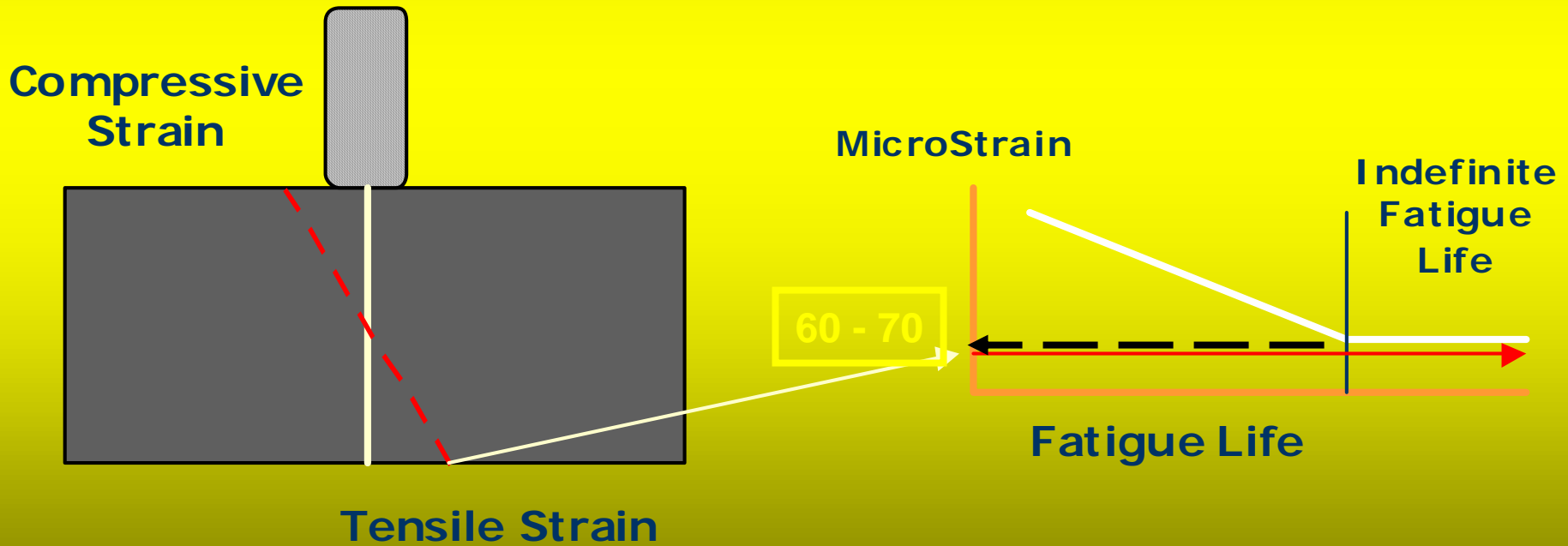
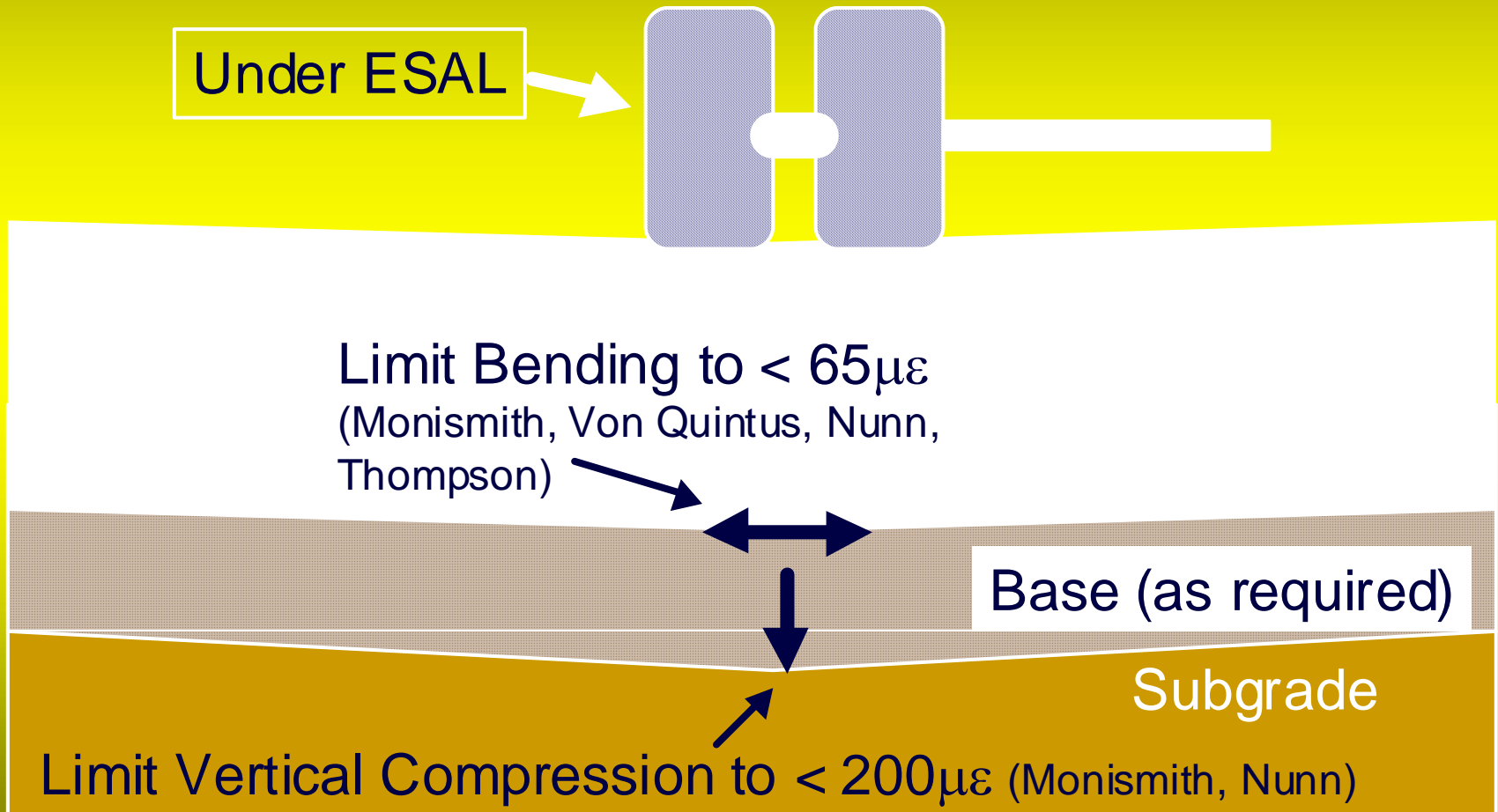


