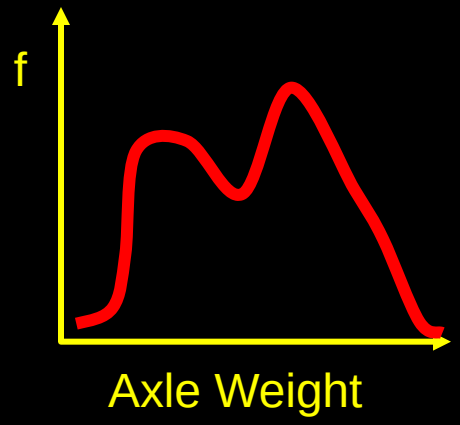
2003 Test Sections

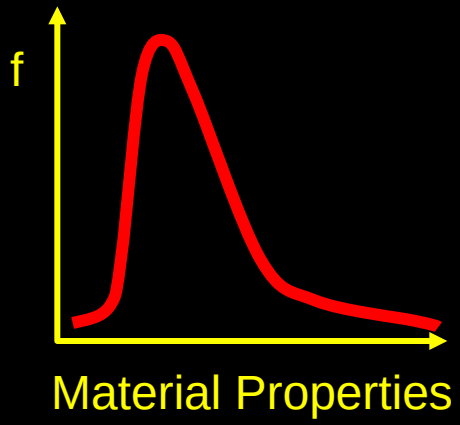


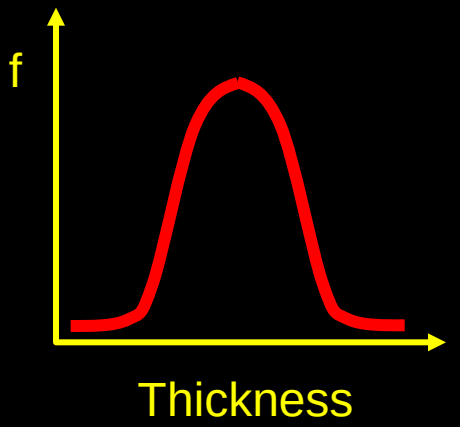
2006 Test Sections



Probabilistic Design – Monte Carlo Simulation

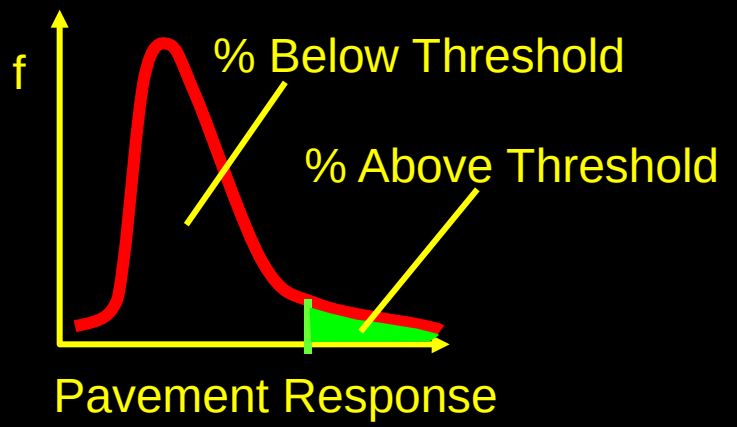






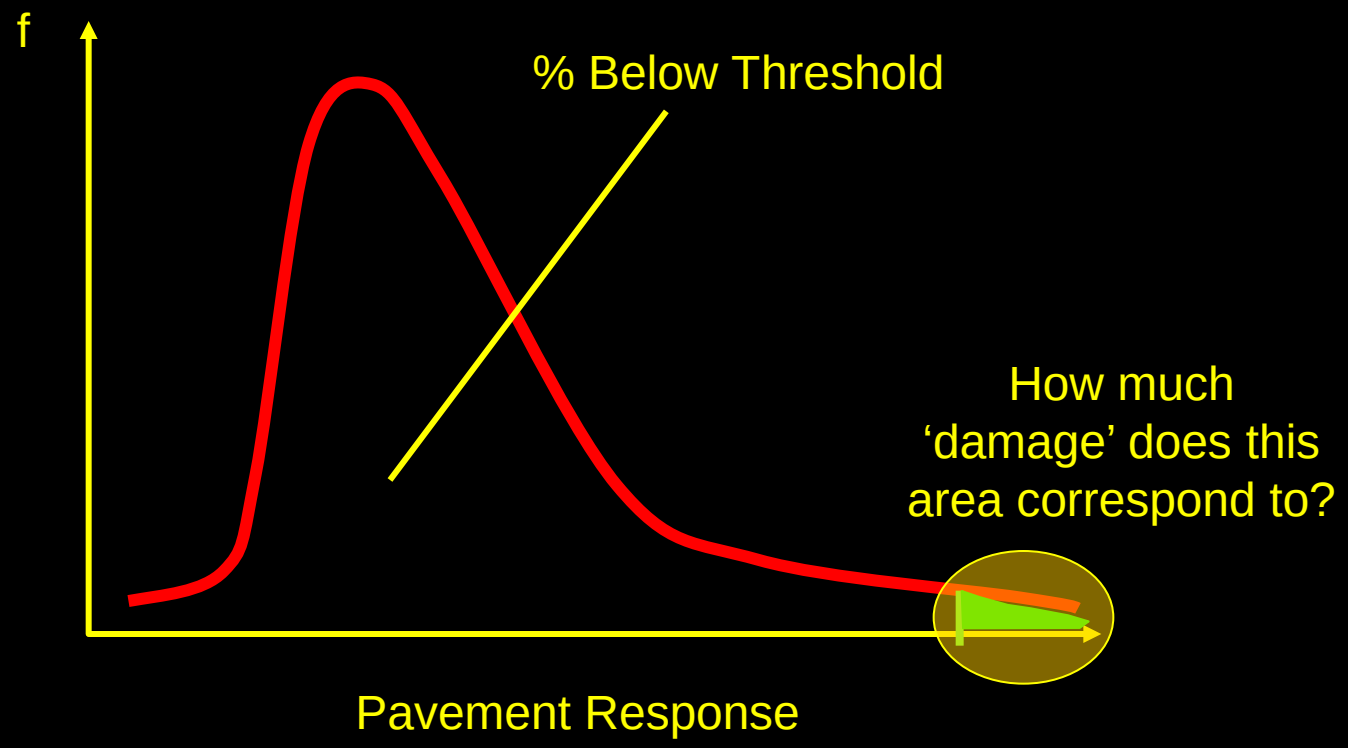
