# OVERVIEW OF THE MEPDG (2002) PAVEMENT DESIGN GUIDE

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# Acknowledgements

***Guide for Design of New and Rehabilitated Pavements Structures (NCHRP 1-37A and 1-40D).***

- Applied Research Associates, Inc. (John Hallin, Michael Darter, & many others)
- **Arizona State University (Prof. Matt Witczak, Mohamed El-Basyouny, & many others)**
- University of Maryland
- Several consultants around the world

Many slides in this presentation were developed under the above projects

# Outline

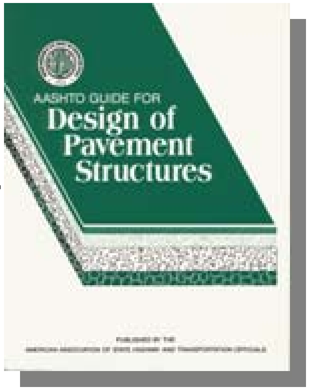
- Background of the Design Guide
- Overview of the MEPDG
- Examples of Minnesota Experience
- Current Status and Summary

# Background of the Design Guide

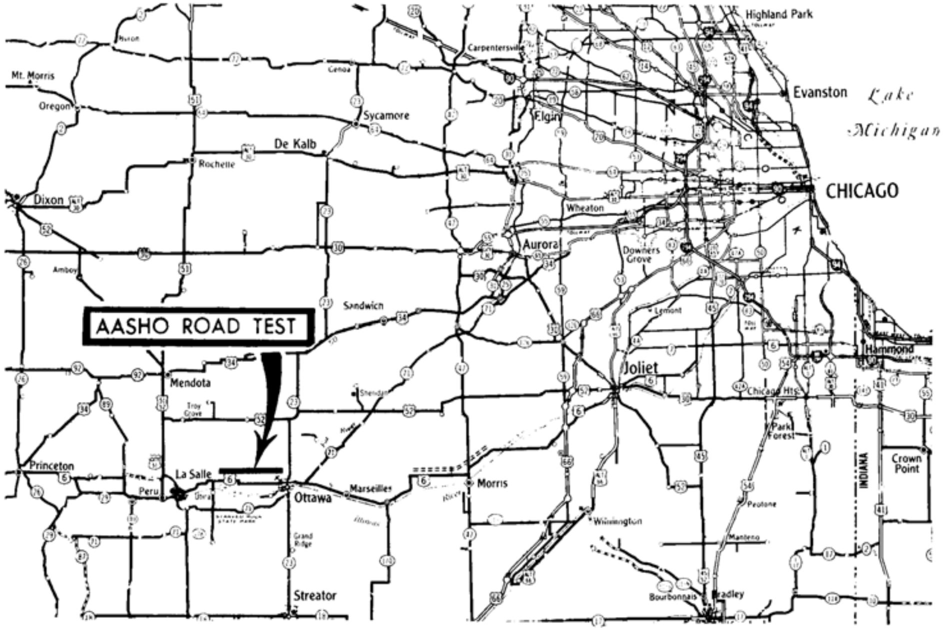
- History of the current design procedure
- Limitation of the current design guide
- Needs for new design procedure
- Background of the new mechanistic-empirical design procedure

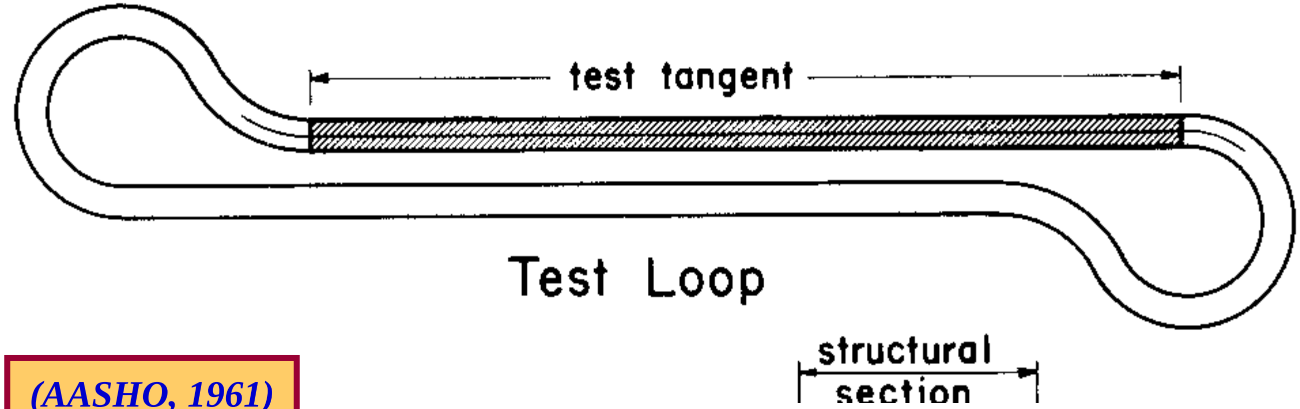
# History of the Current AASHTO Pavement Design Guide

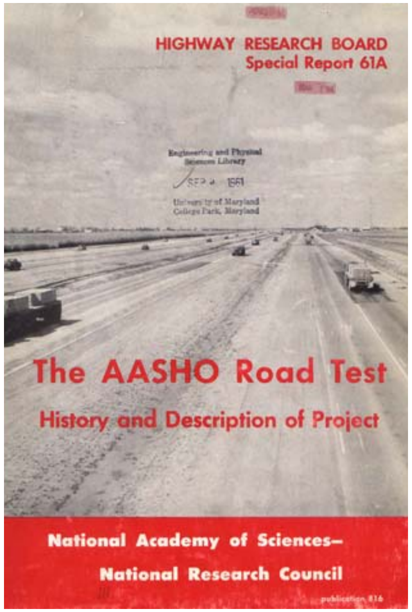
- Empirical design methodology based on AASHO Road Test in the late 1950's
- Several versions:
  - 1961 (Interim Guide), 1972, 1986
  - 1986 version included refined material characterization
  - 1993 revised version
    - More on rehabilitation
    - More consistency between flexible, rigid designs
    - Current version for flexible design procedures