› Fatigue Resistant Asphalt Base

- › Minimize Tensile Strain with Pavement Thickness
- › Thicker Asphalt Pavement = **Lower Strain**
- › Strain Below Fatigue Limit = **Indefinite Life**



Mechanistic Performance Criteria



\$\$\$\$ Comparison for Pa DOT

PRICES

HMA Base	\$ 29.00/ton
HMA Rich Bottom	29.90/ton (+1/2% AC @ \$180/ton)
HMA PG 64-22	36.36/ton
HMA PG 76-22	42.00/ton

Scratch Course	34.00/ton
Seal Coat Shoulder	0.85/sy
Mill 2-inches	0.80/sy
Deep Patching	81.00/sy

Notes: 4-inches of Rich Bottom is an additional \$ 0.20/sy
2-inches of PG 76-22 Wearing is an additional \$ 0.62/sy

\$\$\$\$ Comparison for Pa DOT Perpetual Pavement vs DOT AASHTO

<u>Scenario</u>	<u>Initial</u>	<u>LCC</u>
14.5-inch Pavement Section		
PP 15/15 vs DOT 10/10	+ 3.1 %	- 8.1 %
PP 15/12 vs DOT 15/10		- 2.4 %
16-inch Pavement Section		
PP 15/15 vs DOT 10/10	+ 1.9 %	- 7.5 %
PP 15/12 vs DOT 15/10		- 2.3 %

sign reflects perpetual pavement advantage (-) or disadvantage (+)

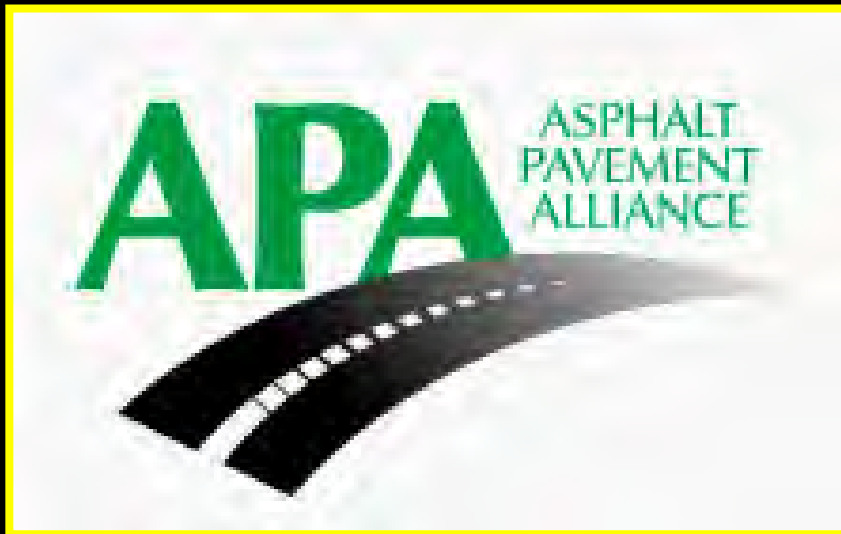
Comparison of Alternates

Alternate	X-section	AC	Strain	Comp	\$/SY
1 standard subgrade	2,3,10,4,8	74	498	36.52	
2 standard	2,3,10,4,12	58	225	33.80	
3 pp PG76	2,7,3,4,8	62	130	33.06	
4 pp PG 76 subgrade	2,8,4,4,12	70	188	40.80	
5 pp PG 70	2,8,4,4,12	50	105	36.19	