Monte Carlo Random Sampling

Mechanistic Model



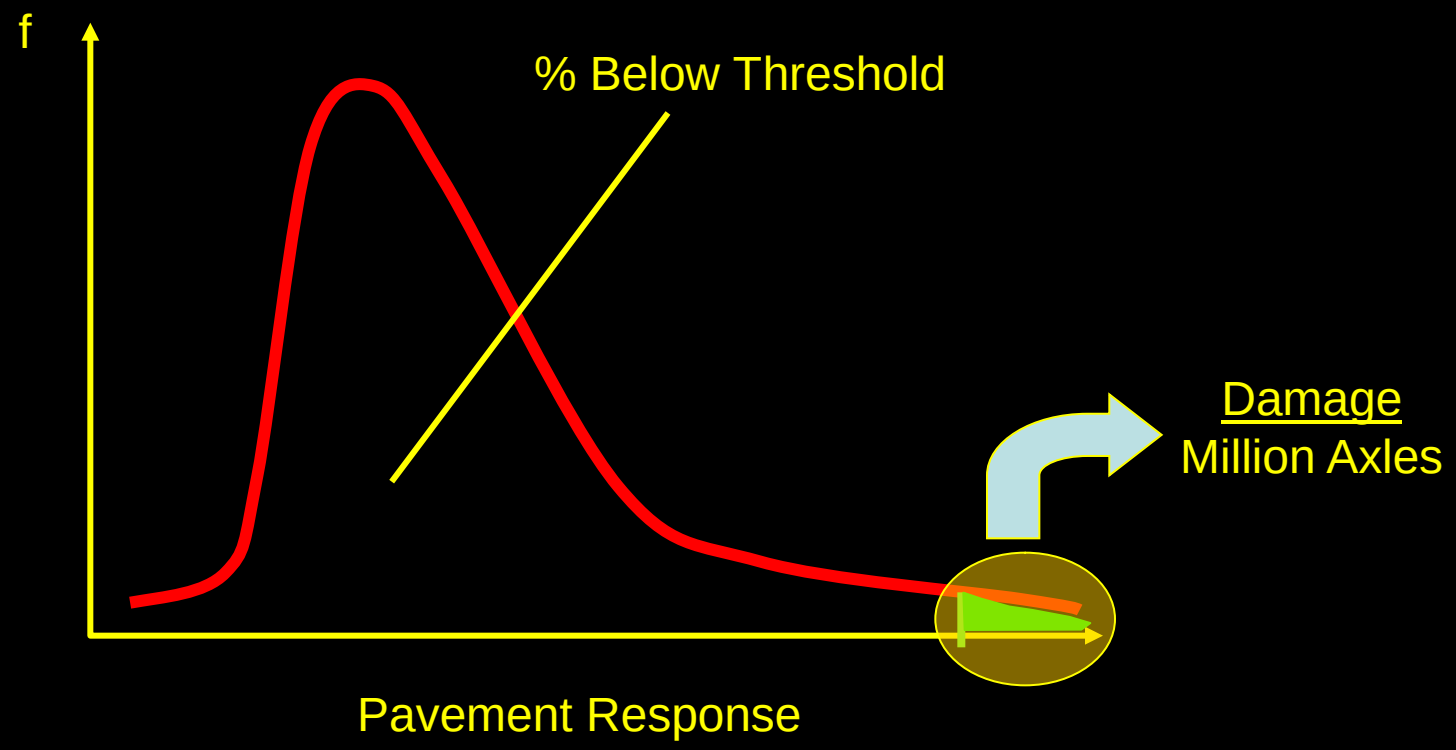
% Below Threshold

- Design should have high % below threshold



‘Damage Computation’

- For responses exceeding threshold, compute N using transfer function
  - User defined
- Calculate damage accumulation rate
  - Damage / Maxles

