

# 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

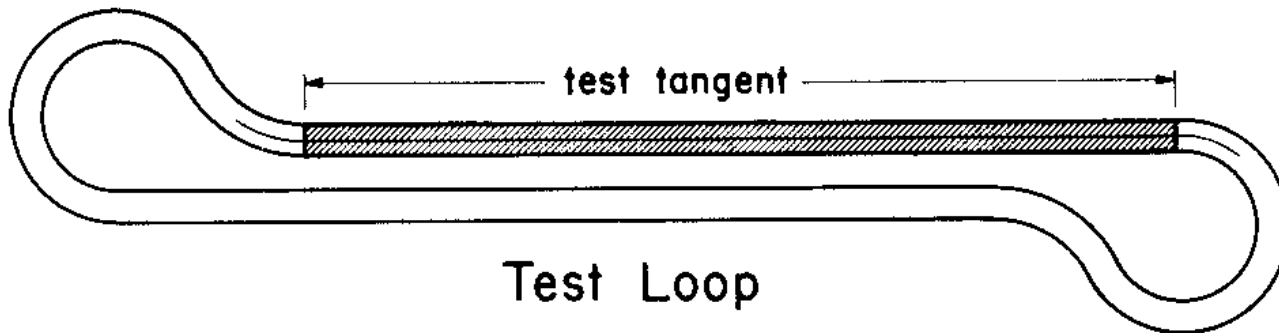
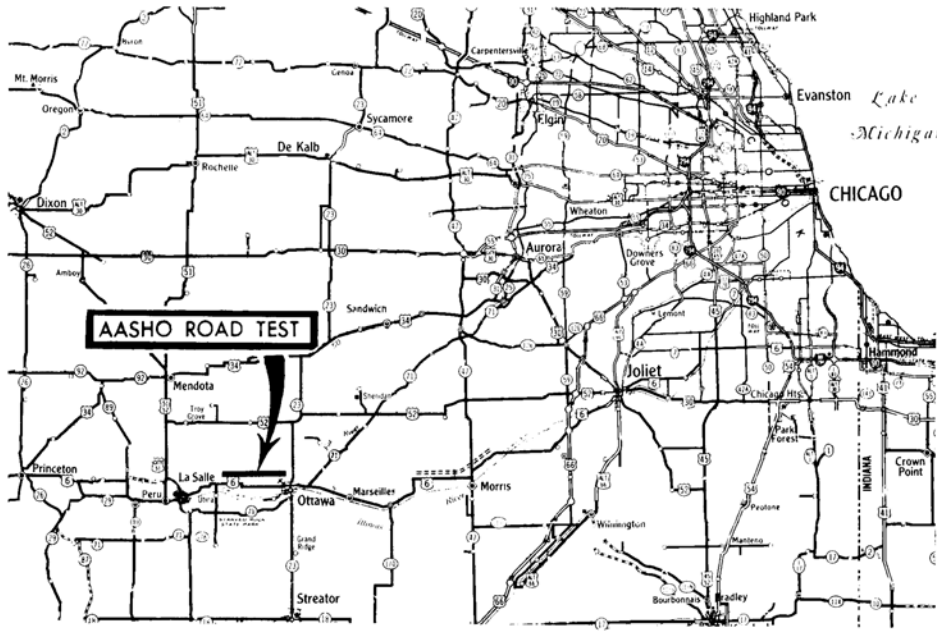
- History of the current design procedure
- Limitation of the current design guide
- Needs for new design procedure
- Background of the new mechanistic-empirical design procedure

# 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

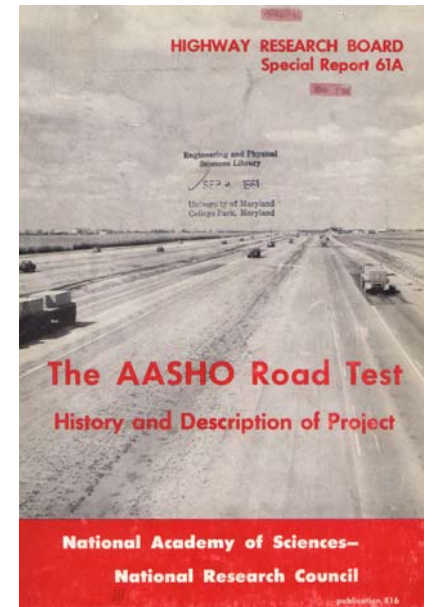


# AASHO Road Test (late 1950's)



Test Loop

(AASHO, 1961)