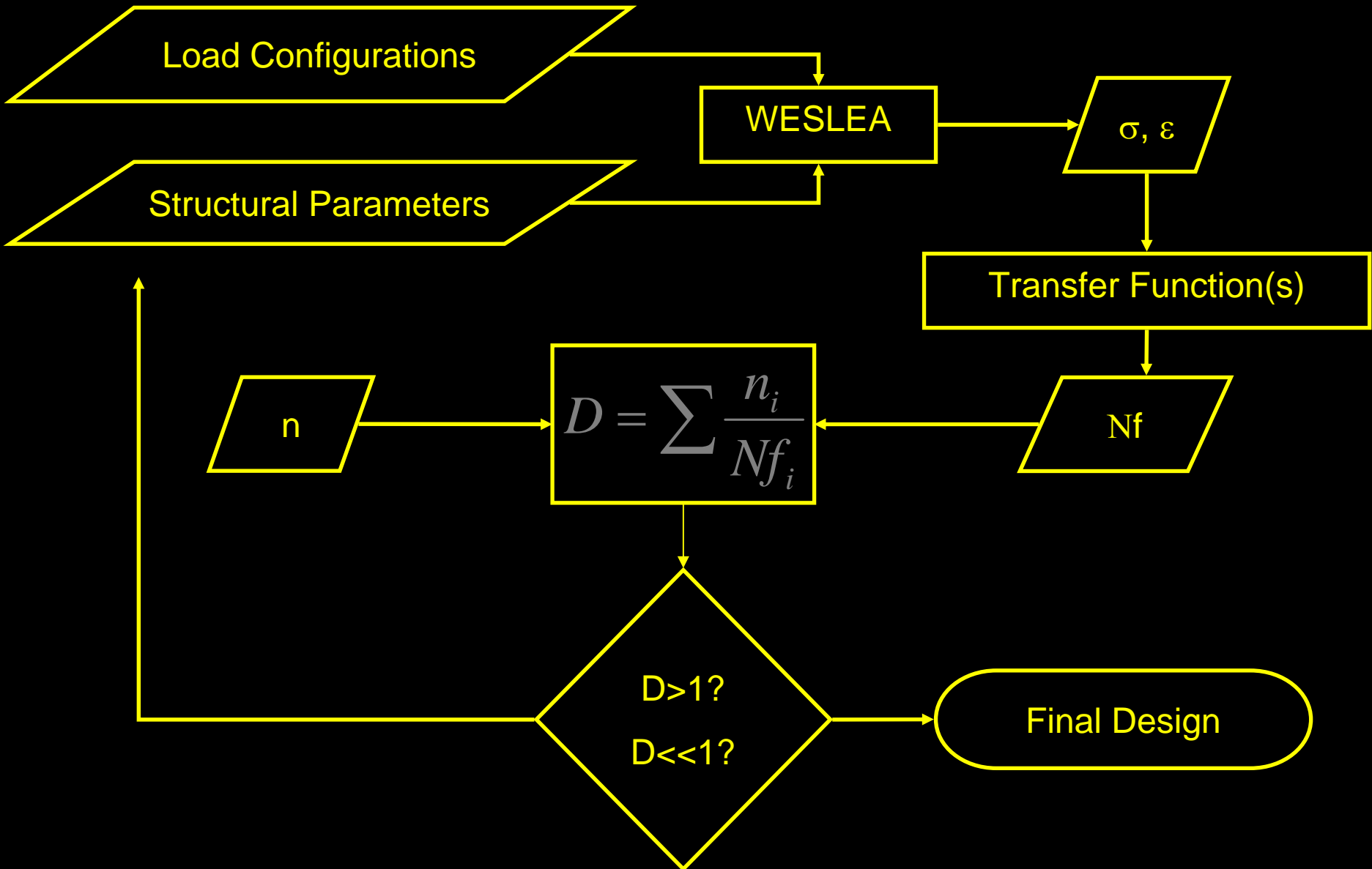
HMA, Rich Bottom, ATPB, Subbase

Perpetual Pavement Design Software

Under development by Dr. David Timm at NCAT
for the Asphalt Pavement Alliance



M-E Design Framework



Key Software Components

- Based on fully functional M-E design software
- Layered elastic analysis
- Incorporates
 - Seasonal effects
 - Thickness variability
 - Material property variability
 - Load Spectra or ESALs
 - Deterministic and Probabilistic analyses
 - Conventional M-E design and Perpetual Pavement Design

Check Seasons to Evaluate

- Summer (Normal Condition) 26 weeks
- Fall (Wet Condition) 8 weeks
- Winter (Frozen Condition) 12 weeks
- Spring (Thaw Condition) 6 weeks
- Second Spring 0 weeks

Number of Pavement Layers

2 3 4 5

Input Season: Summer

AC Temperature Adjustment: 85 F

Edit Equation

	Layer 1	Layer 2	Layer 3
Material Type	AC	GB	Soil
Min Modulus (psi)	50000	5000	3000
Modulus (psi)	290,000	10000	10000
Max Modulus (psi)	2500		
Poisson's Ratio	0.35	0.4	0.45
Min - Max	0.15 - 0.4	0.35 - 0.45	0.2 - 0.45
Thickness (in)	9	12	999
Variability			
Failure Criteria			

Up to 5

Material Type

Stiffness

Structural

Poisson

Thickness

Variability

Perpetual Pavement Failure Criteria

OK

Asphalt Modulus vs. Temperature

AC - Temperature Relationship (F1 for Help)

$$E_{AC} = Q_1 * e^{\left(\frac{(T + Q_2)^2}{Q_3} \right)}$$

Note: Changing these coefficients will update ALL of the asphalt concrete seasonal moduli, according to temperature.