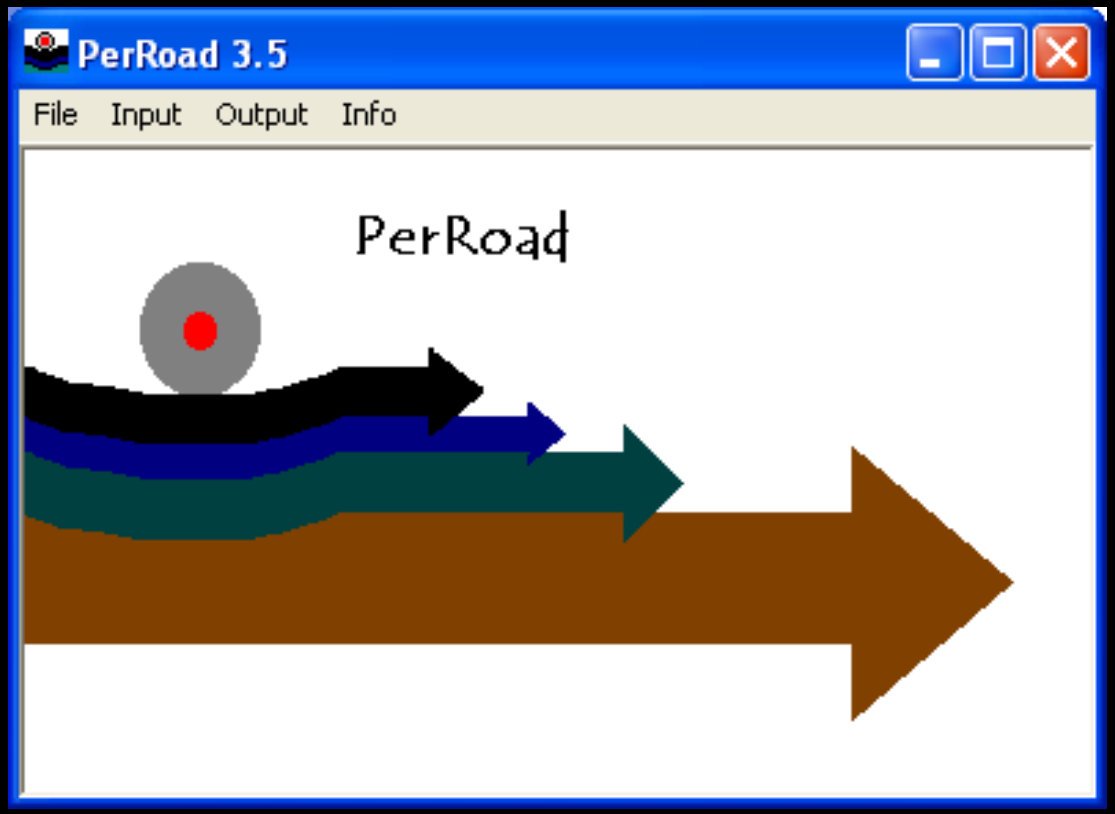


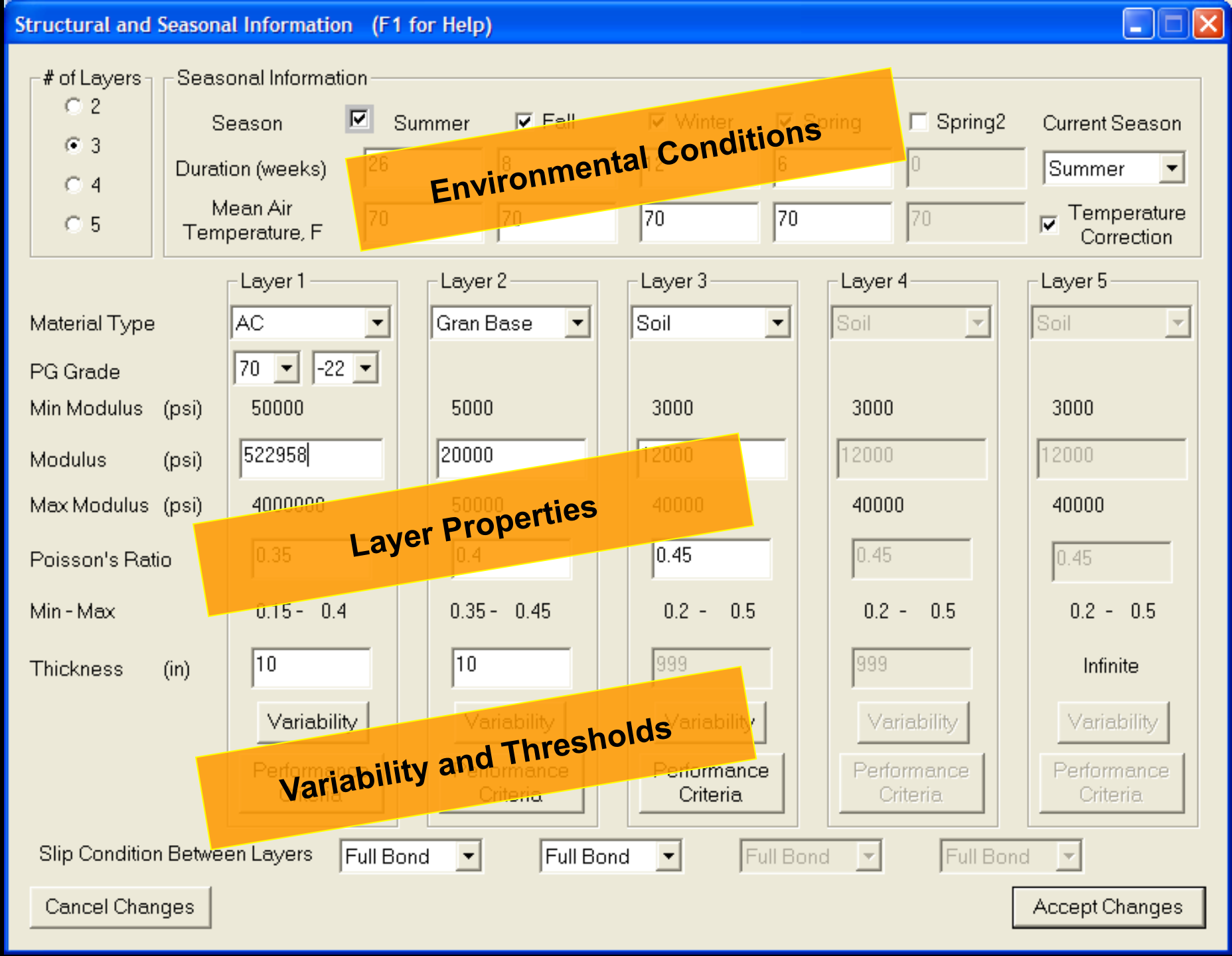
Estimated Long Life

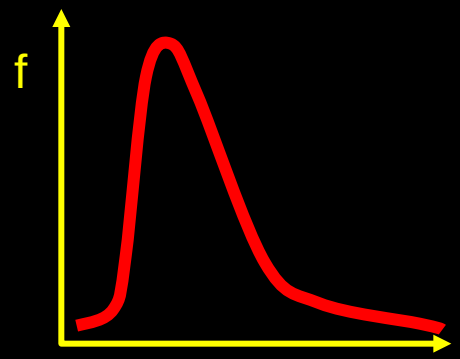
- Convert damage rate into an estimated time
  - Use traffic volume and growth
  - Calculate when damage = 0.1

