Perpetual Pavement Design

An Introduction to the PerRoad Program

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Auburn University / NCAT

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Texas A&M Transportation Institute

Overview

- Pavement design background
  - Layered elastic theory
- Perpetual pavement design philosophy
  - Sensitivity Study
- Program basics
- Example problems – Design simulations

Objectives

- Learn why Perpetual Pavements are important
- Develop basic understanding of M-E Design
- Develop basic understanding of perpetual pavement design
- Demonstrate PerRoad 3.3
- Learn PerRoadXPress

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WHY ARE PERPETUAL PAVEMENTS IMPORTANT?

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Perpetual Pavement Award

- Started by the Asphalt Pavement Alliance in 2001.
- Road must be >35 years old.
- No thickness increase >4 inches.
- No overlay interval less than 13 years.
- Nominated by DOT.

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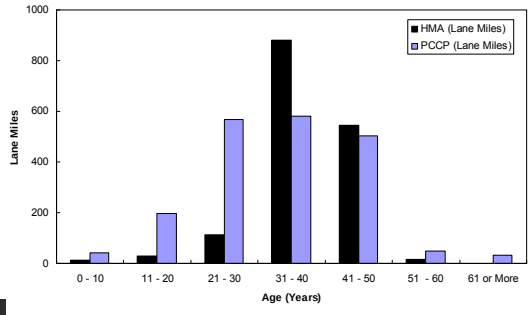
Washington State Performance



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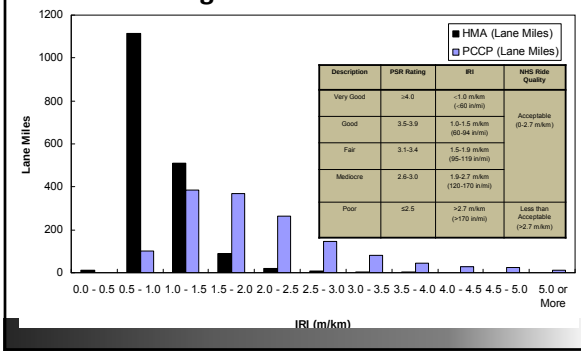
Washington State Performance



Description	PSR Rating	IRI	NHS Ride Quality
Very Good	≥4.0	<1.0 m/km (<60 in/mi)	Acceptable (0-2.7 m/km)
Good	3.5-3.9	1.0-1.5 m/km (60-94 in/mi)	
Fair	3.1-3.4	1.5-1.9 m/km (95-119 in/mi)	
Mediocre	2.6-3.0	1.9-2.7 m/km (120-170 in/mi)	
Poor	≤2.5	>2.7 m/km (>170 in/mi)	Less than Acceptable (>2.7 m/km)

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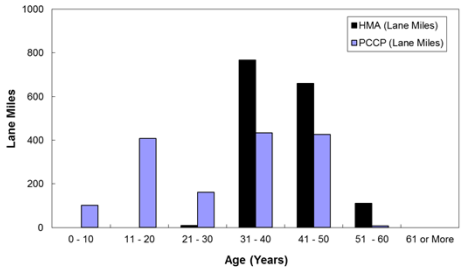
Oregon Performance

ODOT Interstate Ages



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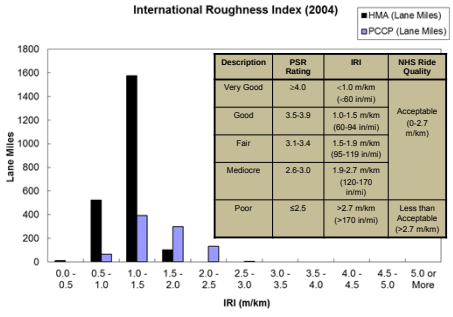
Oregon Performance

International Roughness Index (2004)



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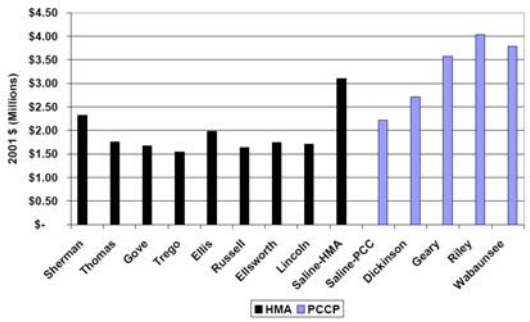
Kansas Interstate Cost Performance, I-70, 40



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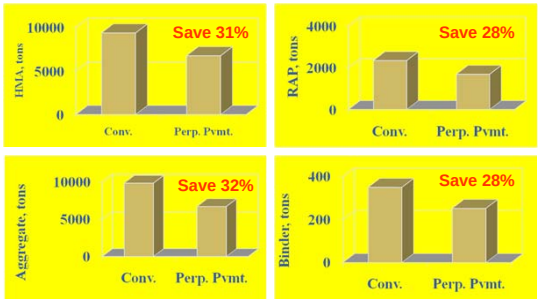
Material Usage