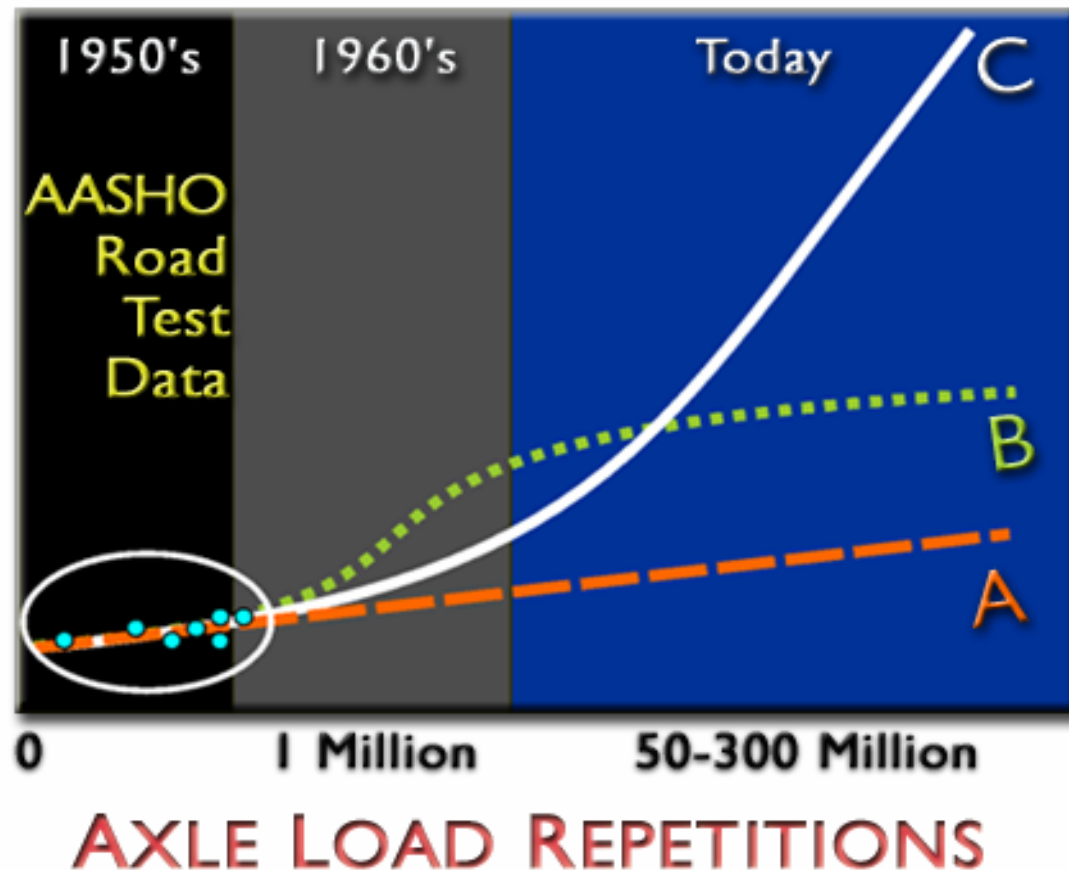
# AASHO Road Test Location



Ottawa, IL

# Low Traffic Levels...

## PAVEMENT THICKNESS



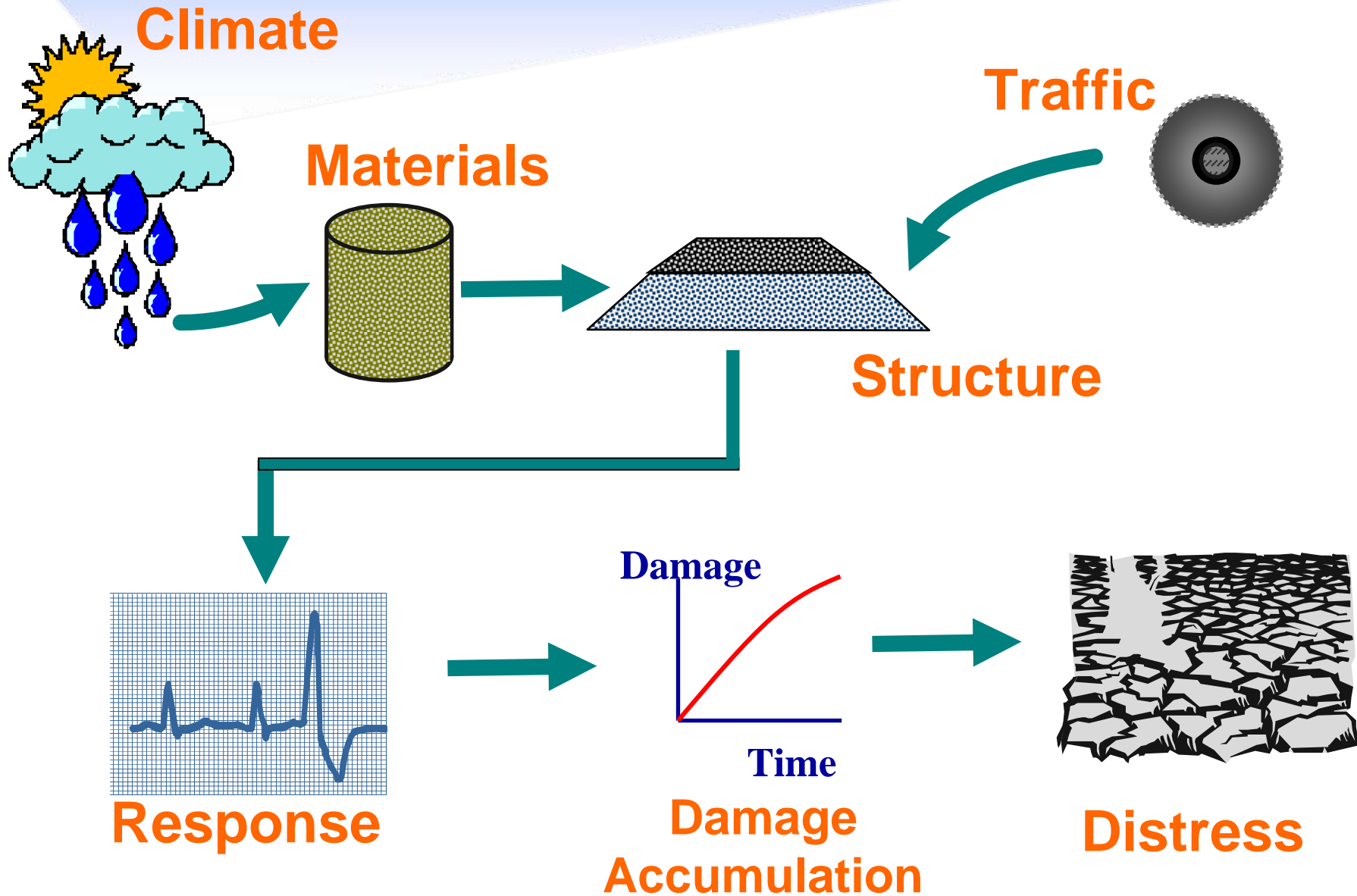


# NCHRP Project 1-37A Objective

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





- 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 Distribution
      - Traffic Growth
    - Axle Load Distribution
    - General Traffic Input
      - Number Axles
      - Axle Configuration
      - 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
  - Punchouts (plot)
  - IRI (plot)
  - Crack Width (plot)
  - LTE (plot)
- CRCP Summary

View Results  
and Outputs

Analysis Status:

Analysis	% Complete
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

Properties

Setting	Value
Units	US Customary
Analysis Type	Deterministic
Default Input	Level 3

 Run Analysis



# Key Advantage of M-E Design

**“Comprehensive” design procedure:**

**Not Just Thickness!**

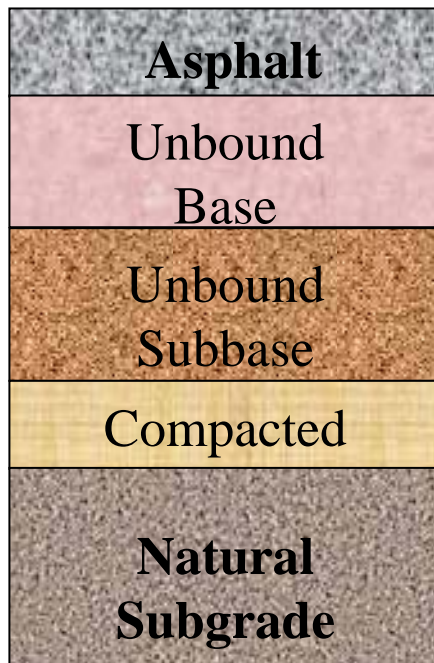
M-E models directly consider true effects and interactions of inputs on structural distress and ride quality.