# AASHO Road Test (late 1950's)



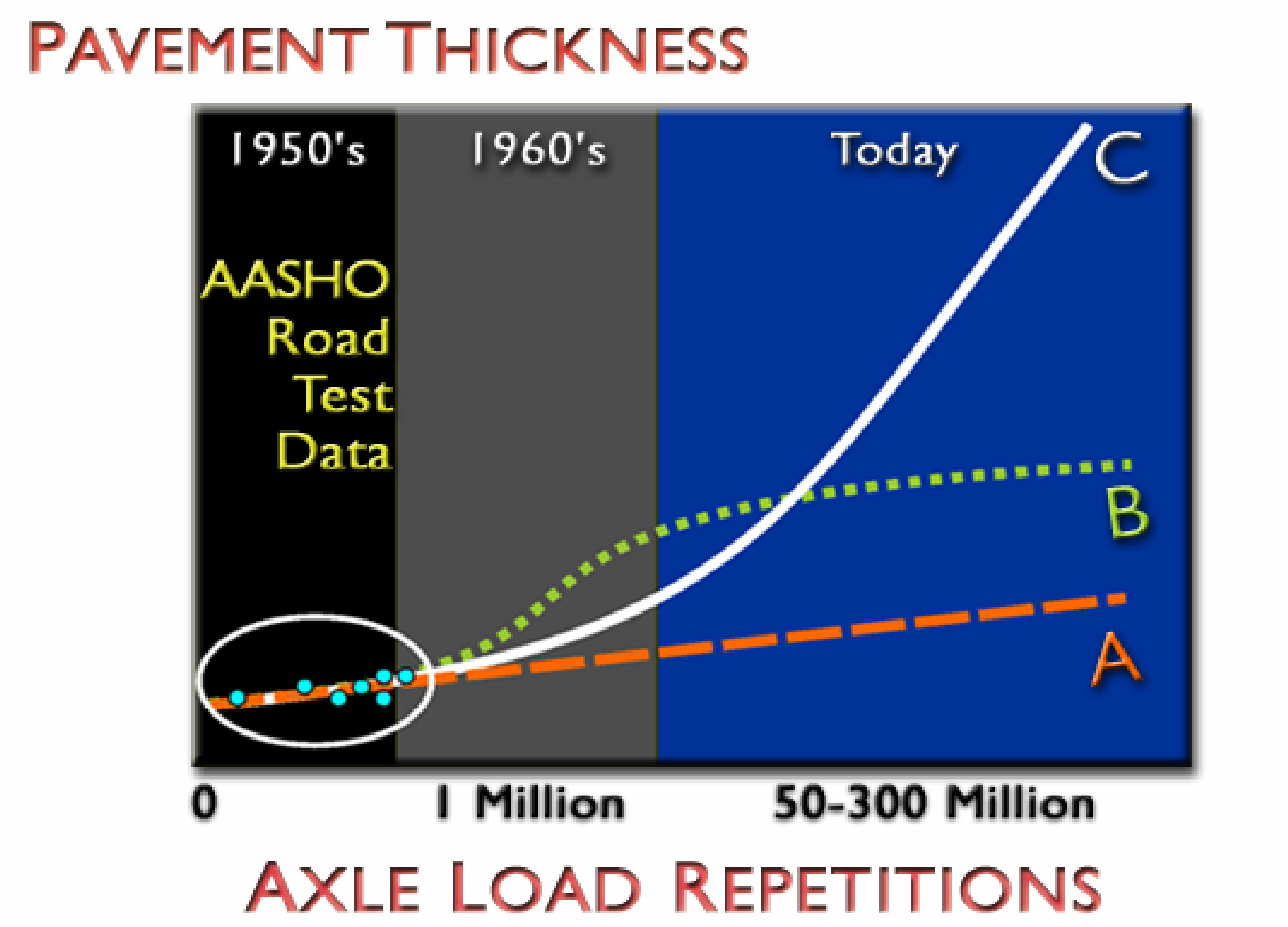




*(AASHO, 1961)*

# AASHO Road Test Location

# Low Traffic Levels...

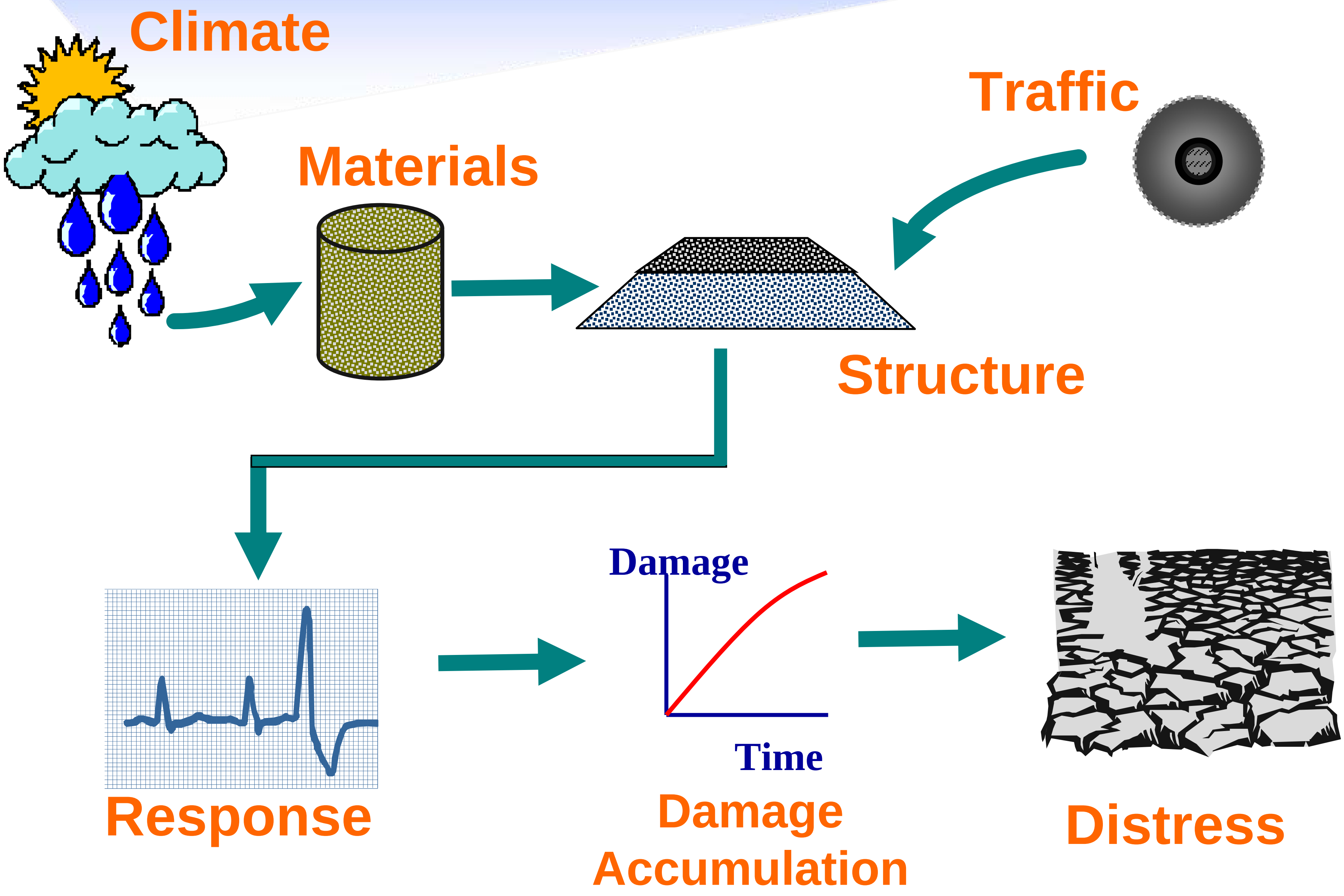


# NCHRP Project 1-37A Objective

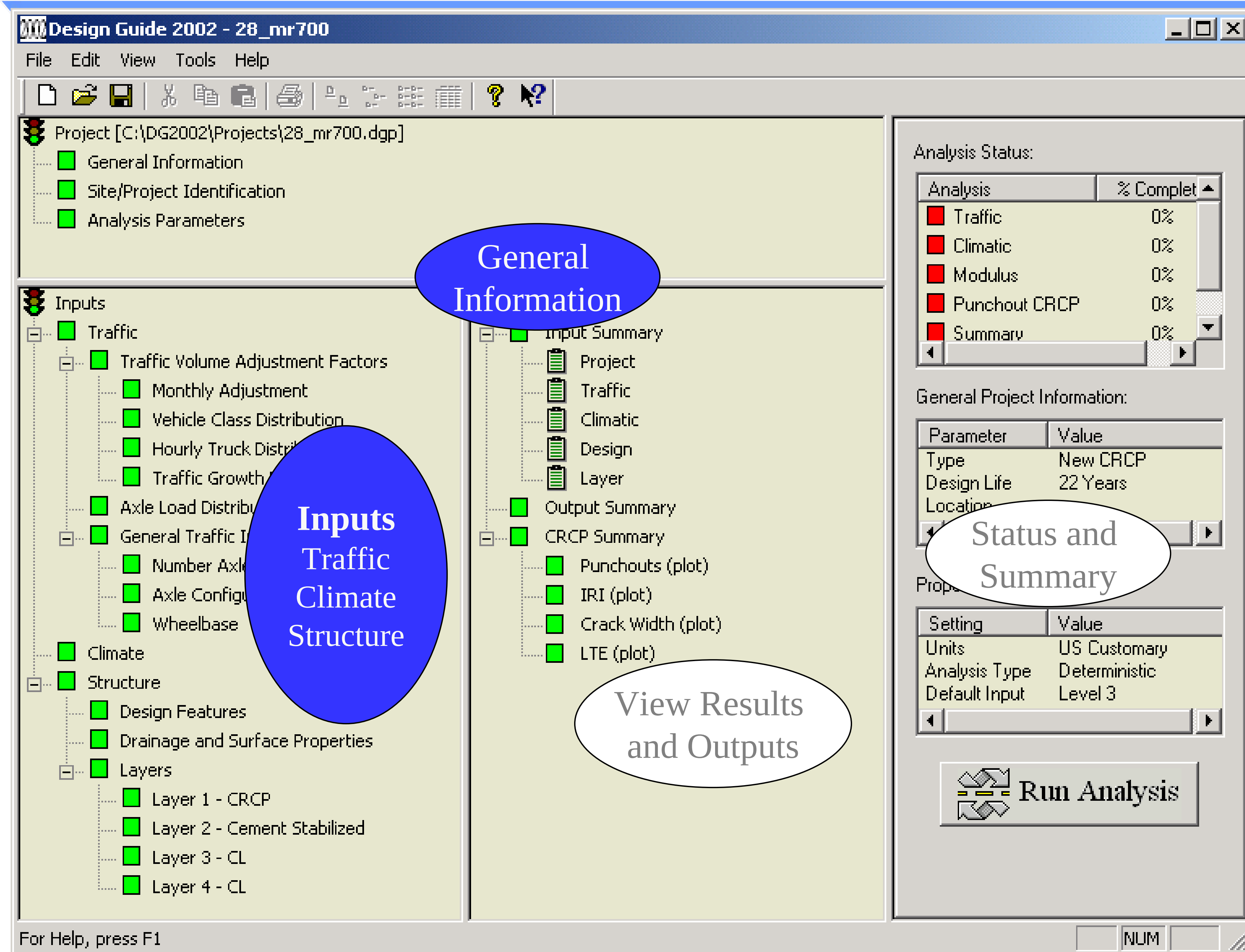
Develop and deliver:

***Guide for Design of New and Rehabilitated Pavements Structures,*** *based on existing mechanistic-empirical technology*, accompanied by the necessary computational software, for adoption and distribution by AASHTO.

# Overview of the MEPDG



# Design Guide Software


Design Guide 2002 - 28_mr700
File Edit View Tools Help
Project [C:\DG2002\Projects\28_mr700.dgp]
General Information
Site/Project Identification
Analysis Parameters
General Information
Inputs
Traffic
Traffic Volume Adjustment Factors
Monthly Adjustment
Vehicle Class Distribution
Hourly Truck Distri
Traffic Growth
Axle Load Distribu
General Traffic I
Number Axle
Axle Config
Wheelbase
Climate
Structure
Design Features
Drainage and Surface Properties
Layers
Layer 1 - CRCP
Layer 2 - Cement Stabilized
Layer 3 - CL
Layer 4 - CL
Inputs
Traffic
Climate
Structure
Input Summary
Project
Traffic
Climatic
Design
Layer
Output Summary
CRCP Summary
Punchouts (plot)
IRI (plot)
Crack Width (plot)
LTE (plot)
View Results and Outputs
Analysis Status:
Analysis
% Complet
Traffic 0%
Climatic 0%
Modulus 0%
Punchout CRCP 0%
Summary 0%
General Project Information:
Parameter
Value
Type New CRCP
Design Life 22 Years
Location
Status and Summary
Prop
Setting
Value
Units US Customary
Analysis Type Deterministic
Default Input Level 3
Run Analysis
For Help, press F1
NUM

# Key Advantage of M-E Design

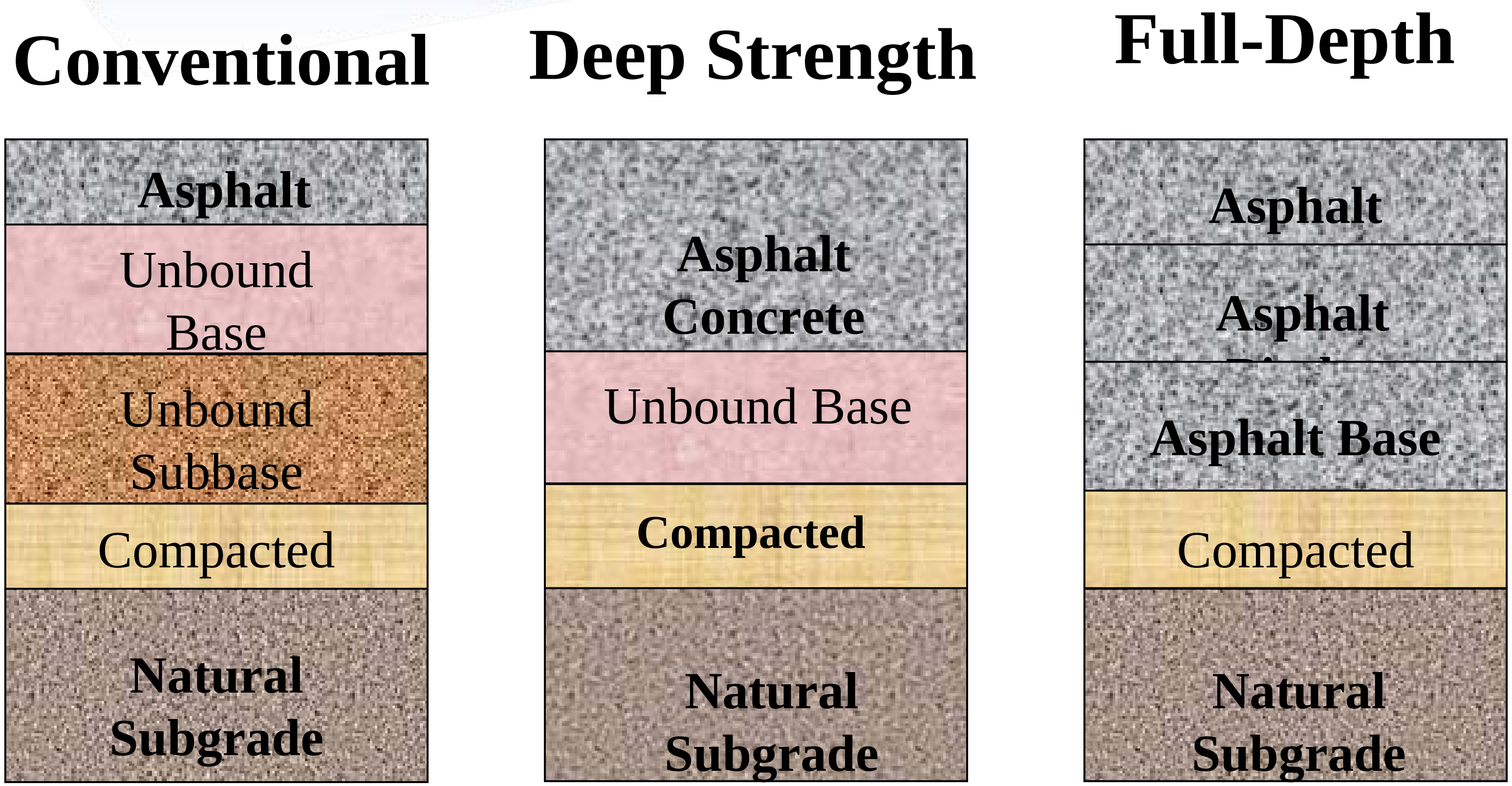
**"Comprehensive" design procedure:**

**Not Just Thickness!**

M-E models directly consider true effects and interactions of inputs on structural distress and ride quality.