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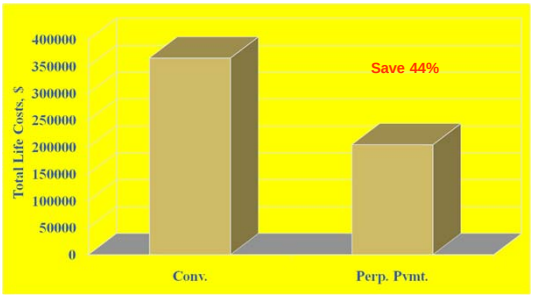
Costs



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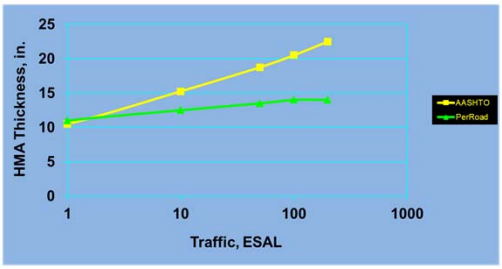
Perpetual Pavement versus Conventional Design



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Goal of Perpetual Pavement Design

- Design the structure such that 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'

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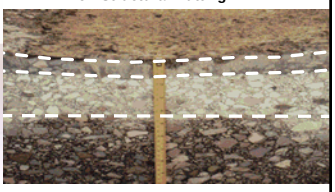
Surface Distresses Only

Top Down Cracking

Non-Structural Rutting



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Pavement Design: Where were we?

- Using 1960s performance equations
- 1950s type of load
- Thin pavement structures (Max. 6” HMA)
- Meaning of structural coefficients
- Limited reliability analysis
- Some movement to M-E

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AASHO Road Test Trucks

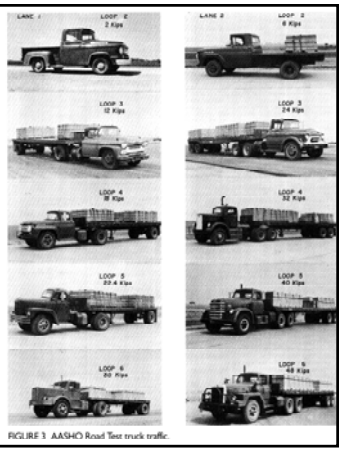
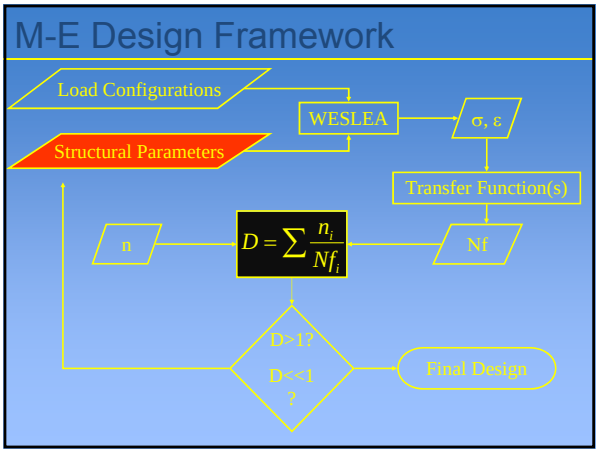
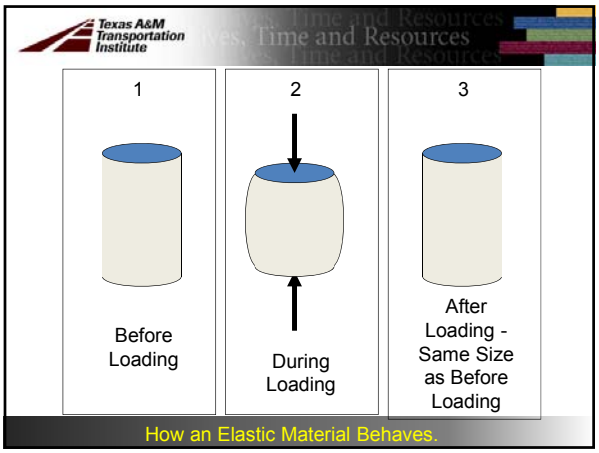


FIGURE 3 AASHO Road Test truck traffic.