Design optimization possible where all distress types are minimized!

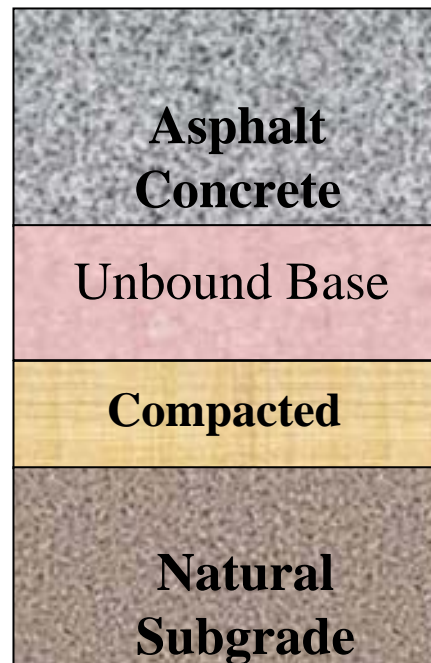


# Flexible Pavements

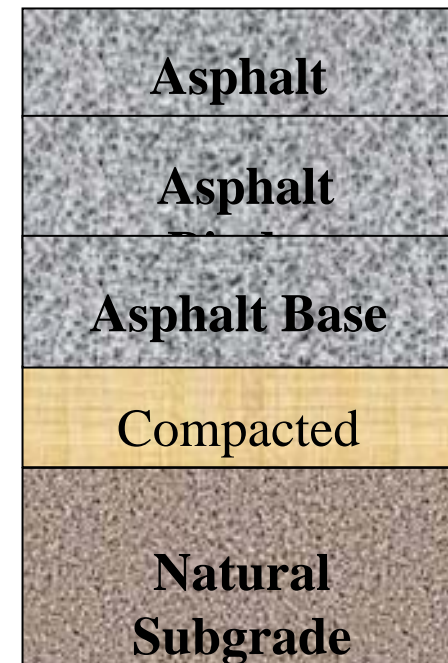
## Conventional



## Deep Strength

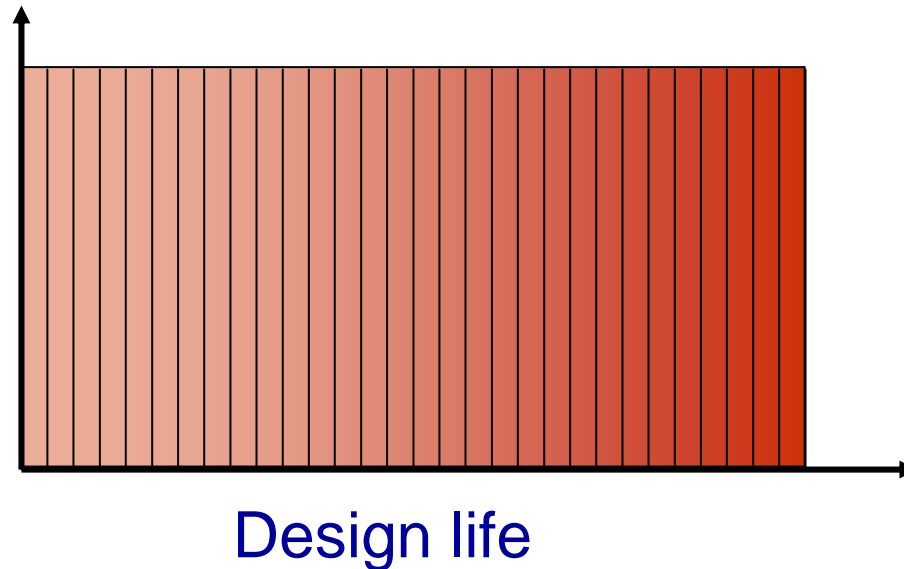


## Full-Depth

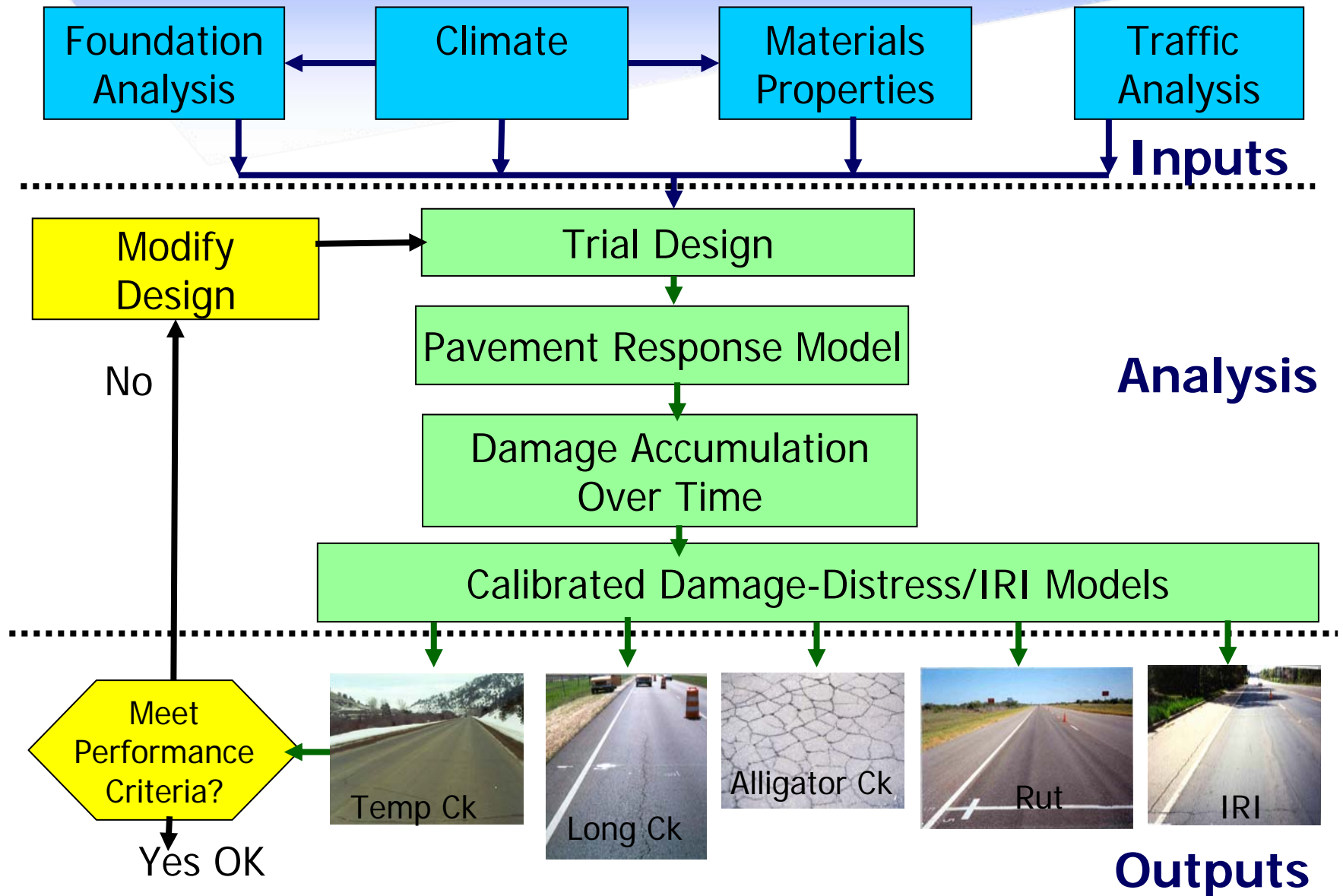


# Damage Accumulation - Incremental Damage Concept

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



# 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

The screenshot displays the 'Untitled - Design Guide 2002' application window. The interface includes a menu bar (File, Edit, View, Tools, Help), a toolbar, and a project tree on the left. The project tree shows a hierarchy of inputs: General Information (green), Analysis Parameters (yellow), and Default Analysis Level (green). The 'Inputs' section is expanded, showing various input categories like Traffic, Climate, and