Q1

Q2

Q3

Perpetual Pavement Failure Criteria

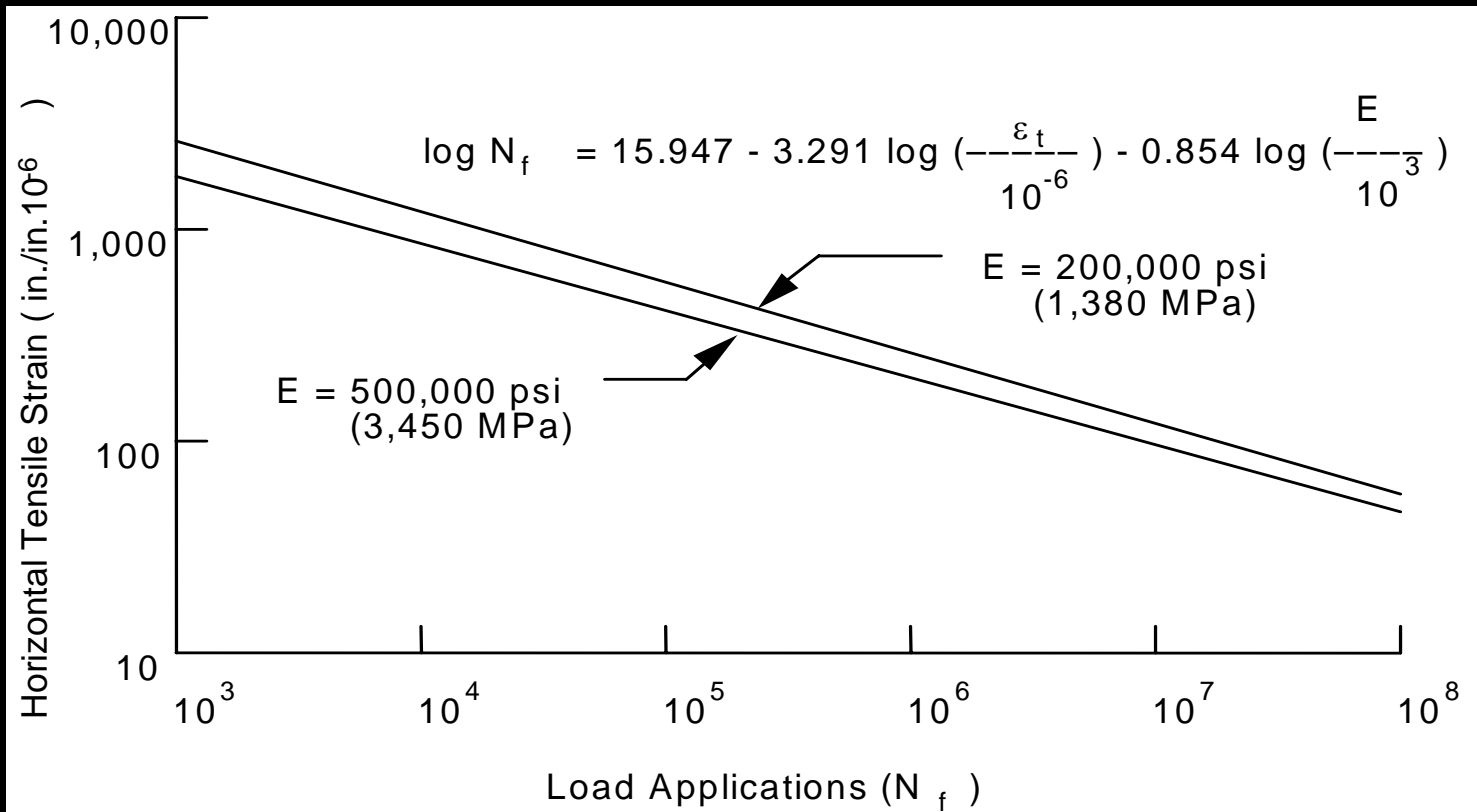
- Designer selects location(s) in layer
- Type of criteria (stress, strain, deflection)
- Threshold value