M-E Design Framework

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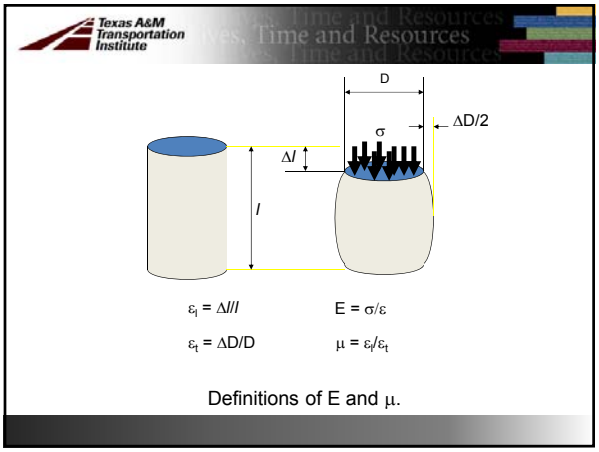
Time and Resources
1
2
3
Before Loading
During Loading
After Loading - Same Size as Before Loading
How an Elastic Material Behaves.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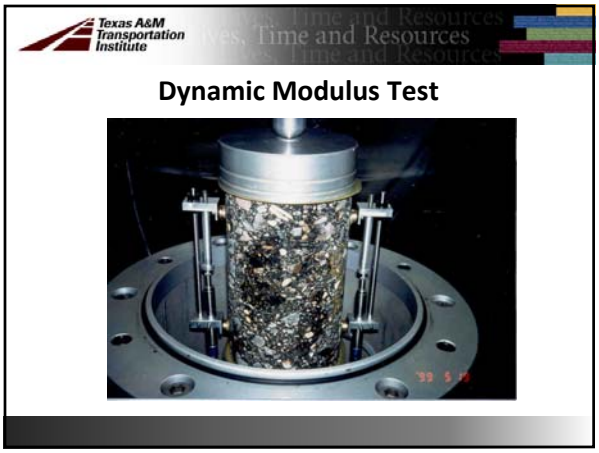
Time and Resources
D
ΔD/2
σ
Δl
l
$\varepsilon_l = \Delta l / l$
$E = \sigma / \varepsilon$
$\varepsilon_t = \Delta D / D$
$\mu = \varepsilon_t / \varepsilon_l$
Definitions of E and μ.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Time and Resources
Dynamic Modulus Test

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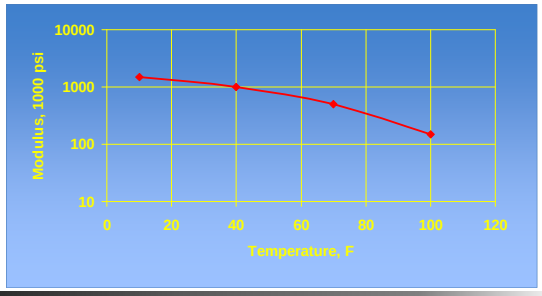
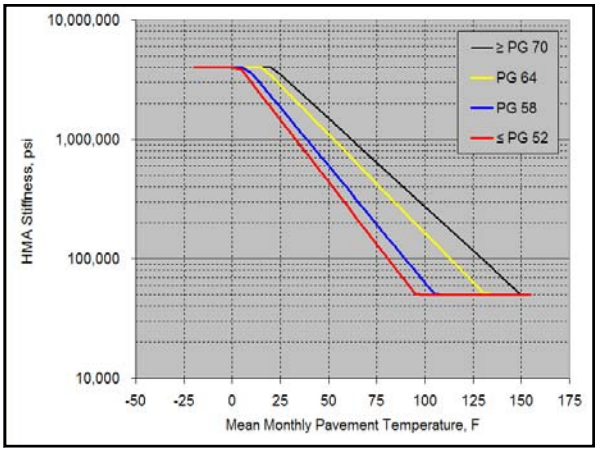
HMA Modulus Versus Temperature





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Soil Modulus Testing

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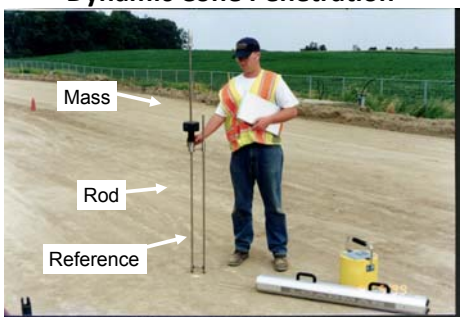
Dynamic Cone Penetration