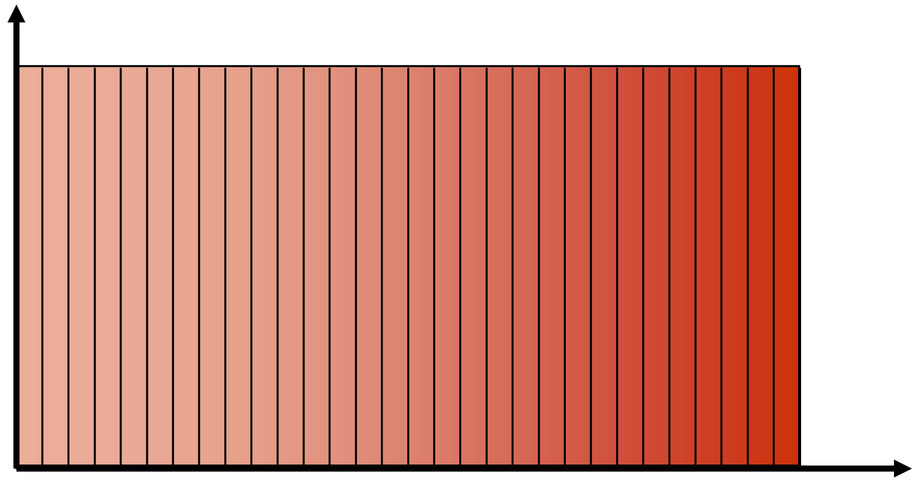
Design optimization possible where all distress types are minimized!

# Flexible Pavements



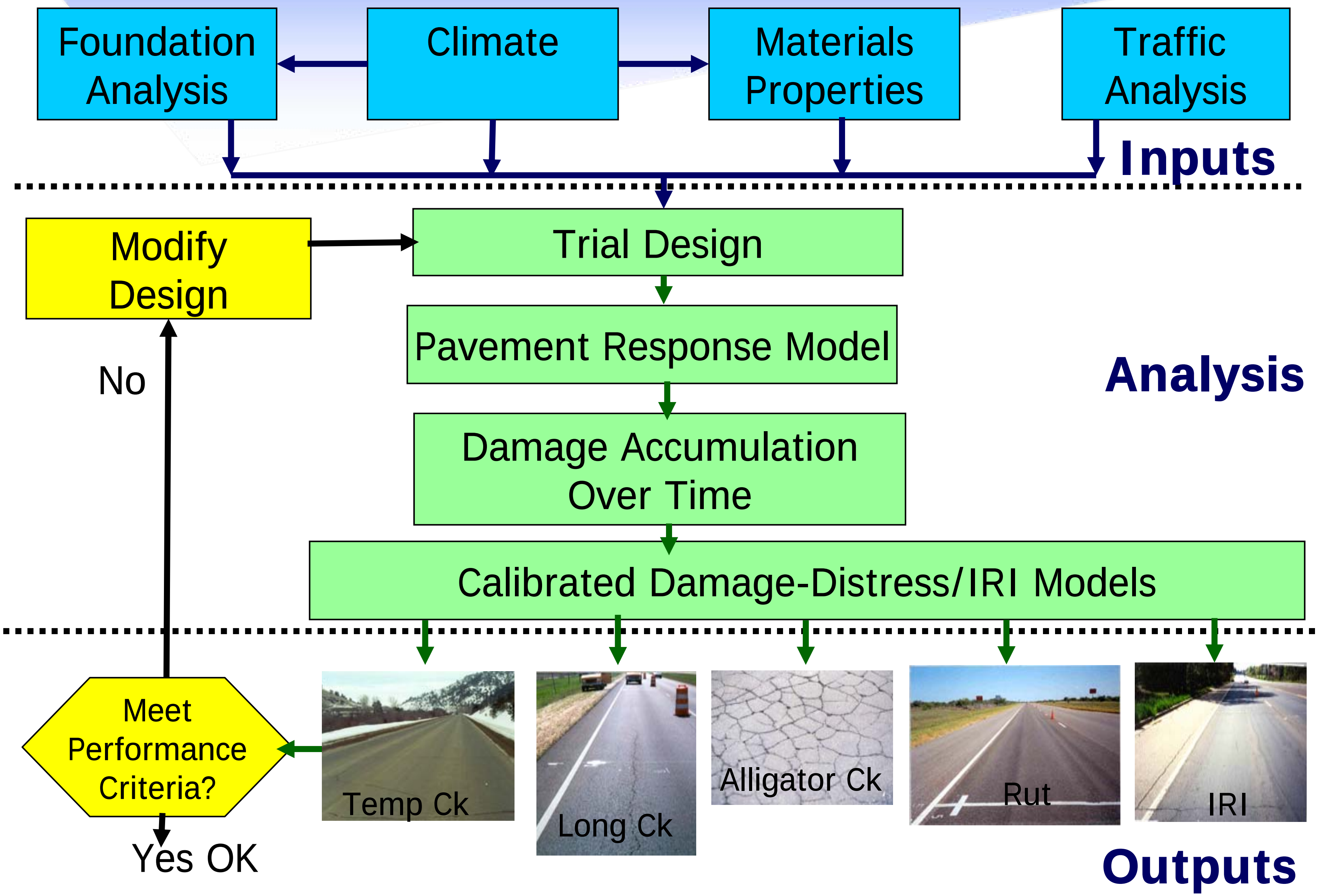
# Damage Accumulation - Incremental Damage Concept

- Design life is divided into time increments of:
  - 1 month for rigid pavements
  - 15 days for flexible pavements



Design life

# Design Process



# Design Inputs – 3 Main Categories

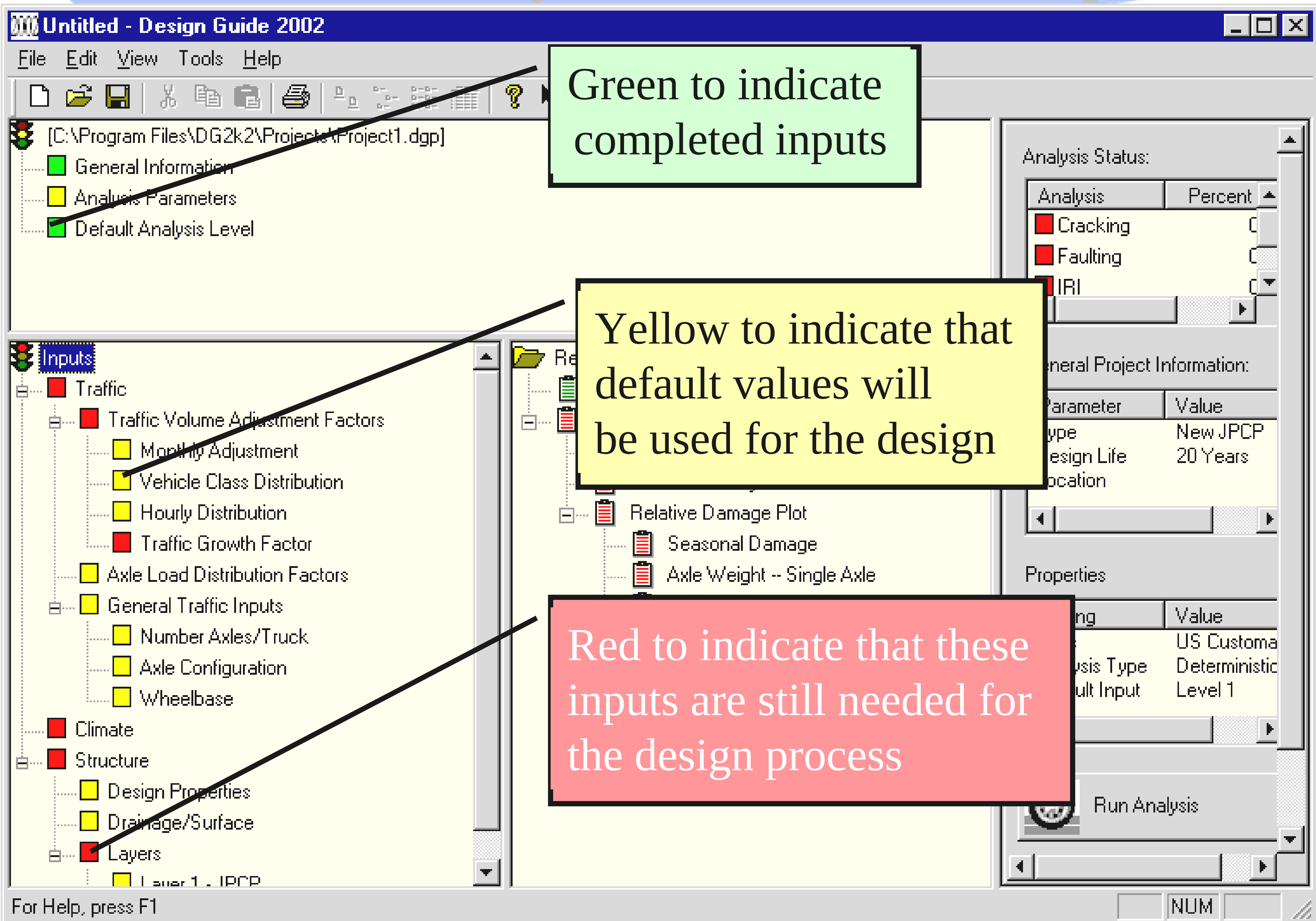
- Traffic
  - Volume
  - Axle load distribution
  - Axle configuration
- Climate
  - Latitude, longitude, elevation, etc.
- Structure
  - Layers, thicknesses, and material properties

# Input Levels

The Design Guide includes three levels to obtain inputs to facilitate use and implementation.

| Input Level | Determination of Input Values | Knowledge of Input Parameter |
|---|---|---|
| 1 | Project/Segment Specific Measurements—Lab, WIM, FWD | Good |
| 2 | Correlations/Regression Equations, Regional Values—CBR, R-Value, Dynamic Cone Penetrometer | Fair |
| 3 | Soil Classifications, Typical values | Fair - Poor |