Structure, each with its own set of sub-inputs. The 'Analysis Status' panel on the right shows a table of analysis results, including Cracking, Faulting, and IRI, with a 'Percent' column. The 'General Project Information' panel shows a table of project parameters, including Type, Design Life, and Location. The 'Properties' panel shows a table of input values, including US Customary, Analysis Type, and Default Input. The 'Run Analysis' button is visible at the bottom right.

Green to indicate completed inputs

Yellow to indicate that default values will be used for the design

Red to indicate that these inputs are still needed for the design process

Analysis	Percent
Cracking	
Faulting	
IRI	

Parameter	Value
Type	New JPCP
Design Life	20 Years
Location	

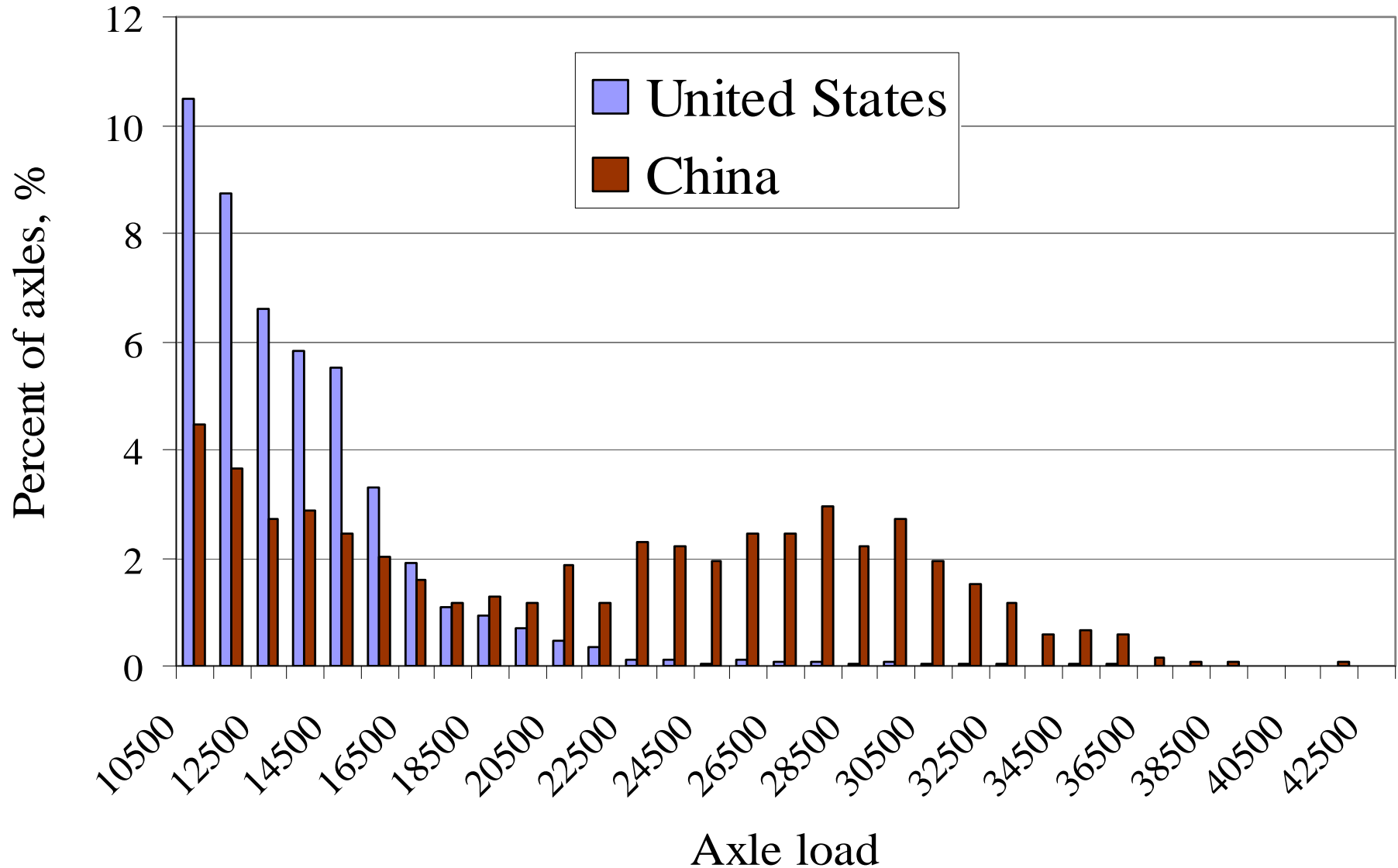
Property	Value
Design Type	US Customary
Analysis Type	Deterministic
Default Input	Level 1