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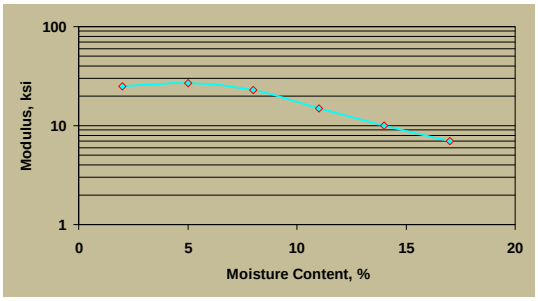
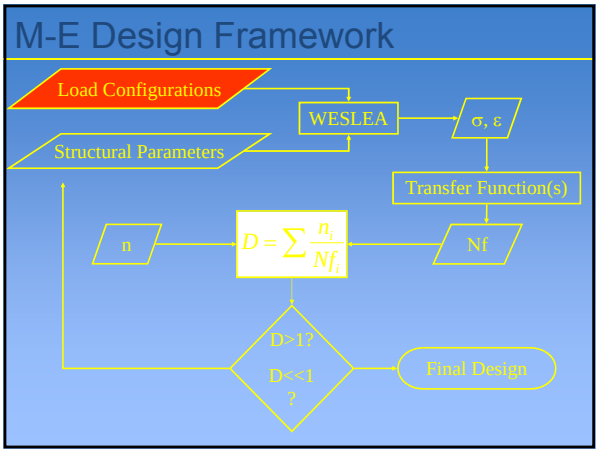
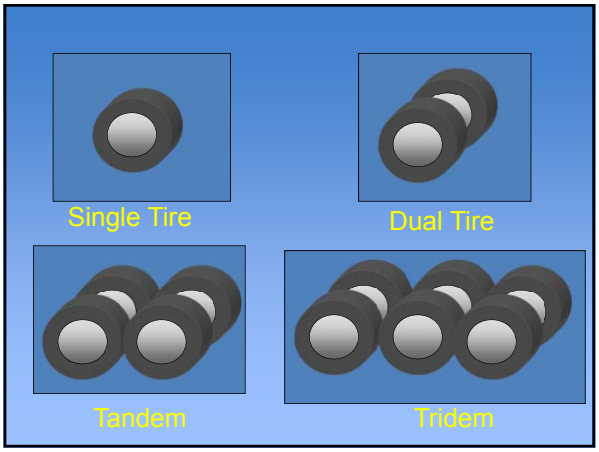
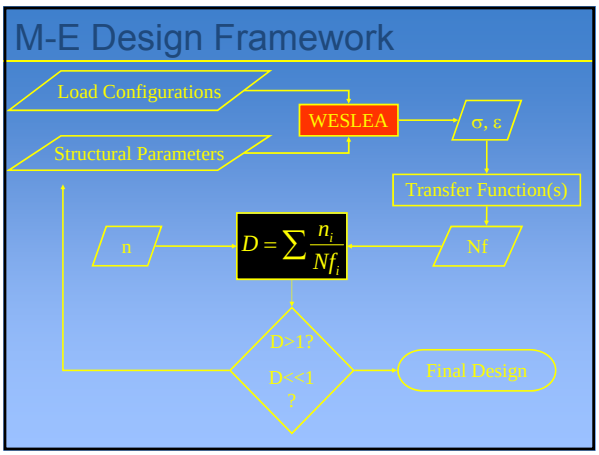
Effect of Moisture Content



M-E Design Framework




Single Tire
Dual Tire
Tandem
Tridem


M-E Design Framework
Load Configurations
Structural Parameters
WESLEA
σ, ε
Transfer Function(s)
n
$D = \sum \frac{n_i}{Nf_i}$
Nf
D>1?
D<<1
?
Final Design

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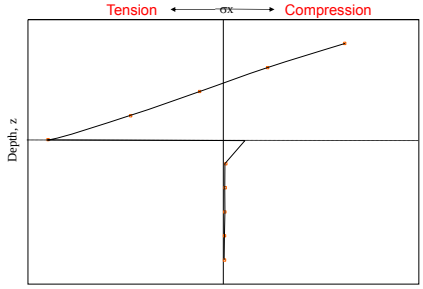
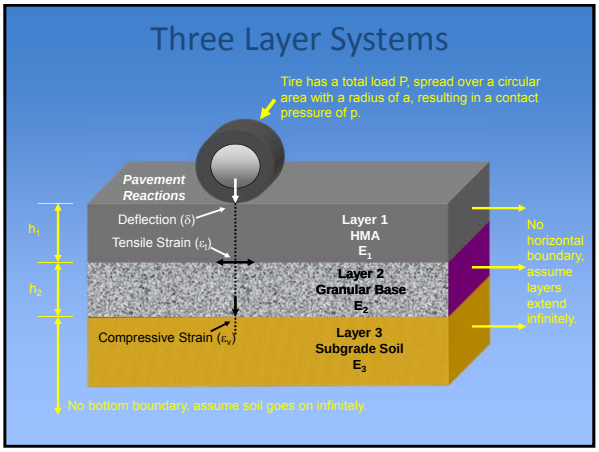
Two-Layer System – Tensile Stresses



Three Layer Systems



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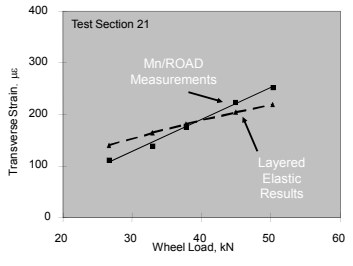