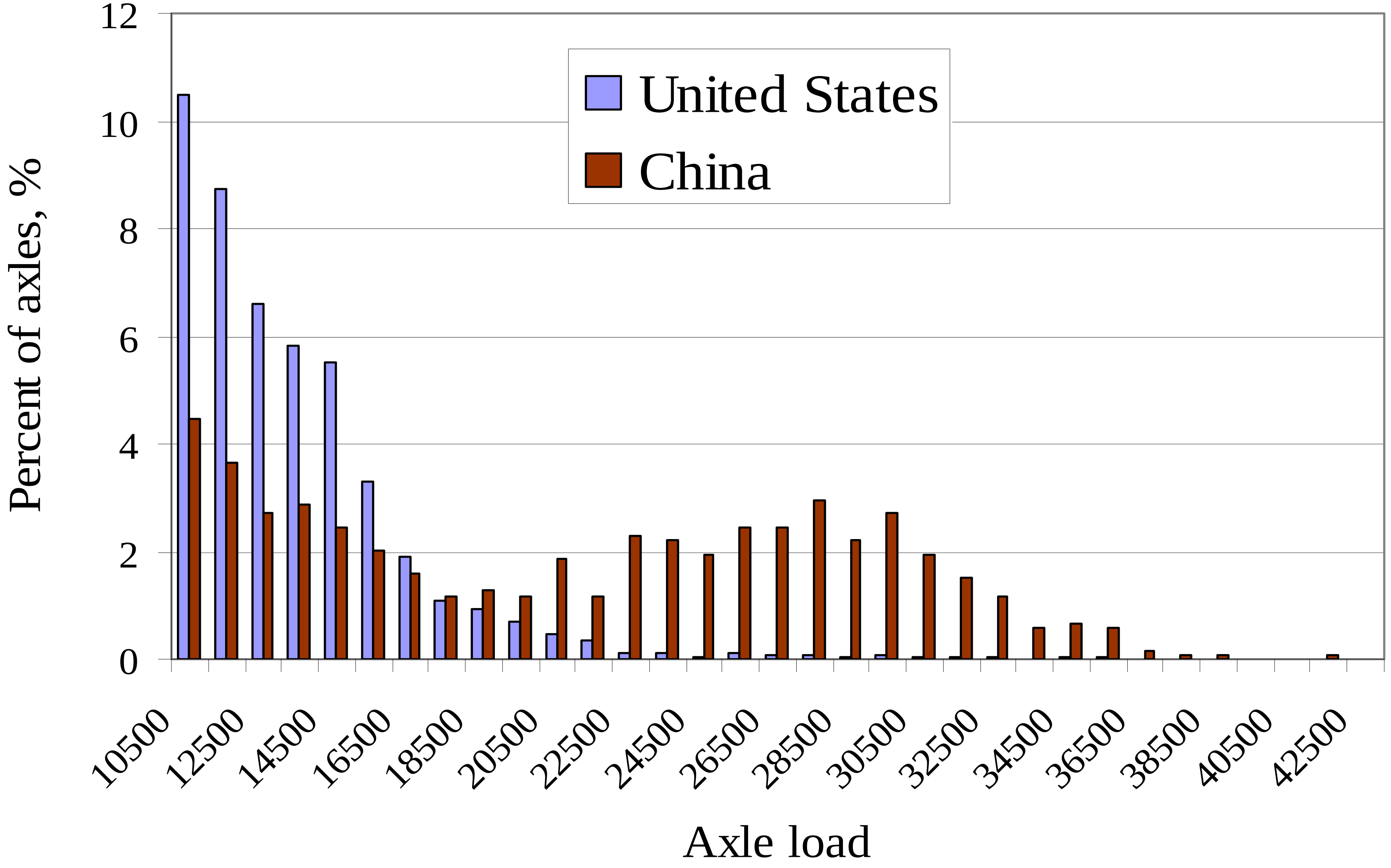
# User-Friendly Color-Coded Inputs



# Traffic Loading Inputs

- Vehicle volume, growth & classification
- Single, tandem, tridem, quad axle load distributions
- Monthly vehicle distribution
- Hourly load distribution
- Lateral lane distribution
- Tire pressure
- Tractor wheelbase
- Truck speed

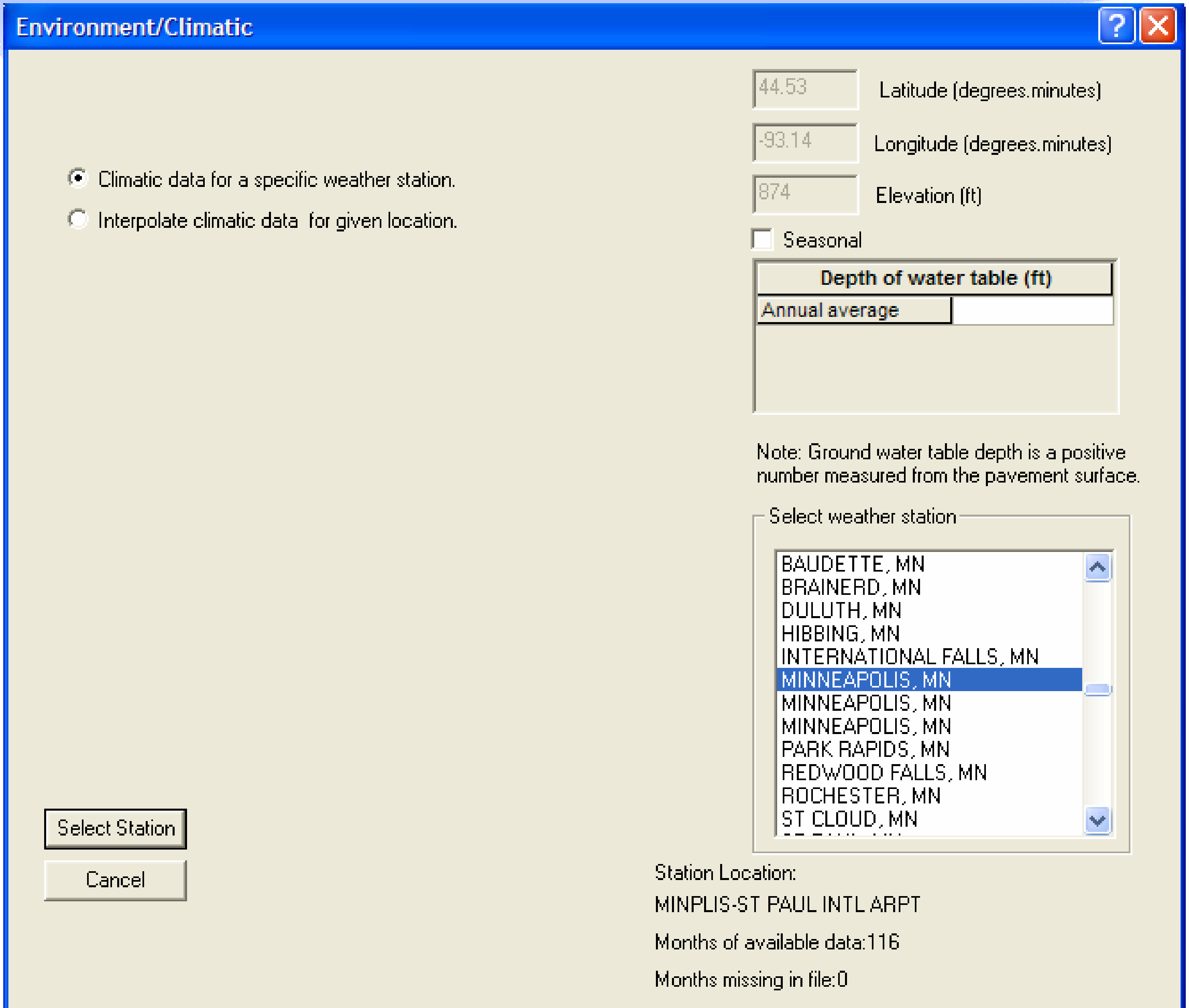
# Axle Load Spectrum (Single Axles)



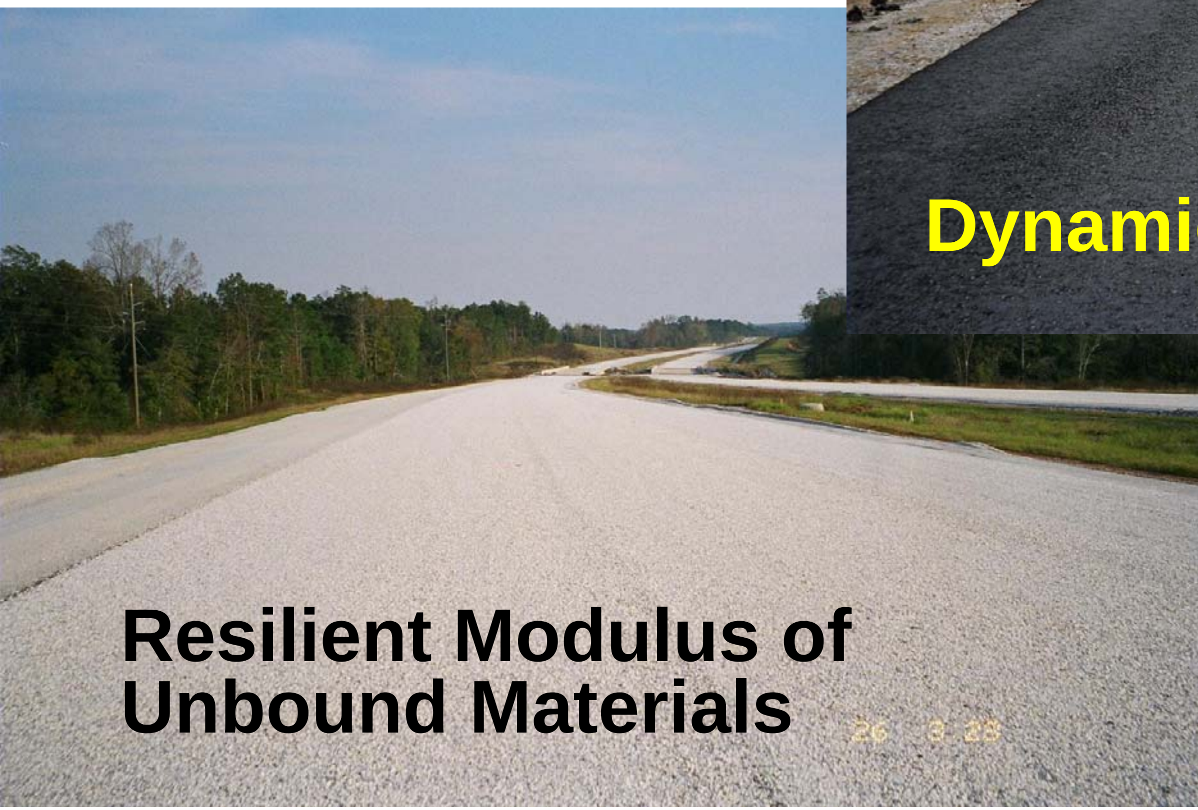
# Climate Inputs

- Hourly climatic data: Weather Stations
  - Temperature
  - Precipitation
  - Wind speed
  - Cloud cover
  - Relative ambient humidity
- Water table level