# 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



**Environment/Climatic**

☒ Climatic data for a specific weather station.  
☐ Interpolate climatic data for given location.

Latitude (degrees.minutes)

Longitude (degrees.minutes)

Elevation (ft)

☐ Seasonal

Depth of water table (ft)	
Annual average	<input type="text"/>

Note: Ground water table depth is a positive number measured from the pavement surface.

Select weather station

- BAUDETTE, MN
- BRAINERD, MN
- DULUTH, MN
- HIBBING, MN
- INTERNATIONAL FALLS, MN
- MINNEAPOLIS, MN**
- MINNEAPOLIS, MN
- MINNEAPOLIS, MN
- PARK RAPIDS, MN
- REDWOOD FALLS, MN
- ROCHESTER, MN
- ST CLOUD, MN

Select Station

Cancel

Station Location:  
MINPLIS-ST PAUL INTL ARPT

Months of available data:116

Months missing in file:0

44.53	Latitude (degrees.minutes)
-93.14	Longitude (degrees.minutes)
874	Elevation (ft)

Depth of water table (ft)	
Annual average	

- Select weather station

Select Station

Cancel

Station Location:

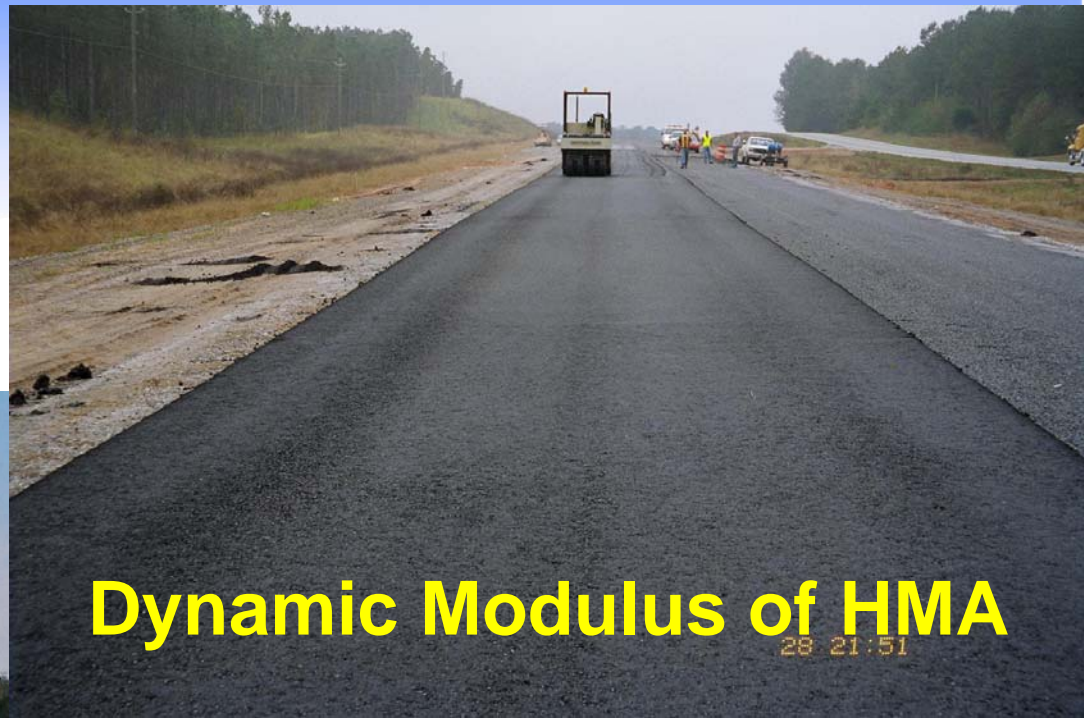
MINPLIS-ST PAUL INTL ARPT

Months of available data:116

Months missing in file:0

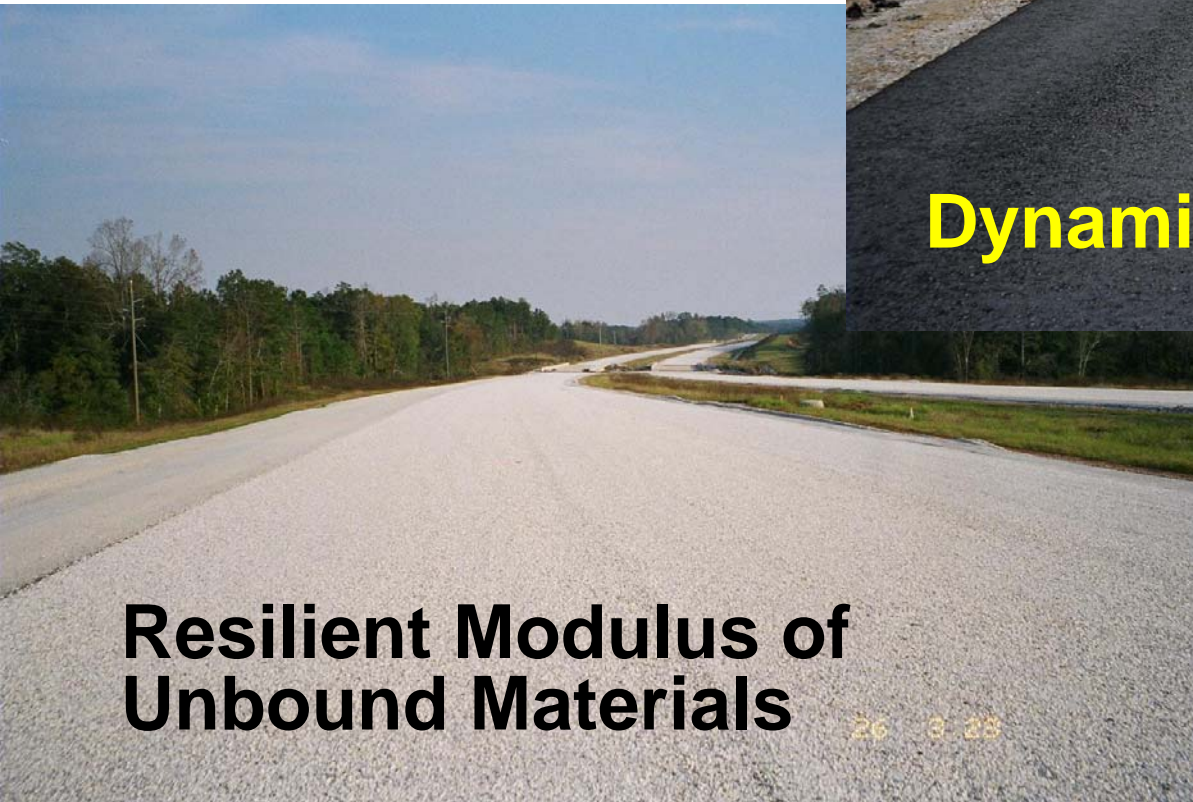


# Materials Inputs



**Dynamic Modulus of HMA**

28 21:51



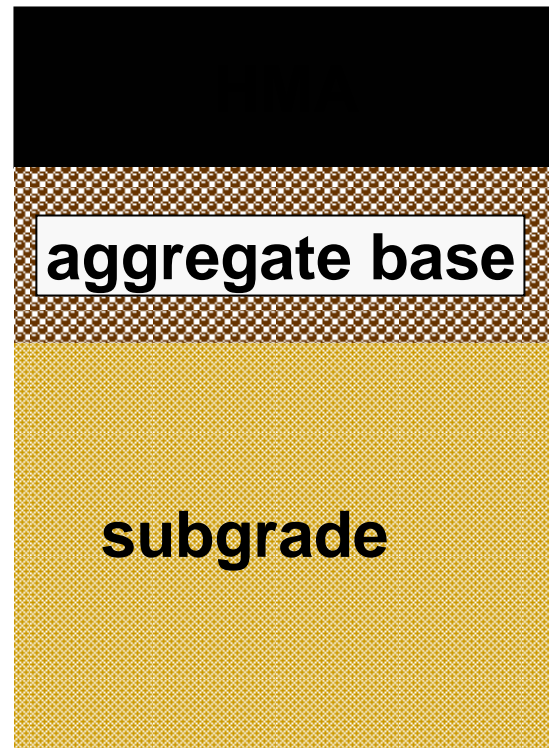
**Resilient Modulus of  
Unbound Materials**

26 3:23

Material modulus  
& volumetrics  
are key  
properties.



# Layer Materials Characterization



Asphalt Mixtures  
**Dynamic Modulus**  
ASTM D3496