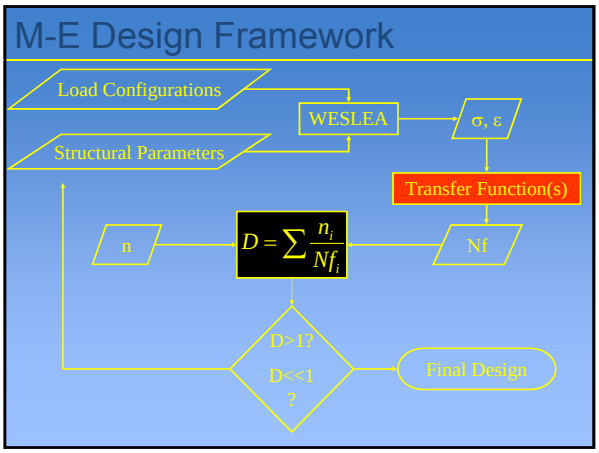
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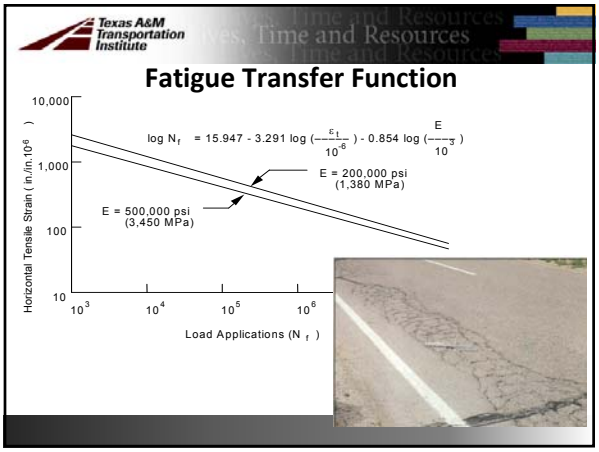
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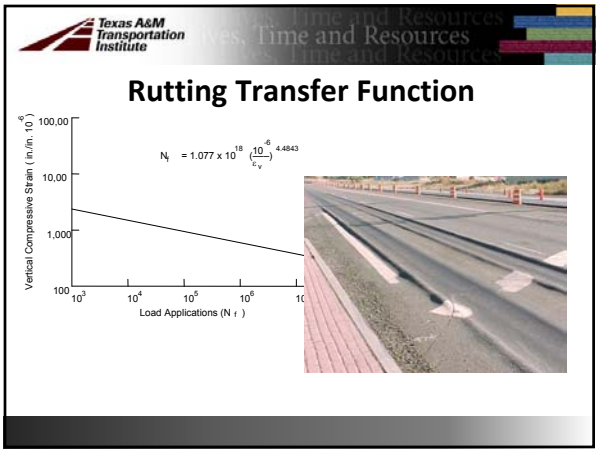
Fatigue Transfer Function
$\log N_f = 15.947 - 3.291 \log(\frac{\varepsilon_t}{10^{-6}}) - 0.854 \log(\frac{E}{10^3})$
E = 200,000 psi (1,380 MPa)
E = 500,000 psi (3,450 MPa)
Horizontal Tensile Strain (in./in.10^-6)
10,000
1,000
100
10
10^3
10^4
10^5
10^6
Load Applications (N f)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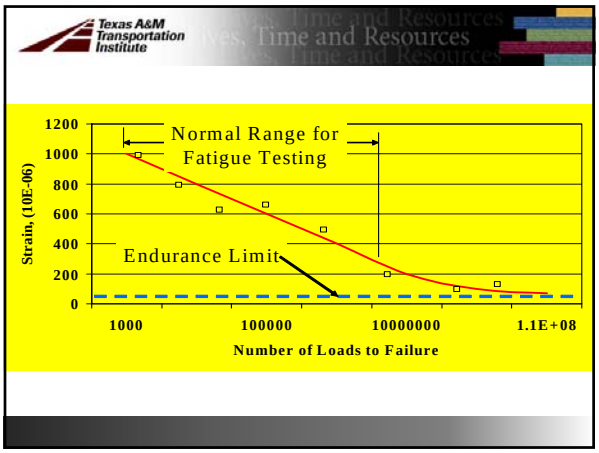
Rutting Transfer Function
$N_f = 1.077 \times 10^{18} (\frac{10^{-6}}{\varepsilon_v})^{4.4843}$
Vertical Compressive Strain (in./in. 10^-6)
100,00
10,00
1,000
100
10^3
10^4
10^5
10^6
Load Applications (N f)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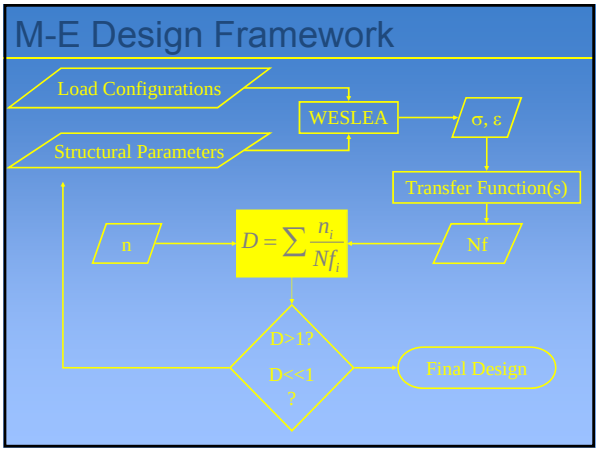
Time and Resources
Normal Range for Fatigue Testing
Endurance Limit
Strain, (10E-06)
1200
1000
800
600
400
200
0
1000
100000
10000000
1.1E+08
Number of Loads to Failure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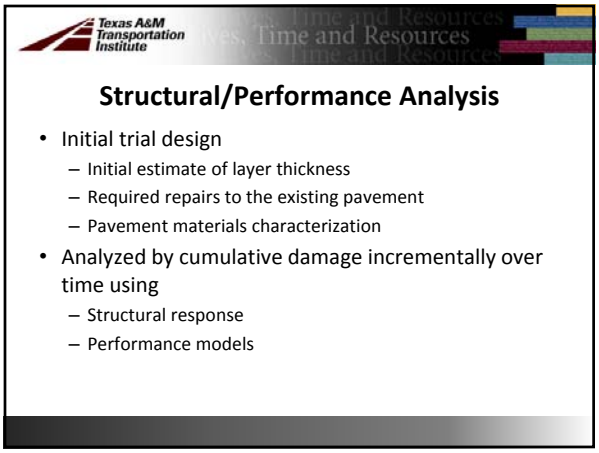
Nf
D>1?
D<<1
?
Final Design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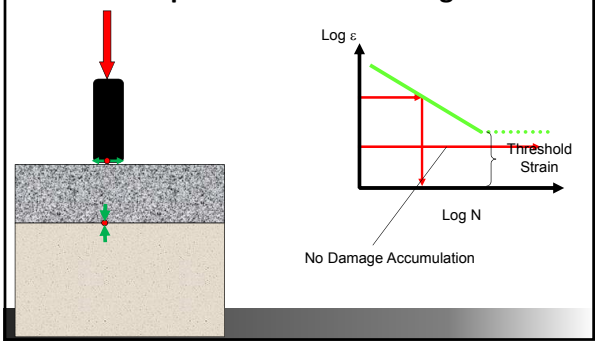
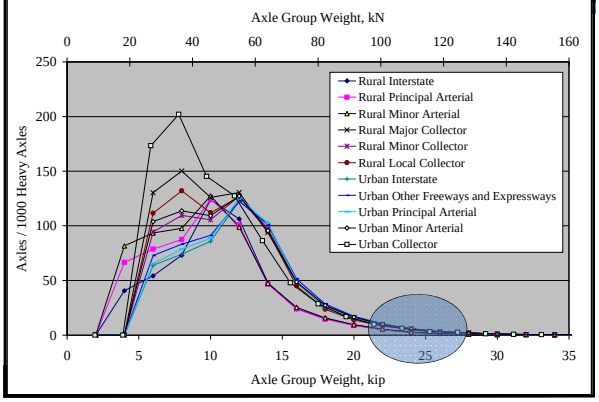
Time and Resources
Structural/Performance Analysis
• Initial trial design
– Initial estimate of layer thickness
– Required repairs to the existing pavement
– Pavement materials characterization
• Analyzed by cumulative damage incrementally over time using
– Structural response
– Performance models