# Simplified Climatic Inputs

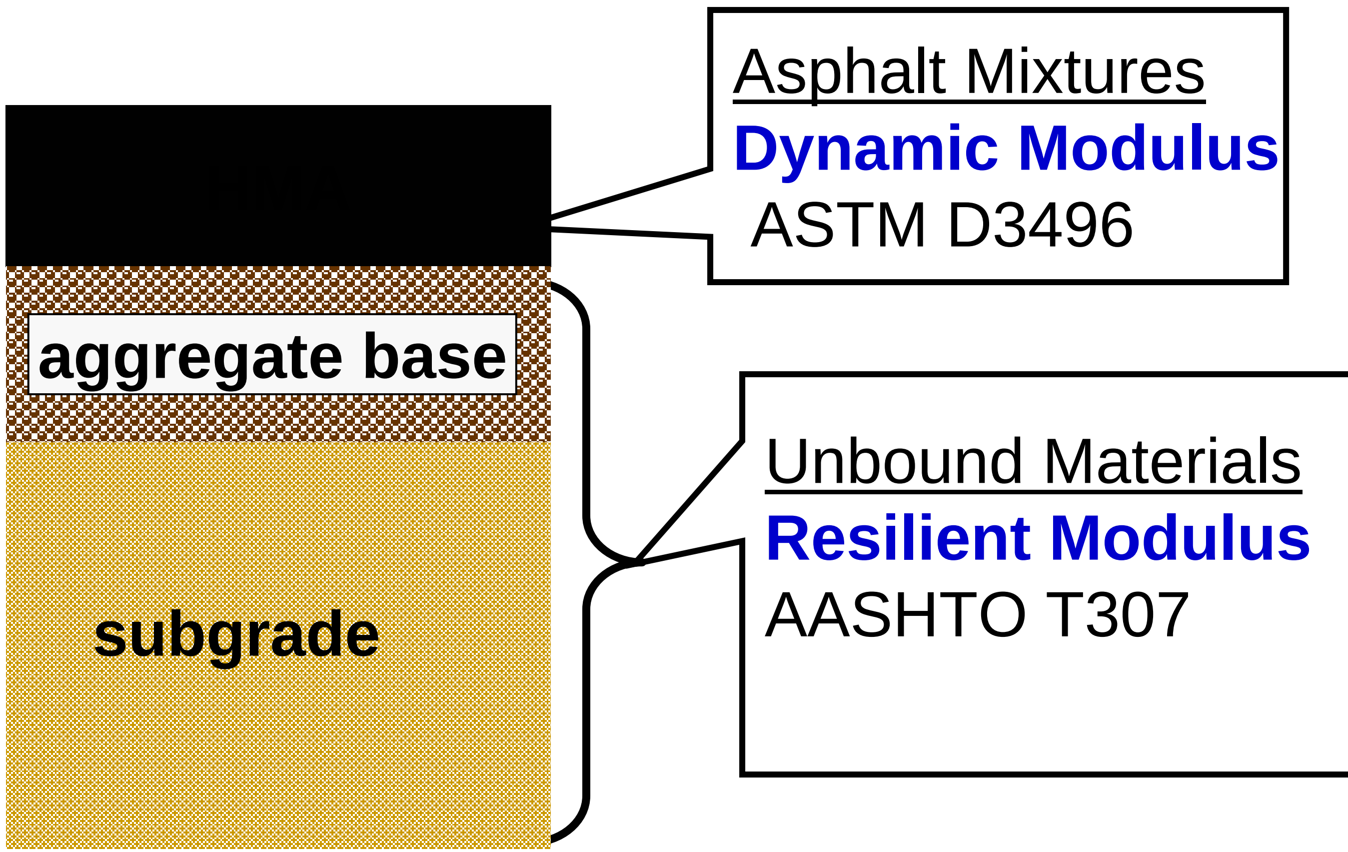


# Materials Inputs


Material modulus & volumetrics are key properties.

# Layer Materials Characterization



# Empirical Relation for |E*|

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

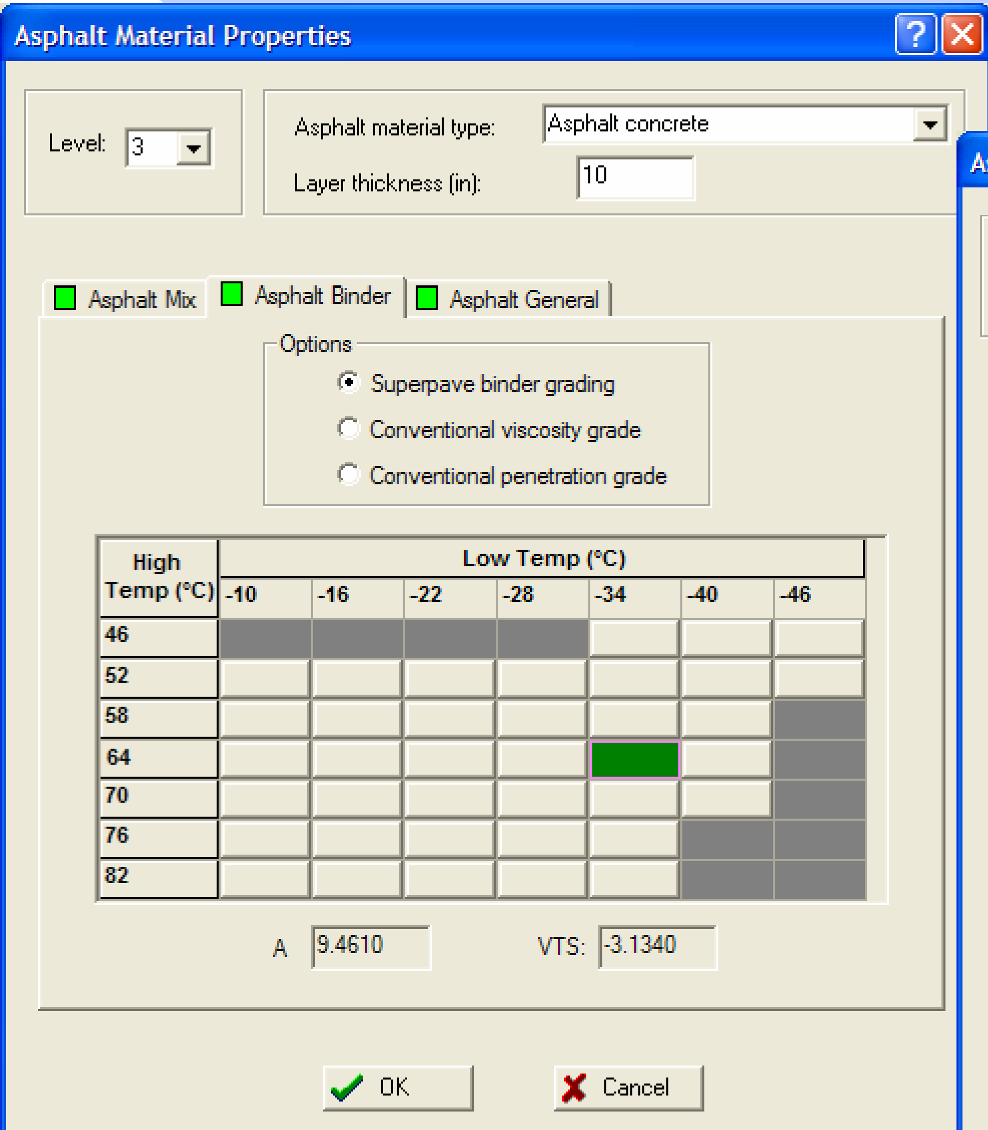
(2.3)

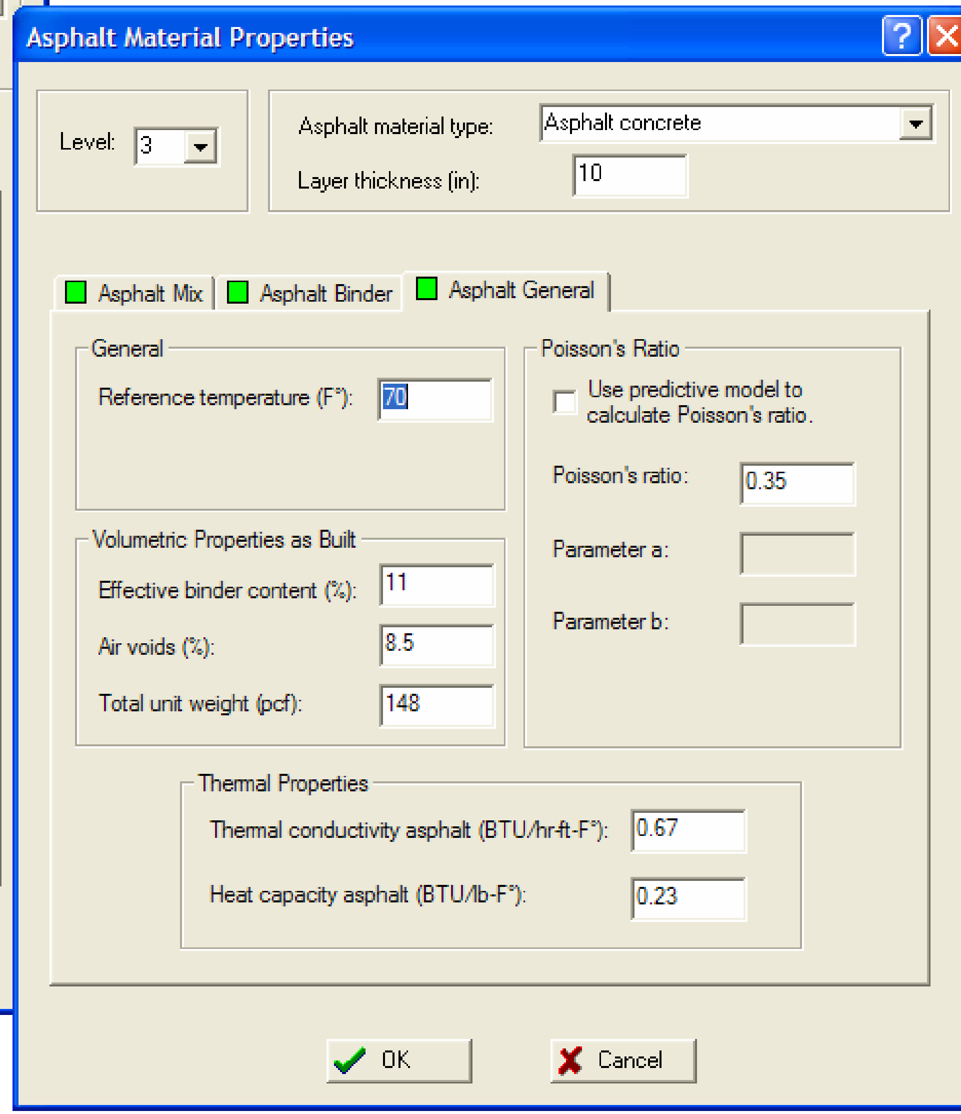
where:

| | | |
|---|---|---|
| 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 |
| $\rho_{34}$ | = | Cumulative % retained on the 19-mm sieve |
| $\rho_{38}$ | = | Cumulative % retained on the 9.5-mm sieve |
| $\rho_4$ | = | Cumulative % retained on the 4.76-mm sieve |
| $\rho_{200}$ | = | % passing the 0.075-mm sieve |