PerRoad 3.5

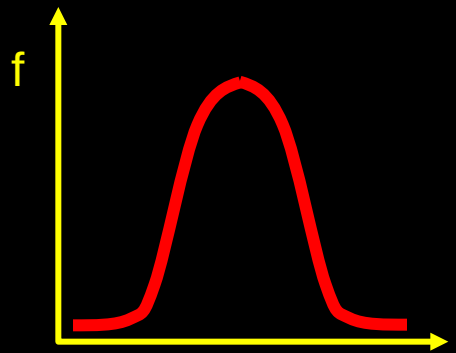
- Sponsored by APA
- Developed at Auburn University / NCAT
- M-E Perpetual Pavement Design and Analysis Tool




Structural and Seasonal Information (F1 for Help)
# of Layers
2
3
4
5
Seasonal Information
Season
Summer
Fall
Winter
Spring
Spring2
Current Season
Duration (weeks)
26
8
6
0
Summer
Mean Air Temperature, F
70
70
70
70
70
Temperature Correction
Environmental Conditions
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5
Material Type
AC
Gran Base
Soil
Soil
Soil
PG Grade
70
-22
Min Modulus (psi)
50000
5000
3000
3000
3000
Modulus (psi)
522958
20000
12000
12000
12000
Max Modulus (psi)
40000
40000
40000
Poisson's Ratio
0.35
0.4
0.45
0.45
0.45
Layer Properties
Min - Max
0.15 - 0.4
0.35 - 0.45
0.2 - 0.5
0.2 - 0.5
0.2 - 0.5
Thickness (in)
10
10
999
999
Infinite
Variability
Variability
Variability
Variability
Variability
Performance Criteria
Performance Criteria
Performance Criteria
Performance Criteria
Performance Criteria
Variability and Thresholds
Slip Condition Between Layers
Full Bond
Full Bond
Full Bond
Full Bond
Cancel Changes
Accept Changes