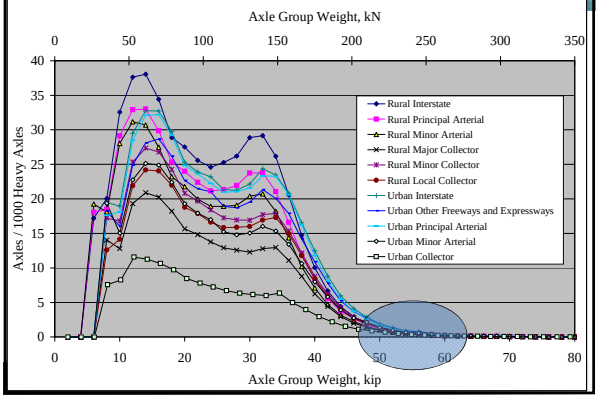
Perpetual Pavement Design



Single Axles

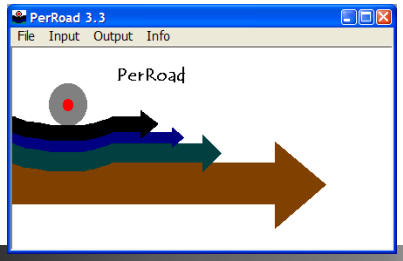


Tandem Axles



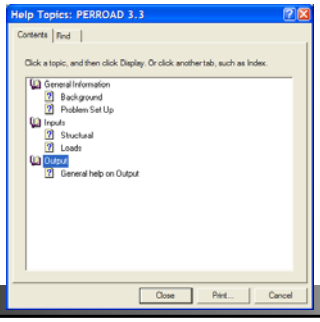
PerRoad 3.3

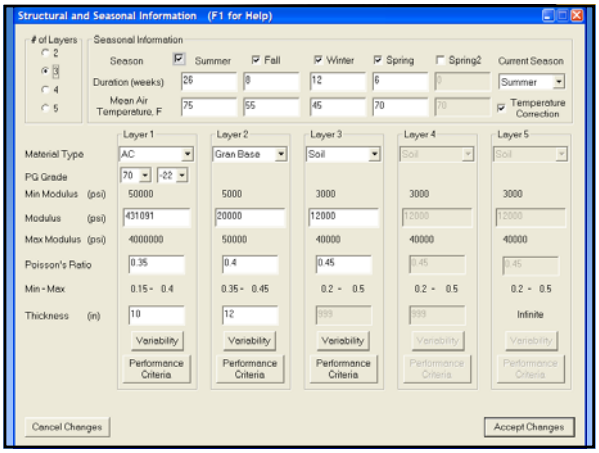
- Sponsored by APA
- Developed at Auburn University / NCAT
- M-E Perpetual Pavement Design and Analysis Tool