(Witczak *et al.*)

# Simplified Asphalt Materials Inputs (Level 3)

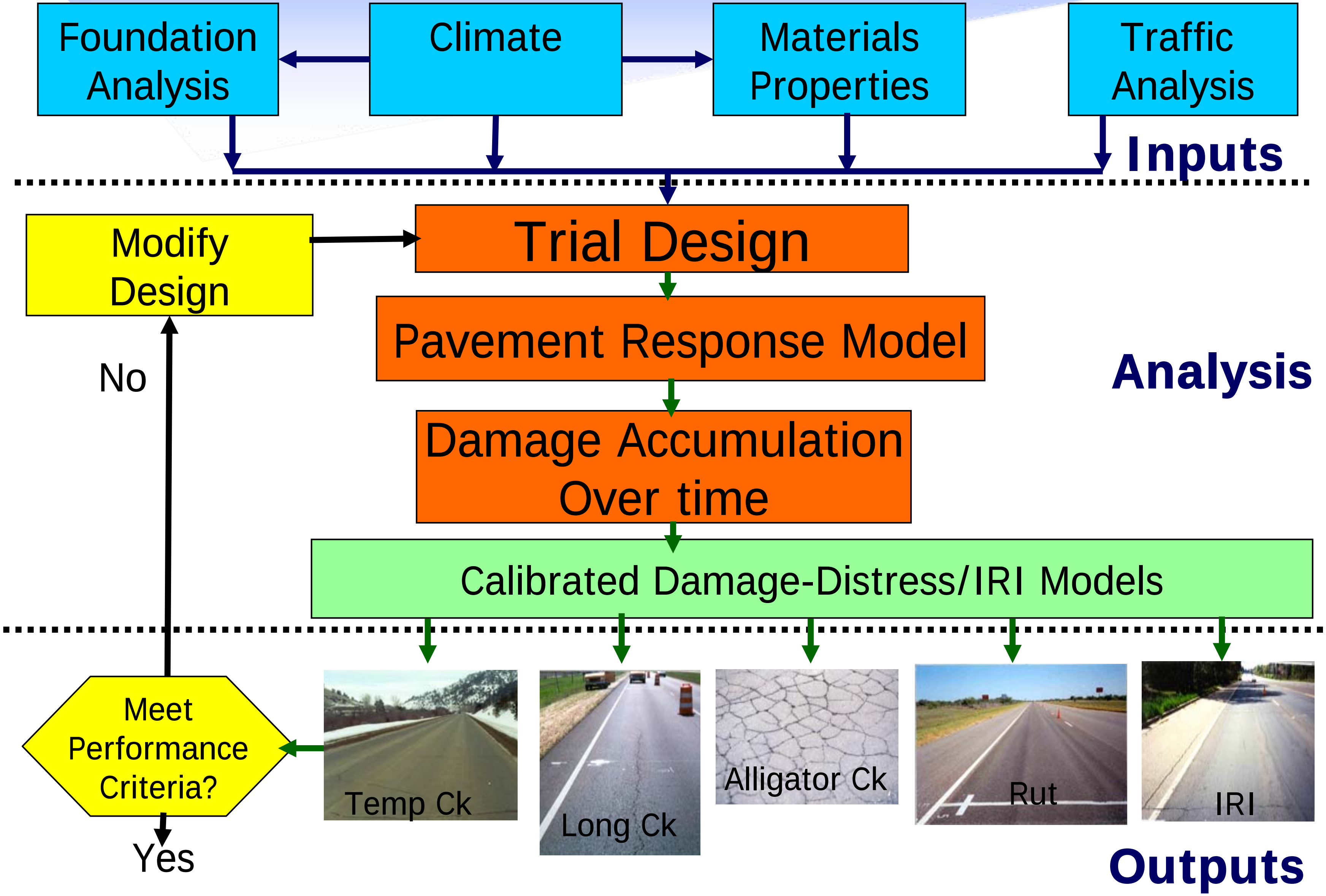


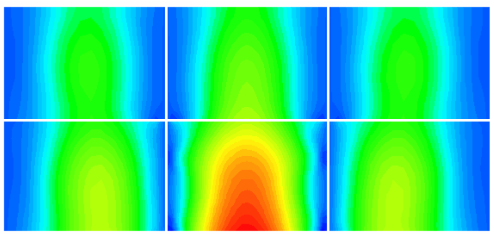
# Materials Testing: Unbound Base/Soils

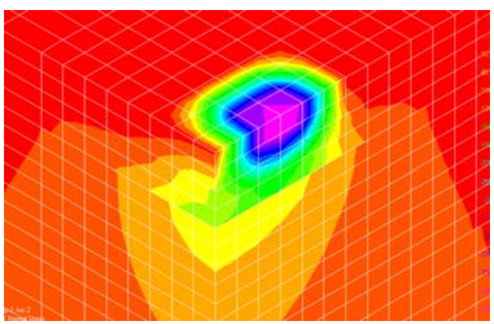
- Resilient modulus, Mr
  - Laboratory
  - Back-calculated from deflection data
- Or estimate from:
  - CBR,
  - R-Value, or
  - Dynamic Cone Penetration
  - Soil Classification

# Design Process



# Structural Response Models





- For rigid pavements
  - ISLAB2000—Finite Element Model (FEM) program
- For flexible pavements
  - JULEA—Linear elastic layered analysis program

# Cumulative Incremental Damage Approach

- Changes over time
  - Material strength and stiffness
    - Aging of asphalt
    - Moisture changes of soils & aggregates
    - Temperature changes & freezing
  - Traffic hourly, seasonally, and growth over time