Layer Failure Criteria

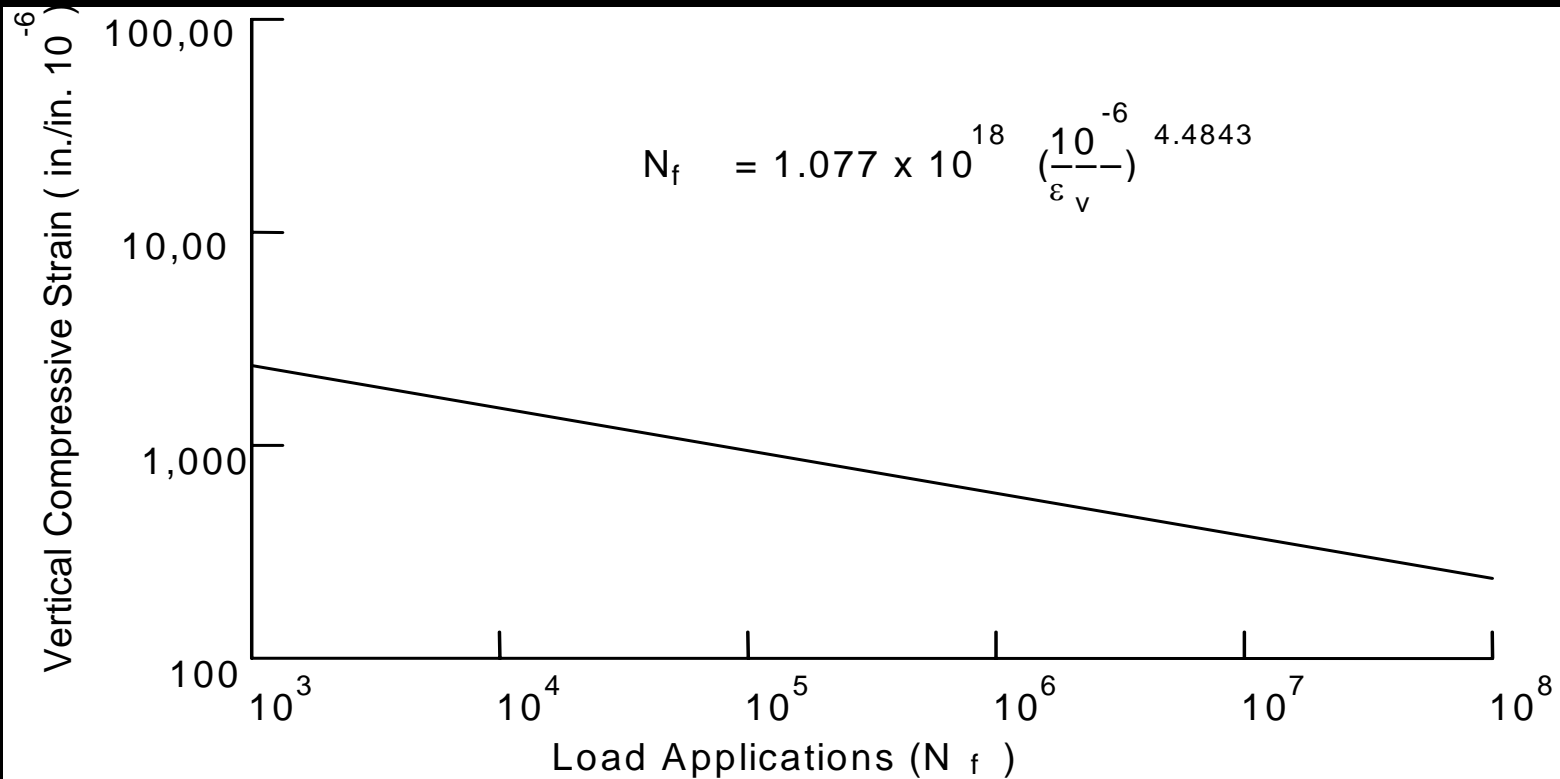
Layer: 1

Position	Criteria	Threshold
<input checked="" type="checkbox"/> Top	Vertical Deflection	0.001
<input type="checkbox"/> Middle		
<input checked="" type="checkbox"/> Bottom	Horizontal Strain	70

OK Cancel



Fatigue Cracking and N_{fatigue}



Total Pavement Rut Depth and N_{rutting}

Transfer Functions

Transfer Functions (F1 for Help) [X]