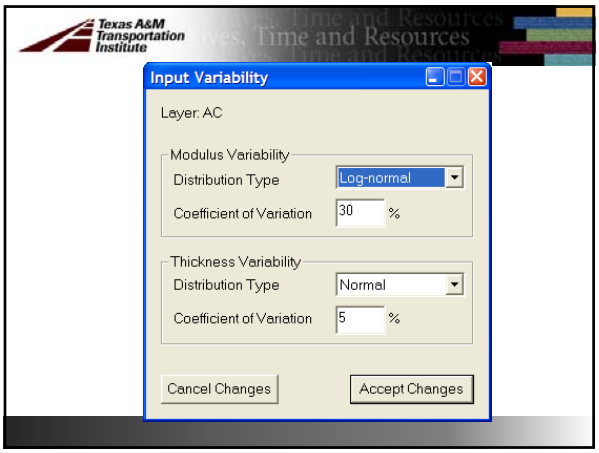


Help File

- Help, Contents and Index
- F1 from any program window



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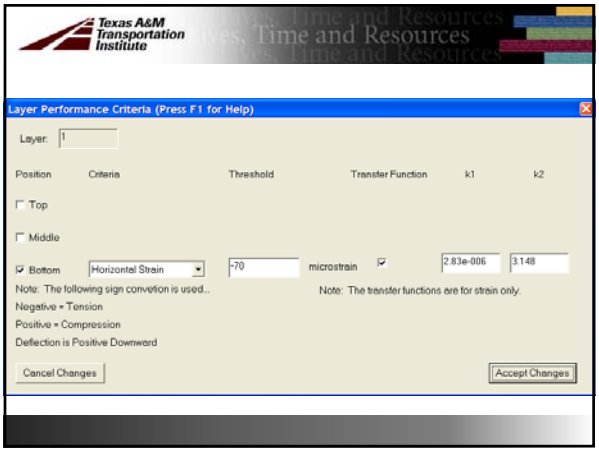
Time and Resources
Input Variability
Layer: AC
Modulus Variability
Distribution Type
Log-normal
Coefficient of Variation
30
%
Thickness Variability
Distribution Type
Normal
Coefficient of Variation
5
%
Cancel Changes
Accept Changes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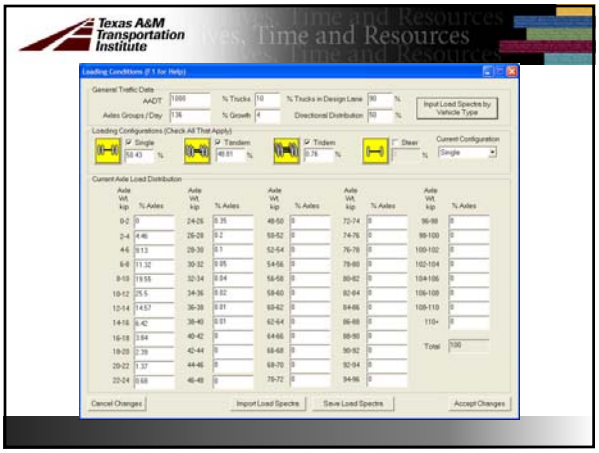
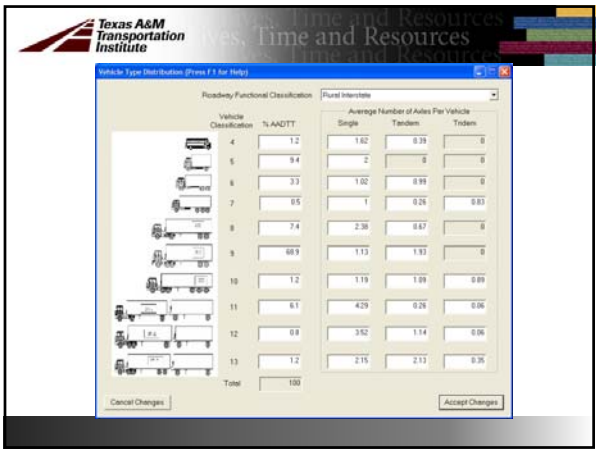
Time and Resources
Layer Performance Criteria (Press F1 for Help)
Layer:
1
Position
Criteria
Threshold
Transfer Function
k1
k2
Top
Middle
Bottom
Horizontal Strain
-70
microstrain
2.83e-006
3.148
Note: The following sign convention is used...
Negative = Tension
Positive = Compression
Deflection is Positive Downward
Note: The transfer functions are for strain only.
Cancel Changes
Accept Changes