# Matrix of Adjustment Coefficients For Resilient Moduli of Unbound Layers

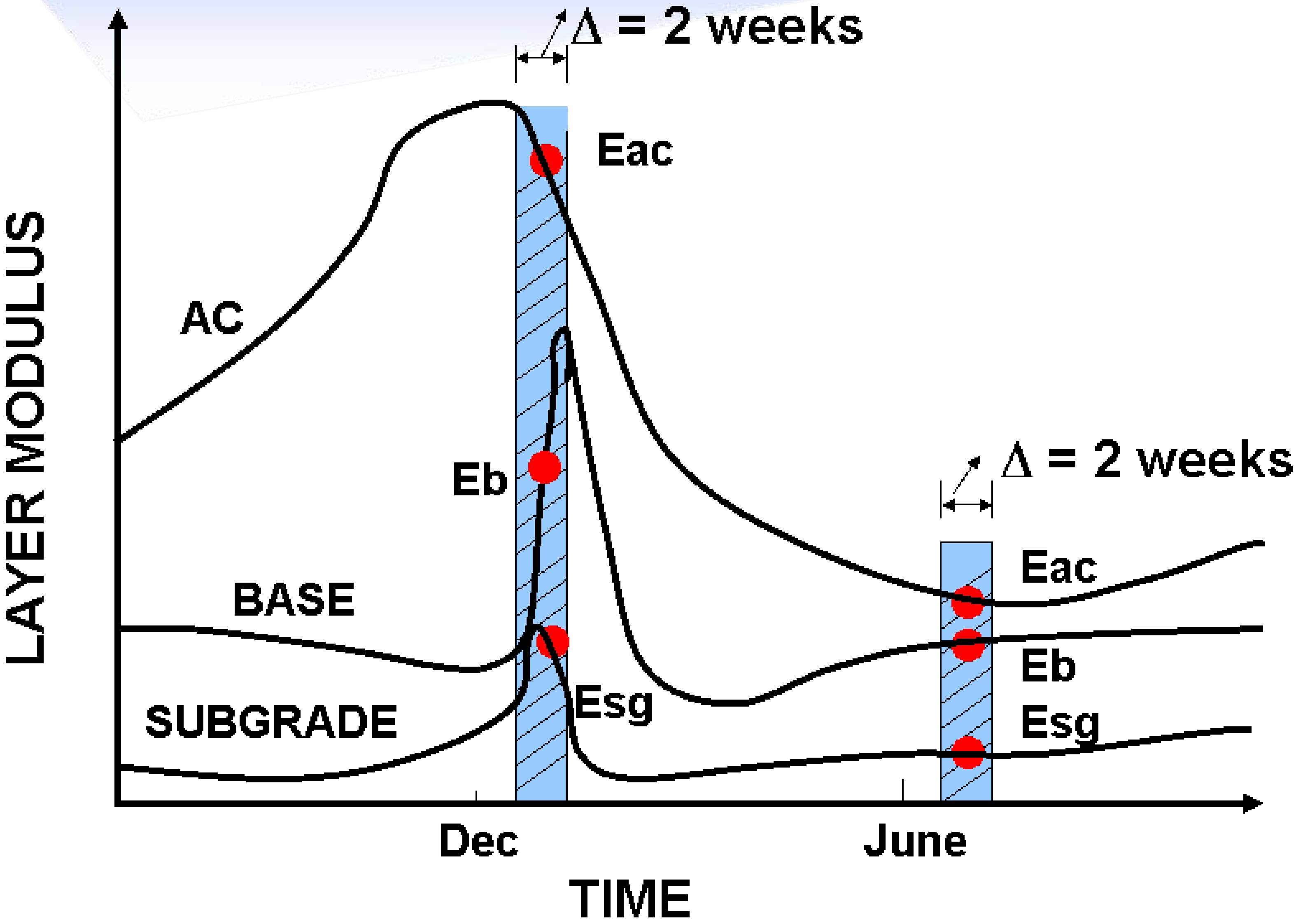
**LEGEND:**

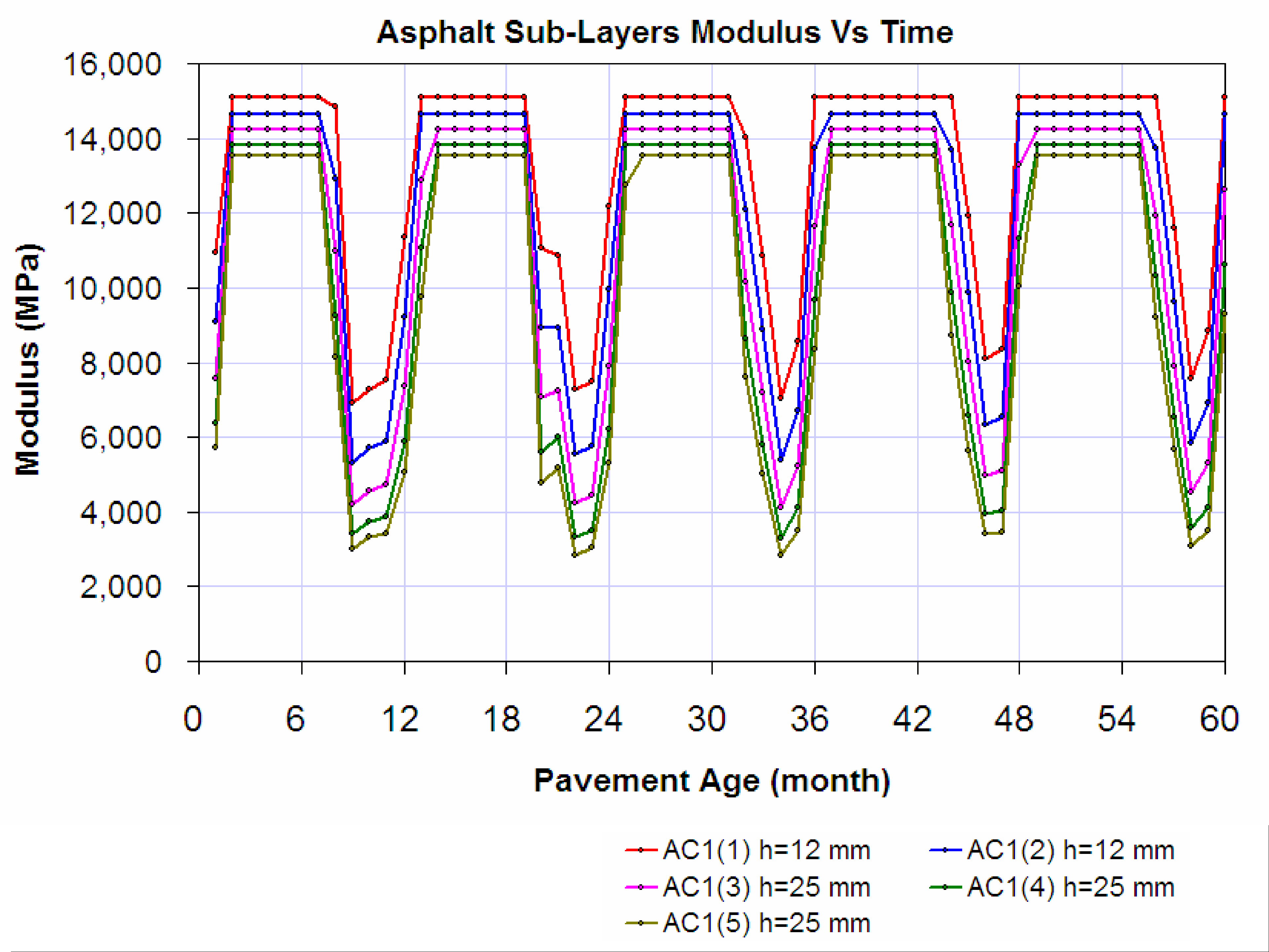
- FROZEN
- RECOVERING
- UNFROZEN

*Time (days)*

| *Nodes* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | *10* | *11* | *12* | *13* | *14* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *1* | | | | | | | | | | | | | | | AC |
| *2* | | | | | | | | | | | | | | | |
| *3* | *50* | *50* | *50* | *50* | *50* | *50* | *50* | *50* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | BASE |
| *4* | *50* | *50* | *50* | *50* | *50* | *50* | *50* | *50* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | |
| *5* | *50* | *50* | *50* | *50* | *50* | *50* | *50* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | |
| *6* | *50* | *50* | *50* | *50* | *50* | *50* | *50* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | |
| *7* | *50* | *50* | *50* | *50* | *50* | *50* | *50* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | |
| *8* | *50* | *50* | *50* | *50* | *50* | *50* | *50* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | |
| *9* | *75* | *75* | *75* | *75* | *75* | *75* | *75* | *0.6* | *0.6* | *0.6* | *0.6* | *0.6* | *0.6* | *0.6* | SUBBASE |
| *10* | *75* | *75* | *75* | *75* | *75* | *75* | *75* | *0.6* | *0.6* | *0.6* | *0.6* | *0.6* | *0.6* | *0.6* | |
| *11* | *75* | *75* | *75* | *75* | *75* | *75* | *0.6* | *0.6* | *0.6* | *0.6* | *0.6* | *0.6* | *0.6* | *0.7* | |
| *12* | *75* | *75* | *0.6* | *0.6* | *0.6* | *0.6* | *0.6* | *0.6* | *0.6* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | |
| *13* | *75* | *0.6* | *0.6* | *0.6* | *0.6* | *0.6* | *0.6* | *0.6* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | |
| *14* | *0.8* | *0.8* | *0.8* | *0.8* | *0.9* | *0.9* | *0.9* | *0.9* | *0.9* | *0.9* | *0.9* | *1* | *1* | *1* | |
| *15* | *0.8* | *0.8* | *0.8* | *0.9* | *0.9* | *0.9* | *0.9* | *0.9* | *0.9* | *0.9* | *1* | *1* | *1* | *1* | |
| *16* | *0.8* | *0.9* | *0.9* | *0.9* | *0.9* | *0.9* | *0.9* | *0.9* | *1* | *1* | *1* | *1* | *1* | *1* | |
| *17* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.9* | *0.9* | *0.9* | *0.9* | *0.9* | *0.9* | *0.9* | *0.9* | *0.9* | SUBGRADE |
| *18* | *0.7* | *0.7* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | |
| *19* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | |
| *20* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | |
| *21* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | |
| *22* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | *0.8* | |
| *23* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | |
| *24* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | *0.7* | |

# Annual Modulus Variability

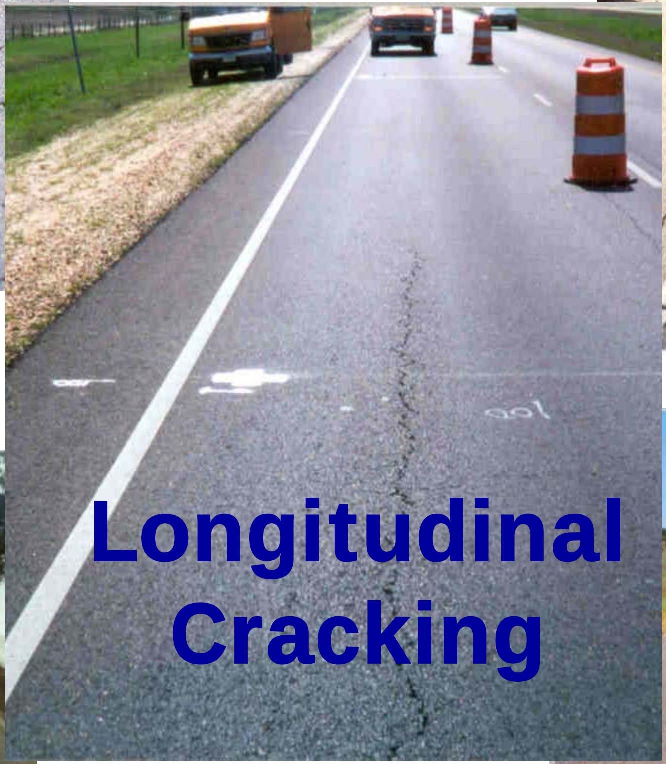


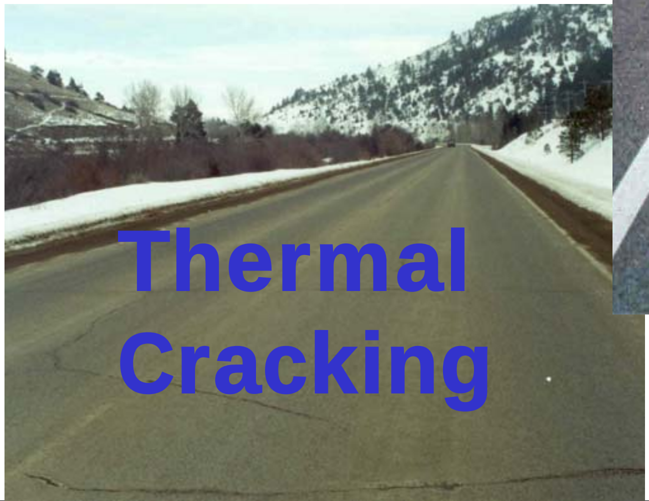


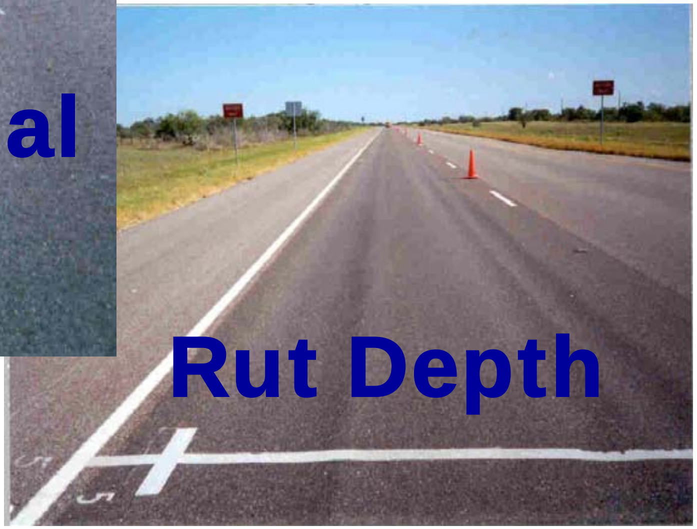
Asphalt Sub-Layers Modulus Vs Time
Modulus (MPa)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0
6
12
18
24
30
36
42
48
54
60
Pavement Age (month)
AC1(1) h=12 mm
AC1(2) h=12 mm
AC1(3) h=25 mm
AC1(4) h=25 mm
AC1(5) h=25 mm