Material Properties



Thickness

Input Variability

Layer: AC

Modulus Variability

Distribution Type: Log-normal

Coefficient of Variation: 30 %

Thickness Variability

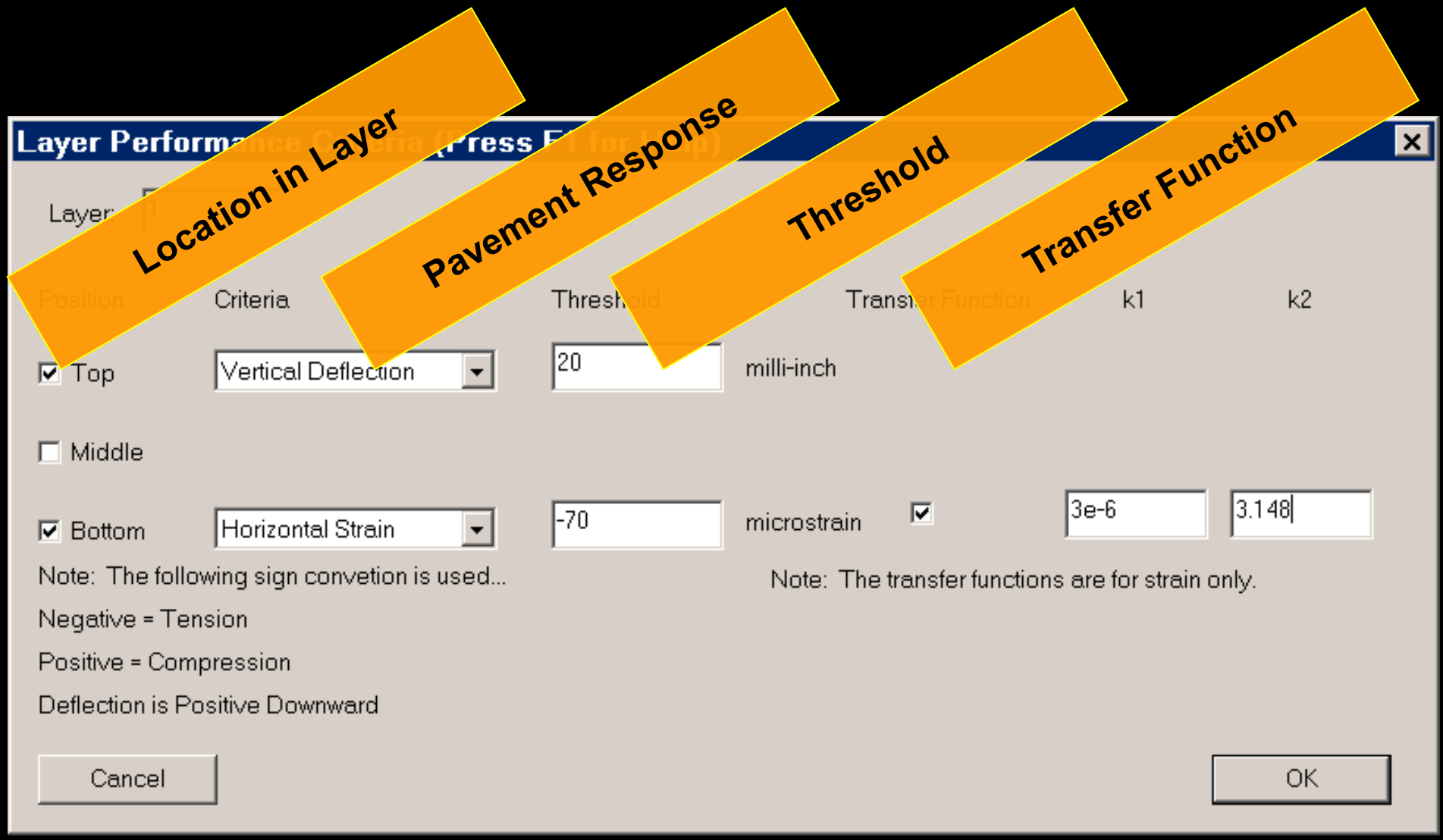
Distribution Type: Normal

Coefficient of Variation: 5 %

Cancel

OK

Performance Criteria



Loading Conditions (F1 for Help)

General Traffic Data

AADT 1000

Axles Groups / Day 136

% Trucks 10

% Growth 4

% Trucks in Design Lane 90 %

Directional Distribution 50 %

Input Load Spectra by Vehicle Type

Traffic Volume

Loading Configurations (Check All That Apply)

Single 50.43 %

Tandem 48.81 %

Tridem

Steer 0 %

Types of Axles

Current Configuration: Single

Current Axle Load Distribution

Axle Wt, kip	% Axles	Axle Wt, kip	% Axles	Axle Wt, kip	% Axles	Axle Wt, kip	% Axles	Axle Wt, kip	% Axles
0-2	0	24-26	0.35	48-50	0	72-74	0	96-98	0
2-4	4.46	26-28	0.2	50-52	0	74-76	0	98-100	0
4-6	9.13	28-30	0.1	52-54	0	76-78	0	100-102	0
6-8	11.32	30-32	0.05	54-56	0	78-80	0	102-104	0
8-10	19.55	32-34	0.02	56-58	0	80-82	0	104-106	0
10-12	25.5	34-36	0.02	58-60	0	82-84	0	106-108	0
12-14	14.57	36-38	0.01	60-62	0	84-86	0	108-110	0
14-16	6.42	38-40	0.01	62-64	0	86-88	0	110+	0
16-18	3.84	40-42	0	64-66	0	88-90	0		
18-20	2.39	42-44	0	66-68	0	90-92	0	Total	100
20-22	1.37	44-46	0	68-70	0	92-94	0		
22-24	0.68	46-48	0	70-72	0	94-96	0		

Axle Weight Distribution

Cancel Changes | Import Load Spectra | Save Load Spectra | Accept Changes

Vehicle Type Distribution (Press F1 for Help)

Functional Classification

Roadway Functional Class

Vehicle Frequency

Number of Axles

Vehicle Classification	% AADTT	Average Number of Axles Per Vehicle		
		Single	Tandem	Tridem
4	1.2	1.62	0.39	0
5	9.4	2	0	0
6	3.3	1.02	0.99	0
7		1	0.26	0.83
	7.4	2.38	0.67	0
9	68.9	1.13	1.93	0
10	1.2	1.19	1.09	0.89
11	6.1	4.29	0.26	0.06
12	0.8	3.52	1.14	0.06
13	1.2	2.15	2.13	0.35
Total	100			

Cancel Changes

Accept Changes

Output & Design Module (F1 for Help)

Reliability Analysis

Perform Analysis

Perpetual Pavement Design Results

Layer	Location	Criteria	Threshold	Units	Percent ...	Damage/Million...	Years to D=0.1
1	Bottom	Horizontal Str...	-70.	micr...	64.6	8.1606e-002	17.512
3	Top	Vertical Strain	200.	micr...	87.2	NA	NA

Percent Below Threshold

Damage Accumulation

Design "Life"

Thickness Design Studio

Number of Pavement Layers: 3

	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5
Material	AC	Gran Base	Soil	Soil	Soil
Thickness, in.	10	10	999	999	Infinite