Fatigue

$$N_F = K_1 \left(\frac{10^6}{\epsilon_t} \right)^{K_2}$$

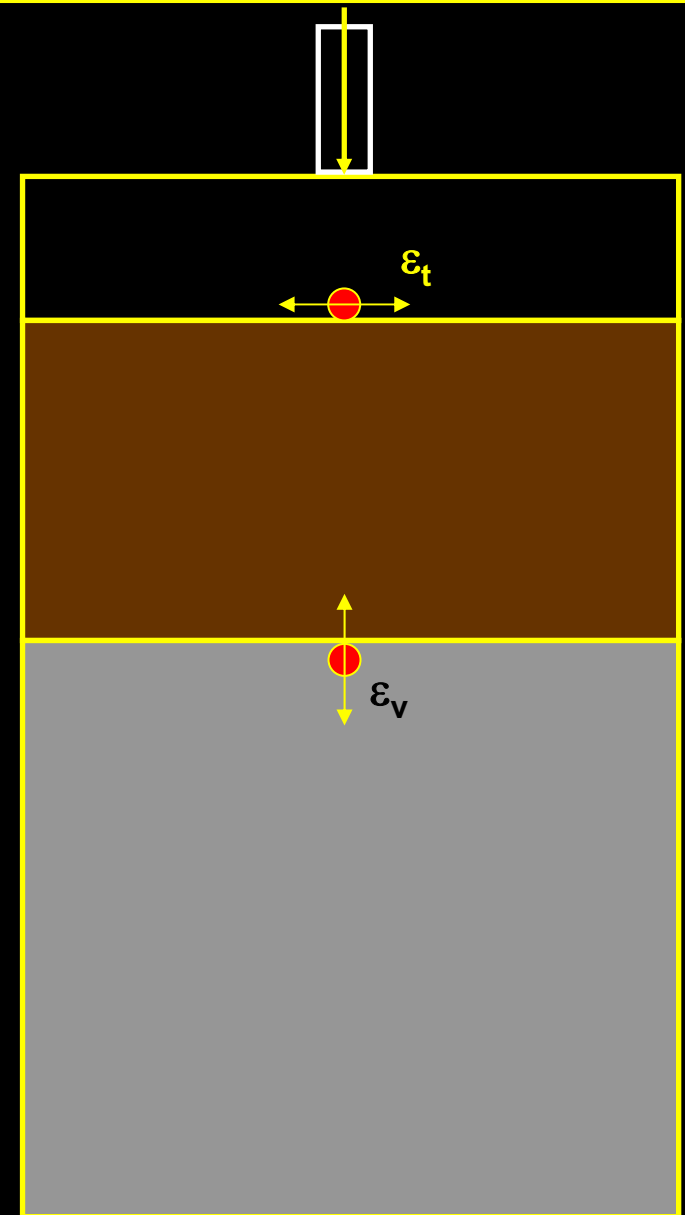
K1: 2.83e-006
K2: 3.20596
Reset Defaults

Rutting

$$N_R = K_3 \left(\frac{1}{\epsilon_v} \right)^{K_4}$$

K3: 5.5e+015
K4: 3.929
Reset Defaults

OK Cancel







Load Spectra

- Consider weight distributions of singles, tandems, tridem and steer axles separately

Loading Conditions (F1 for Help)

Loading Configurations (Check All That Apply)

 Single  Tandem  Tridem  Steer

Choose Current Configuration

Single

Expected Number of Axles in Given Weight Classes. Note: Weight expressed in kips.

0-2	<input type="text" value="0"/>	14-16	<input type="text" value="0"/>	28-30	<input type="text" value="0"/>	42-44	<input type="text" value="0"/>
2-4	<input type="text" value="0"/>	16-18	<input type="text" value="0"/>	30-32	<input type="text" value="0"/>	44-46	<input type="text" value="0"/>
4-6	<input type="text" value="0"/>	18-20	<input type="text" value="0"/>	32-34	<input type="text" value="0"/>	46-48	<input type="text" value="0"/>
6-8	<input type="text" value="0"/>	20-22	<input type="text" value="0"/>	34-36	<input type="text" value="0"/>	48-50	<input type="text" value="0"/>
8-10	<input type="text" value="0"/>	22-24	<input type="text" value="0"/>	36-38	<input type="text" value="0"/>	50-52	<input type="text" value="0"/>
10-12	<input type="text" value="0"/>	24-26	<input type="text" value="0"/>	38-40	<input type="text" value="0"/>	52-54	<input type="text" value="0"/>
12-14	<input type="text" value="0"/>	26-28	<input type="text" value="0"/>	40-42	<input type="text" value="0"/>	54+	<input type="text" value="0"/>