Unbound Materials  
**Resilient Modulus**  
AASHTO T307

# Empirical Relation for $|E^*|$

$$\log E = -1.249937 + 0.29232 \rho_{200} - 0.001767(\rho_{200})^2 - 0.002841 \rho_4 - 0.058097 V_a$$

$$- 0.802208 \left( \frac{V_{beff}}{V_{beff} + V_a} \right) + \frac{3.871977 - 0.0021 \rho_4 + 0.003958 \rho_{38} - 0.000017(\rho_{38})^2 + 0.005470 \rho_{34}}{1 + e^{(-0.6033 \cdot 3 - 0.313351 \log(f) - 0.393532 \log(\eta))}}$$

(2.3)

where:

$E$	=	Dynamic modulus, $10^5$ psi
$\eta$	=	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)

**Asphalt Material Properties**

Level:  Asphalt material type:  Layer thickness (in):

☒ Asphalt Mix ☒ Asphalt Binder ☒ Asphalt General

Options

- ☒ Superpave binder grading
- ☐ Conventional viscosity grade
- ☐ Conventional penetration grade

High Temp (°C)	Low Temp (°C)						
	-10	-16	-22	-28	-34	-40	-46
46							
52							
58							
64							
70							
76							
82							

A  VTS:

☒ OK ☒ Cancel

**Asphalt Material Properties**

Level:  Asphalt material type:  Layer thickness (in):

☒ Asphalt Mix ☒ Asphalt Binder ☒ Asphalt General

General

Reference temperature (F°):

Poisson's Ratio

☐ Use predictive model to calculate Poisson's ratio.

Poisson's ratio:

Parameter a:

Parameter b:

Volumetric Properties as Built

Effective binder content (%):

Air voids (%):

Total unit weight (pcf):

Thermal Properties

Thermal conductivity asphalt (BTU/hr-ft-F°):

Heat capacity asphalt (BTU/lb-F°):