Disclaimer

Cost Analysis

Export Data

Leave Module

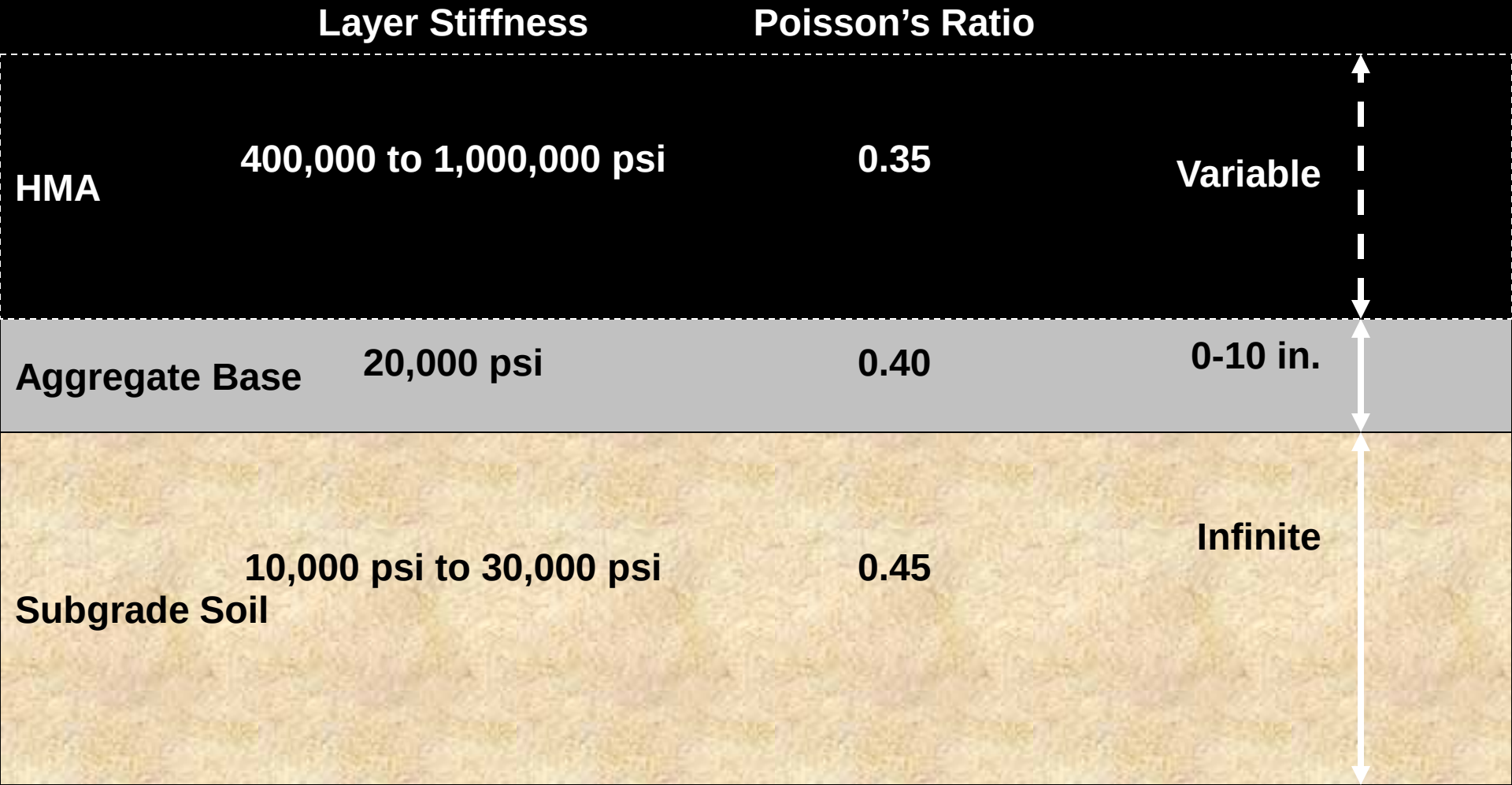
PerRoadXPress – For Low Volume Roads

Methodology - Overview

- Develop a set of boundary conditions
- Execute PerRoad analysis to determine required thickness for each “design”
- Develop design regression equations

- Guiding Principles
  - Limit number of required inputs
  - Make design procedure simple/efficient