Texas A&M Transportation Institute
Time and Resources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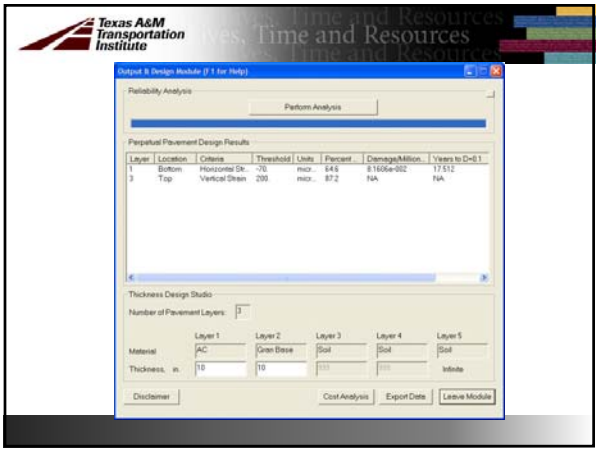
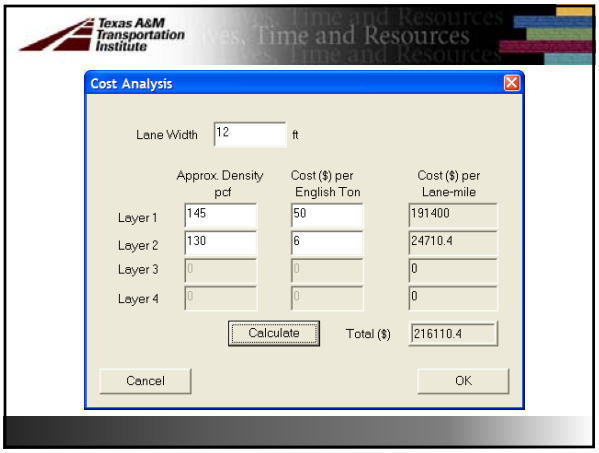
Time and Resources
Vehicle Type Distribution (Press F1 for Help)
Roadway Functional Classification
Rural Interstate
Vehicle Classification
% AADTT
Average Number of Axles Per Vehicle
Single
Tandem
Tridem
Total
100
Cancel Changes
Accept Changes


Texas A&M Transportation Institute
Time and Resources
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
Thickness Design Studio
Number of Pavement Layers:
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5
Material
AC
Gran Base
Soil
Soil
Soil
Thickness, in.
10
10
Infinite
Disclaimer
Cost Analysis
Export Data
Leave Module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Time and Resources
Cost Analysis
Lane Width
12
ft
Approx. Density pcf
Cost ($) per English Ton
Cost ($) per Lane-mile
Layer 1
145
50
191400
Layer 2
130
6
24710.4
Layer 3
0
0
0
Layer 4
0
0
0
Calculate
Total ($)
216110.4
Cancel
OK

Background

- 86% of the developing world's road network is "low-volume" (Behrens, 1999)
- ADT < 5000 for 69% of U.S. federal-aid centerline mileage (Muench, 2004)
- U.S. LVR maintenance and rehabilitation = $82,000,000 per year (Behrens, 1999)
  - 54% of annual road investment
- Long-life pavements typically associated with high volume routes
- Washington State study found perpetual pavements up to 25% more economical than conventional LVR design (Muench, 2004)

Low Volume Roads - Defined

Organization	Definition
TRB	Rural environment with less than 500 vpd
AASHTO	0.7-1 500,000 ESAL
WSDOT	< 50,000 ESALs in 20 years

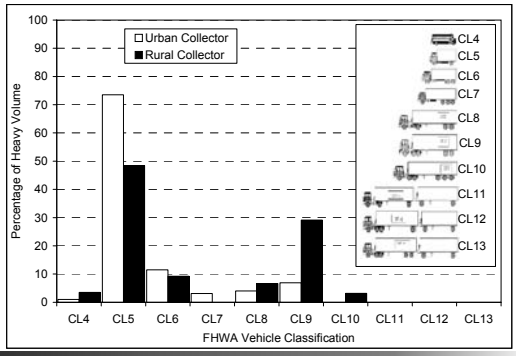
For PerRoad, LVR is any set of conditions resulting in HMA < 8" for a 30 year period

Traffic Parameters

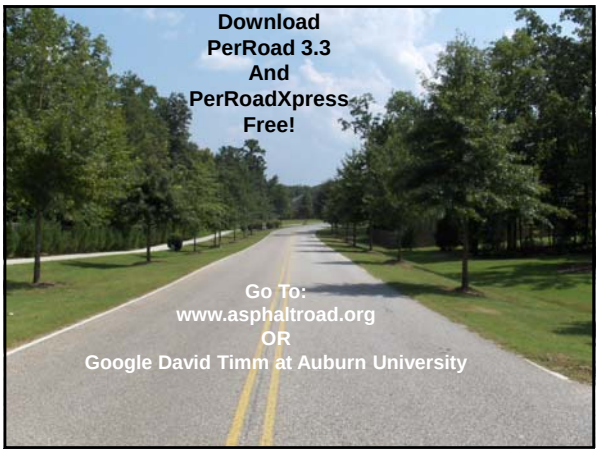
- Rural (Local) Collector vs. Urban Collector
- Volume
  - 500, 1000 and 5000 AADT
  - 0%, 1% and 3% Growth
  - 1%, 5%, 10% and 20% Trucks
- Distribution Factors
  - Assume 2-lane facility
    - 100% Trucks in design lane
  - 50% directional distribution

Volume Range (over 30 years)
27,375 to 8,577,500 trucks

Vehicle Type Distributions



PerRoadXPress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