# Flexible Pavement Performance





# Field Performance - The LTPP Study

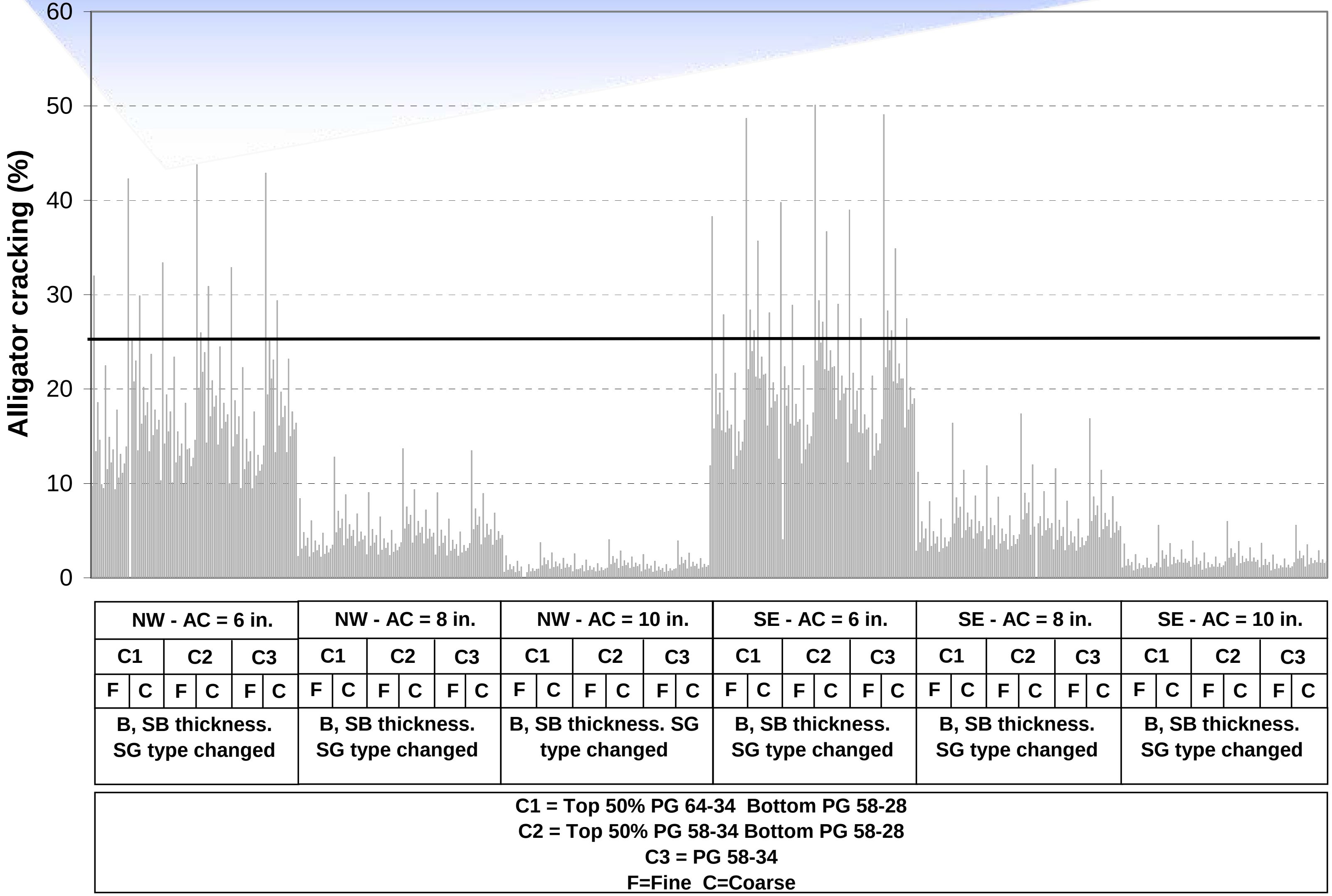
# Implementation of Design Guide

- Procedures to obtain each input
  - Traffic, climate, materials, structure, rehabilitation
- Conduct sensitivity studies
- Develop case studies of existing pavements
- Local calibration (varying climates within country) of distress & IRI models

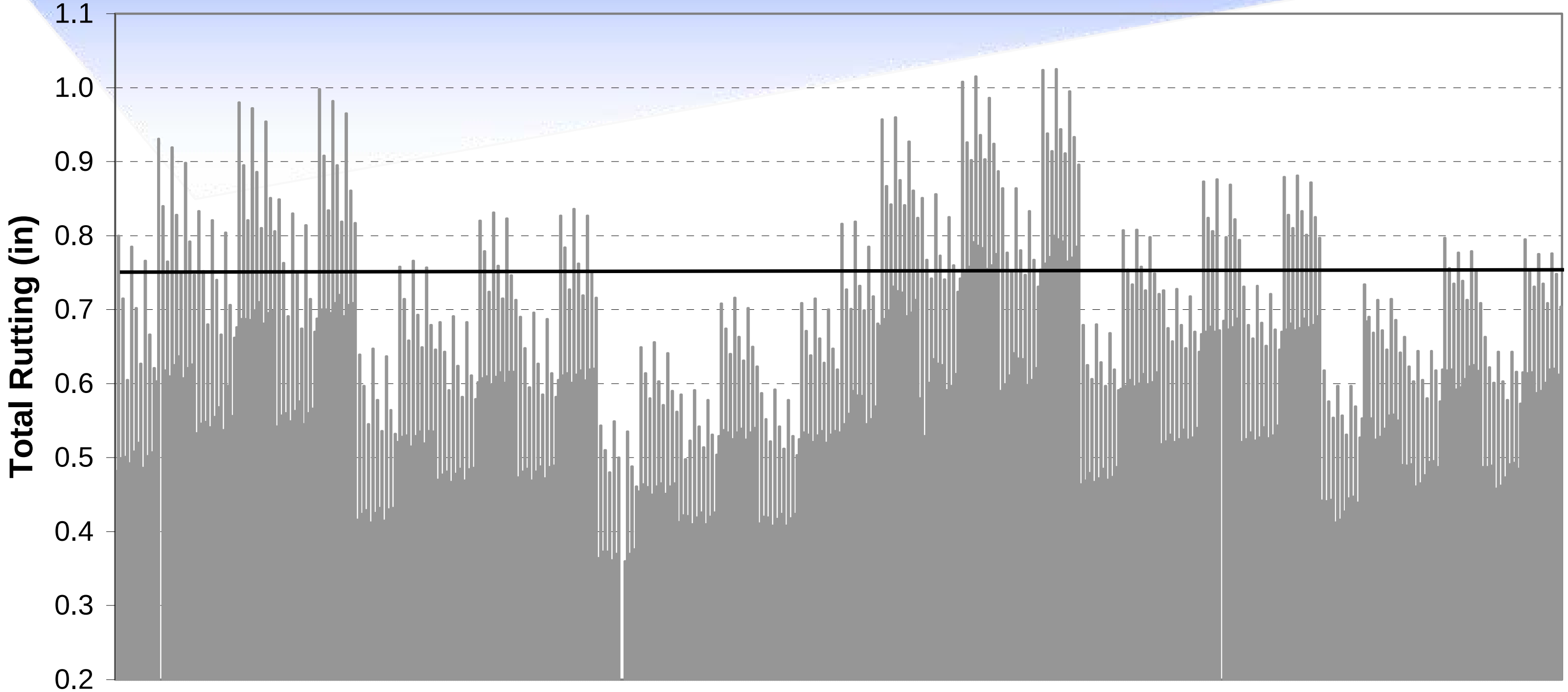
# Sensitivity Analysis – Minnesota Condition

- Design factorial
  - 768 projects
  - Traffic: 2-levels
    - High, approximately 10-million ESALs (AADTT=2000)
    - Low, approximately 1-million ESALs (AADTT=200)
  - Climate: 2-levels
    - Northwest (Grand Forks, ND) and Southeast (Rochester, MN)
- Comparison of performance predictions

# Alligator Cracking, V 0.900, 10 Million ESALs



# Total Rutting, V 0.900, 10 Million ESALs

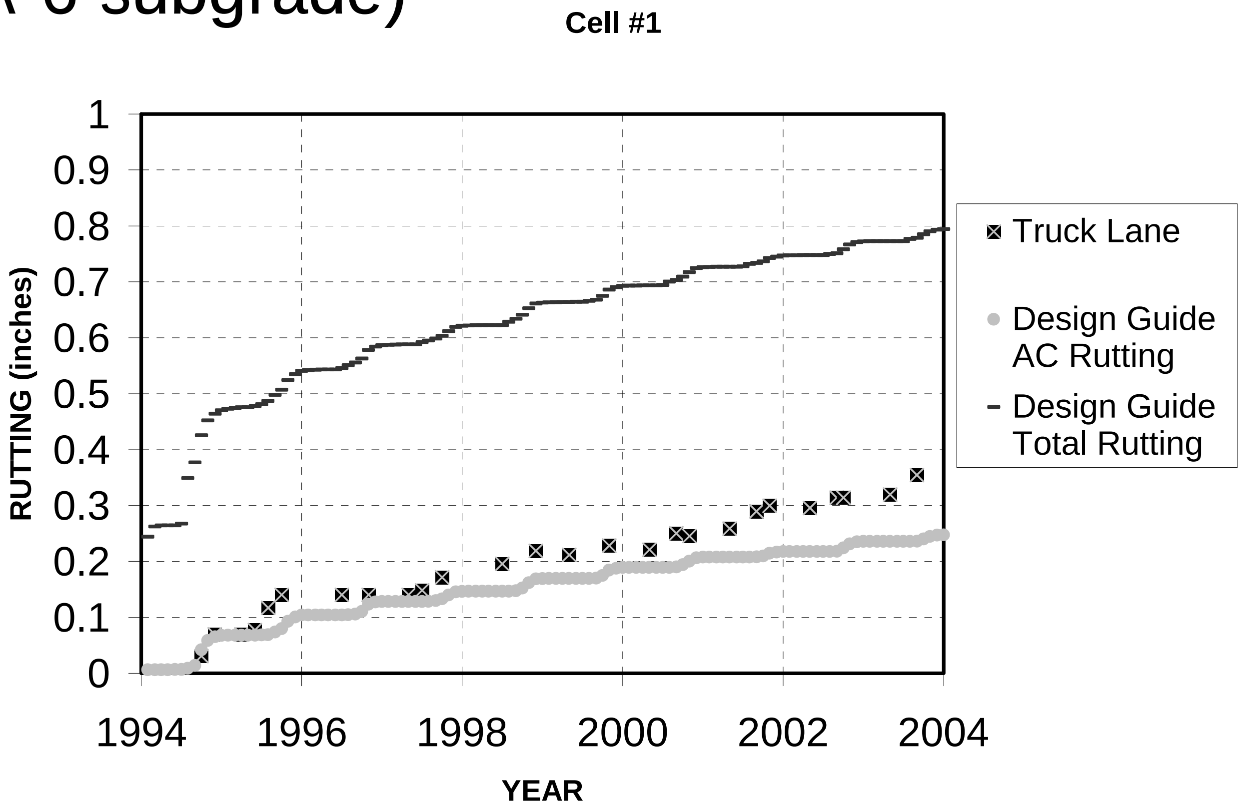



| NW - AC = 6 in. | NW - AC = 8 in. | NW - AC = 10 in. | SE - AC = 6 in. | SE - AC = 8 in. | SE - AC = 10 in. |
|---|---|---|---|---|---|
| C1 C2 C3 | C1 C2 C3 | C1 C2 C3 | C1 C2 C3 | C1 C2 C3 | C1 C2 C3 |
| F C F C F C | F C F C F C | F C F C F C | F C F C F C | F C F C F C | F C F C F C |
| B, SB thickness. SG type changed | B, SB thickness. SG type changed | B, SB thickness. SG type changed | B, SB thickness. SG type changed | B, SB thickness. SG type changed | B, SB thickness. SG type changed |

C1 = Top 50% PG 64-34 Bottom PG 58-28
C2 = Top 50% PG 58-34 Bottom PG 58-28
C3 = PG 58-34
F=Fine C=Coarse

# Comparison with Measured Distresses

– MEPDG predictions were compared to the observed distresses for MnROAD cell 1 (5.9- in AC layer over a 33-in thick granular base resting on an A-6 subgrade)



# Benefits of the 2002 Guide, cont.

- Accounts for many factors that change over time (traffic, climate, materials)
- Allows the prediction of key distress types as well as roughness over time
- Improved traffic characterization
- Improved structural modeling capabilities
- Improved materials characterization

# Status of Design Guide

- 1st Version completed April 2004
- National review July 2004 – December 2005
- Many software & engineering improvements by ARA & ASU.
- Latest **Version 1.0** will be available April 1

# More Information

Transportation Research Board web site:

www.trb.org/mepdg

- Guide Documentation
- Software
- Climatic database