Structural Cross Section



Number of Simulations

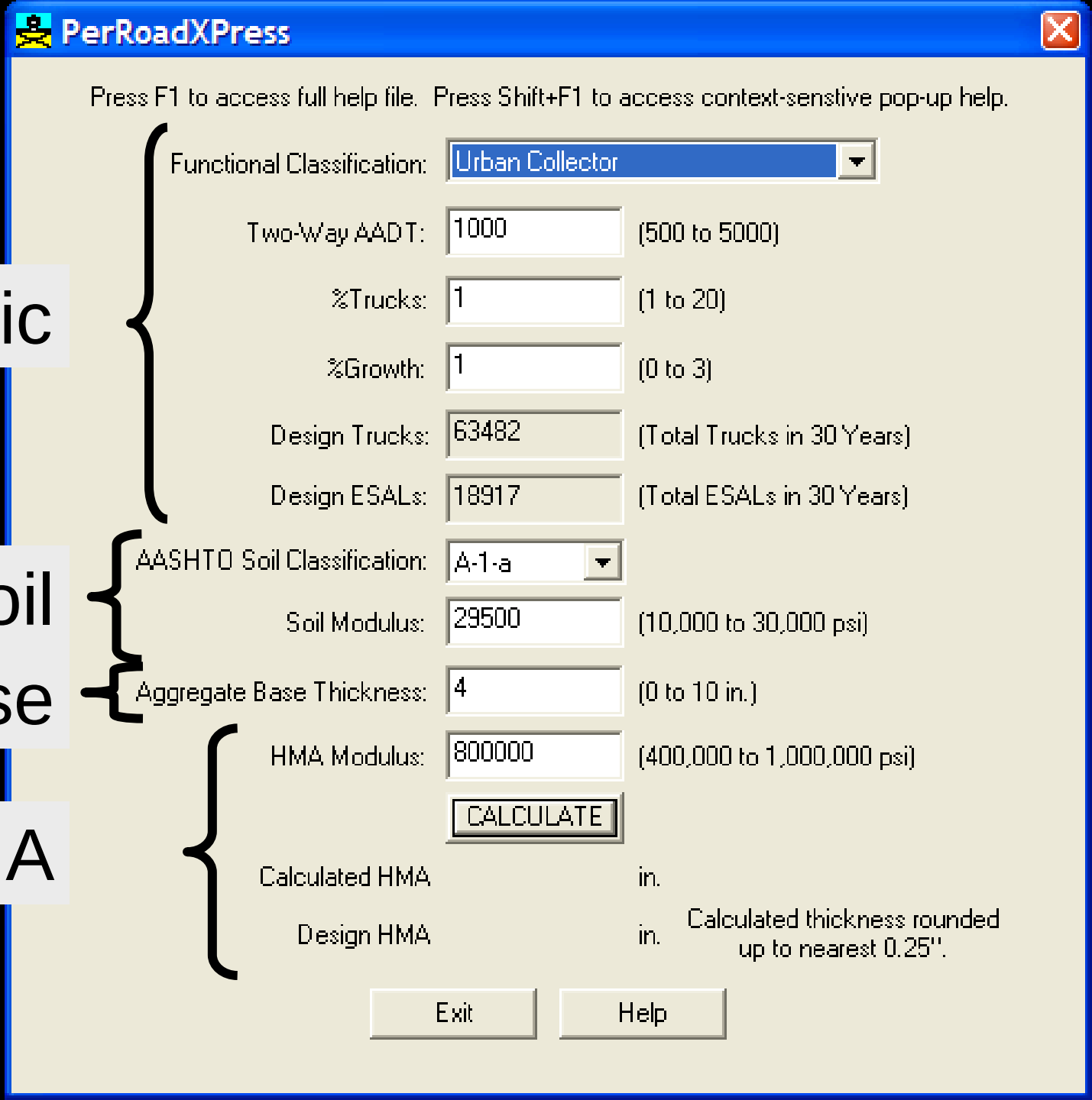
# Simulations =	
	2 Highway Classifications
X	3 Traffic Volumes
X	3 Growth Rates
X	4 Percent Trucks
X	3 Soil Stiffnesses
X	3 HMA Stiffnesses
X	3 Base Thicknesses
	1,944 Pavement Designs

Design Equation

HMA = $C_0 + C_1$*AADT + C_2*%Trucks + C_3*%Growth + C_4*Soil Stiffness + C_5*Base Thickness + C_6*HMA Stiffness

Parameter	Urban Collector	Rural Collector
C_0 (Intercept)	10.1587	10.8162
C_1 (AADT)	6.281E-04	6.396E-04
C_2 (%Trucks)	0.1817	0.1861
C_3 (%Growth)	0.2264	0.2222
C_4 (Soil Stiffness)	-9.437E-05	-9.915E-05
C_5 (Base Thickness)	-0.0780	-0.0743
C_6 (HMA Stiffness)	-5.098E-06	-5.365E-06
R^2	0.90	0.90

PerRoad XPress



Traffic

Soil

Agg. Base

HMA

http://www.eng.auburn.edu/users/timmdav/Software.html