OK Cancel

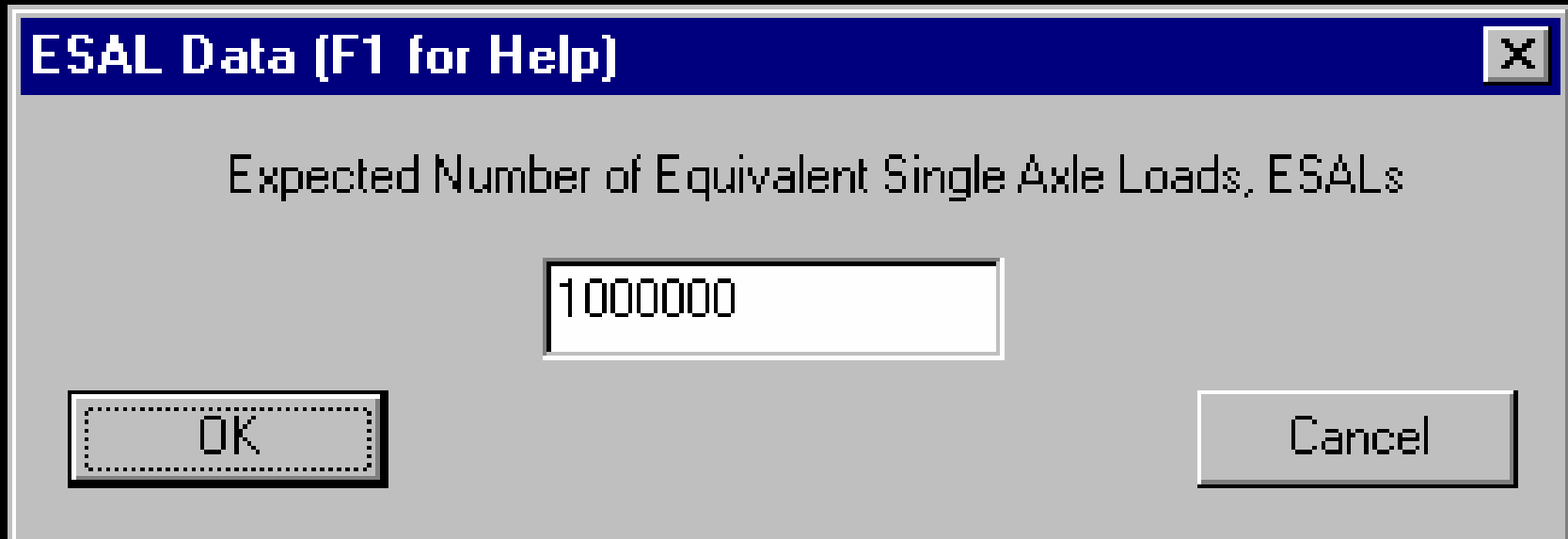
ESAL Approximation

ESAL Data (F1 for Help) X

Expected Number of Equivalent Single Axle Loads, ESALs

1000000

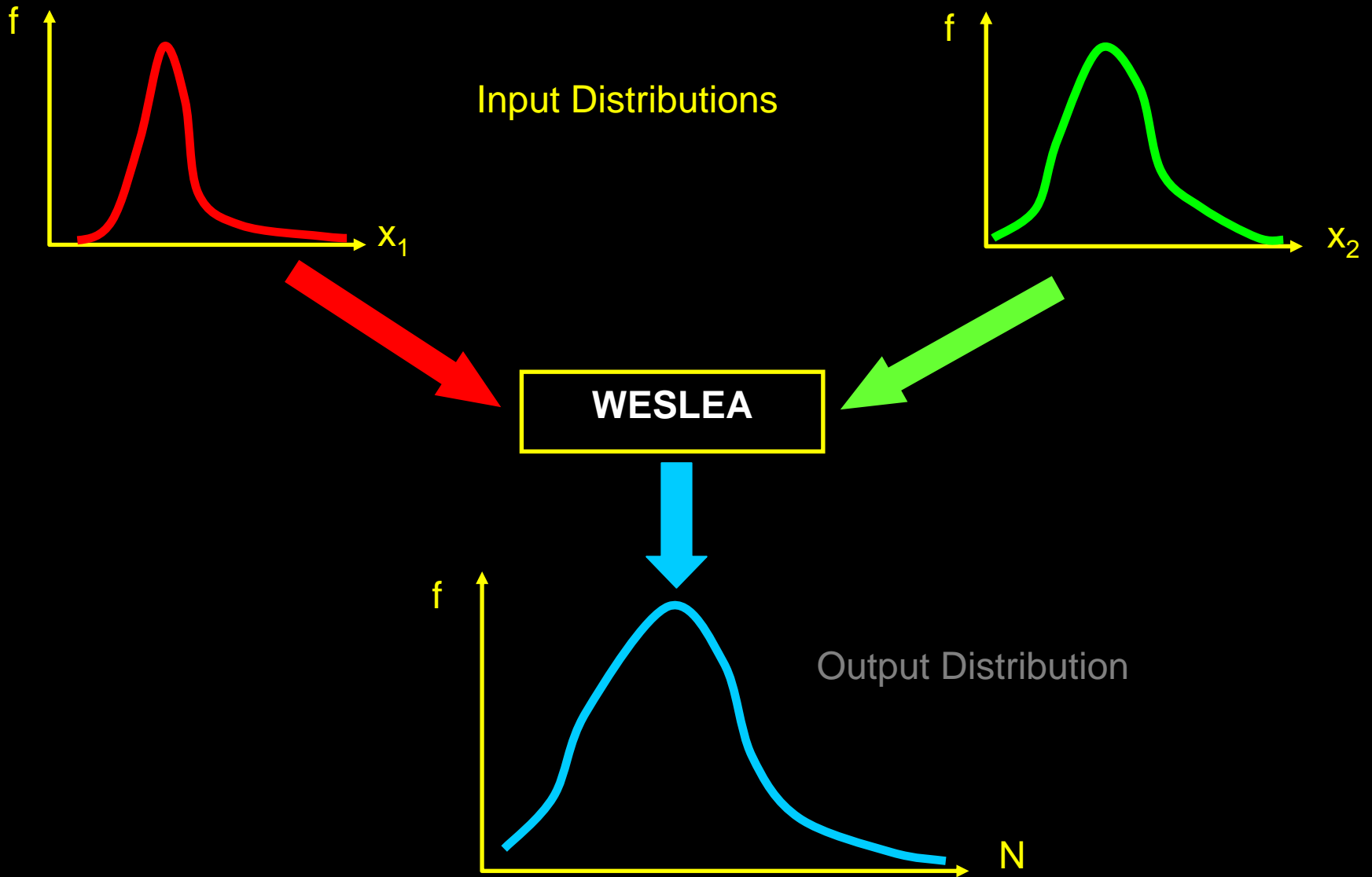
OK Cancel



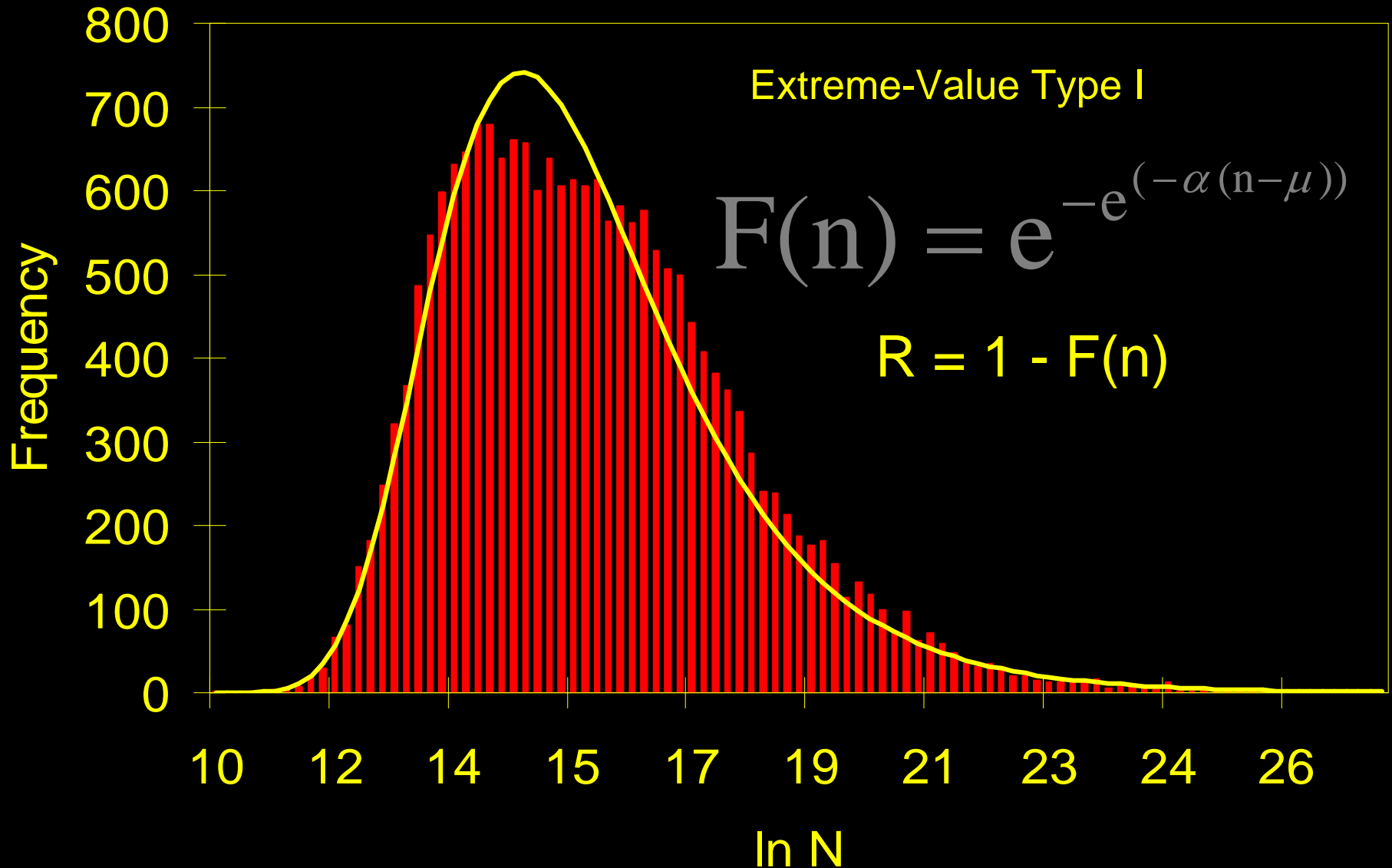
Analysis

- **Deterministic:**
 - Program considers possible combinations of material properties and loadings
 - Calculates pavement responses
 - Determines if thresholds are exceeded (i.e., non-perpetual)
- **Probabilistic:**
 - Program uses Monte Carlo simulation to model input distributions
 - Load, Materials, thickness
 - A distribution of pavement response is determined
 - Reliability = probability that response(s) below threshold

Monte Carlo Simulation



Characteristic Distribution




Program Output

Output & Design Studio (F1 for Help)


Damage Analysis - Using Nominal Values

Fatigue Damage	Rutting Damage
<input type="text" value="0.69"/>	<input type="text" value="0.44"/>



Reliability Analysis

Fatigue Reliability	Rutting Reliability
73%	78%



Thickness Design Studio

Number of Pavement Layers: Type of Design: ESAL, New Construction

	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5
Material	<input type="text" value="AC"/>	<input type="text" value="GB"/>	<input type="text" value="Soil"/>	<input type="text" value="Soil"/>	<input type="text" value="Soil"/>
Thickness, in.	<input type="text" value="6"/>	<input type="text" value="18"/>	<input type="text" value="999"/>	<input type="text" value="999"/>	Infinite

Miner's Hypothesis

- Provides the ability to sum damage for a specific distress type

- $D = \sum n_i/N_i \leq 1.0$

where n_i = actual number of loads
during condition i

N_i = allowable number of loads
during condition i