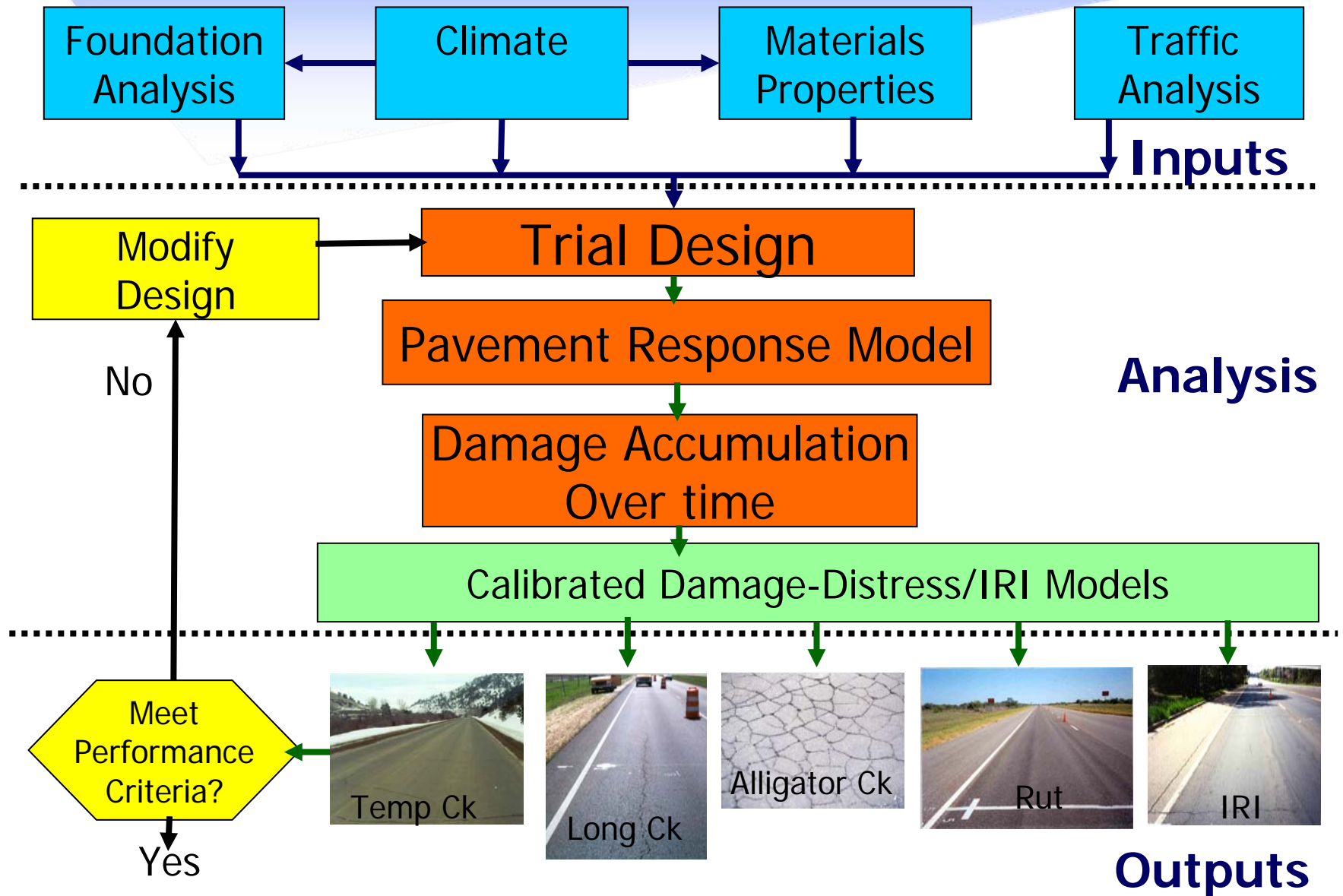
☒ OK ☒ Cancel

# Materials Testing: Unbound Base/Soils

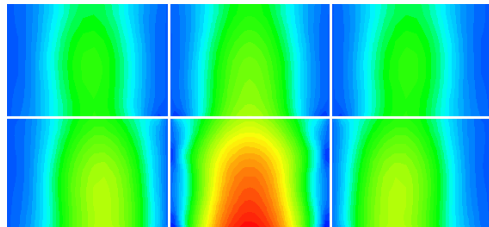


- Resilient modulus,  $M_r$ 
  - Laboratory
  - Back-calculated from deflection data
- Or estimate from:
  - CBR,
  - R-Value, or
  - Dynamic Cone Penetration
  - Soil Classification

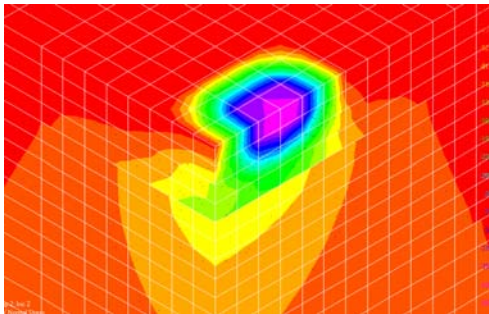
# Design Process



# 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

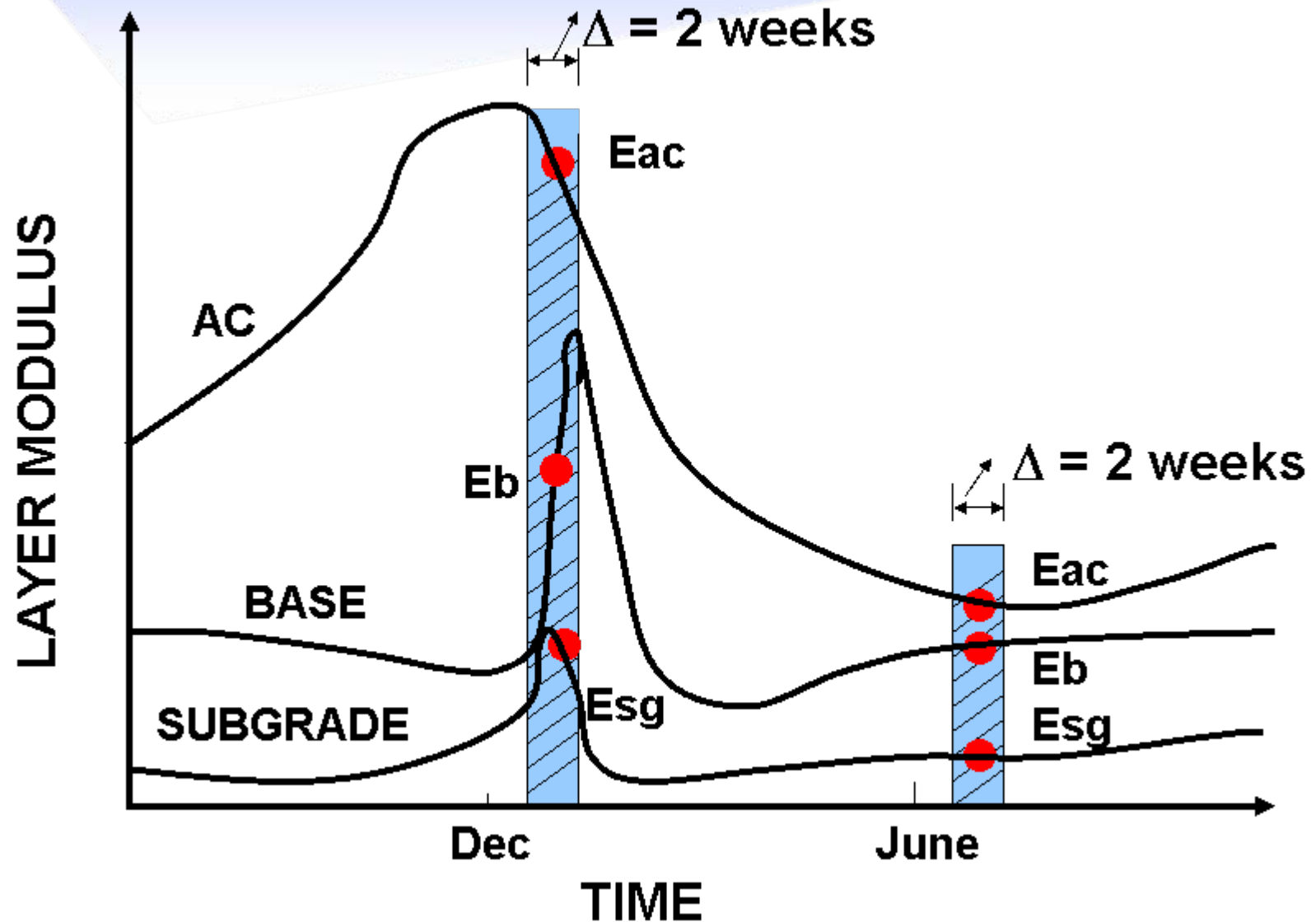
## LEGEND:

FROZEN  
RECOVERING  
UNFROZEN

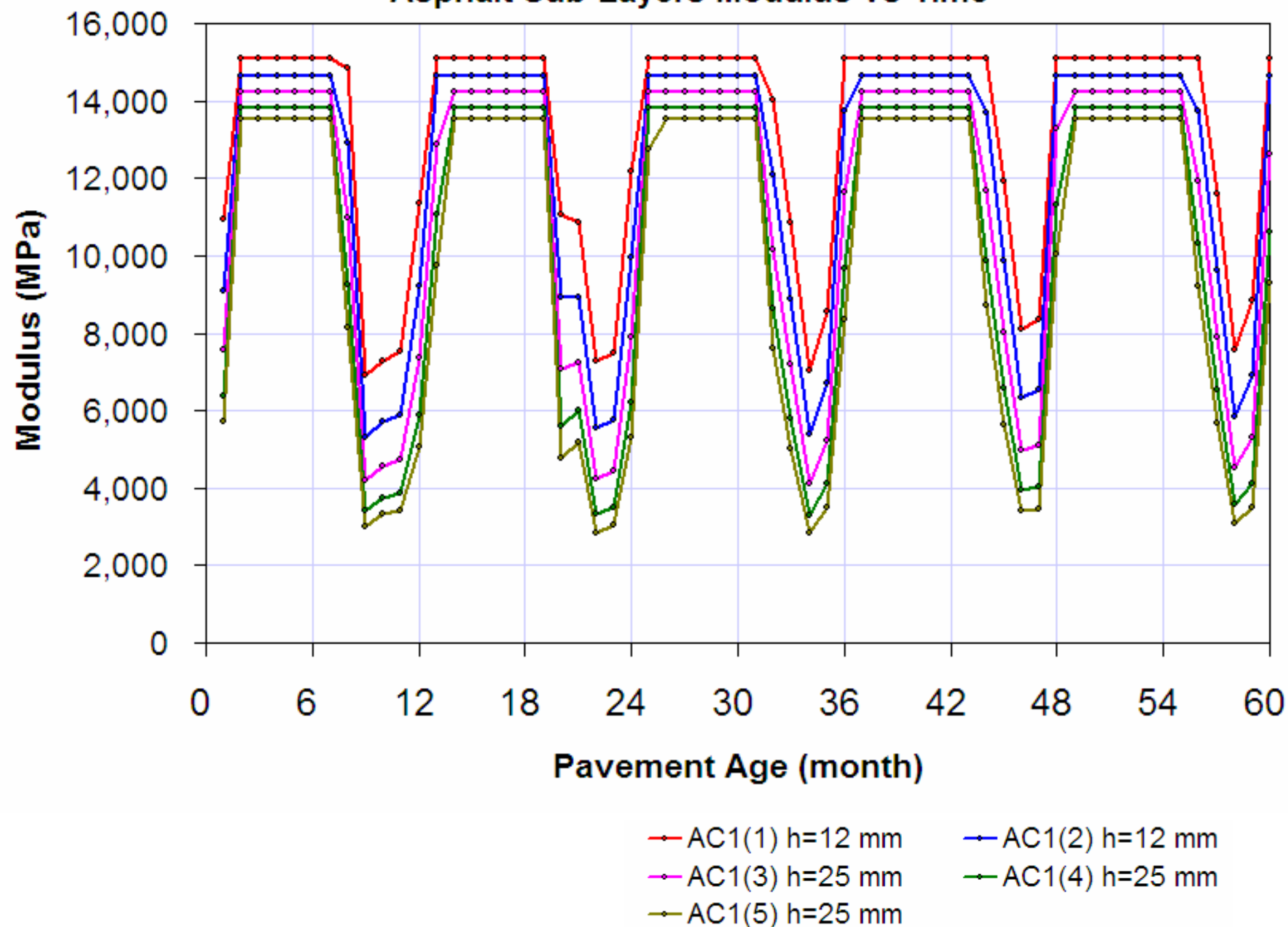
		Time (days)														
Nodes		1	2	3	4	5	6	7	8	9	10	11	12	13	14	
1																AC
2																
3		50	50	50	50	50	50	50	50	0.7	0.7	0.7	0.7	0.7	0.7	BASE
4		50	50	50	50	50	50	50	50	0.7	0.7	0.7	0.7	0.7	0.7	
5		50	50	50	50	50	50	50	0.7	0.7	0.7	0.7	0.7	0.7	0.7	
6		50	50	50	50	50	50	50	0.7	0.7	0.7	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**



# Flexible Pavement Performance



# Field Performance - The LTPP Study



# Implementation of Design Guide

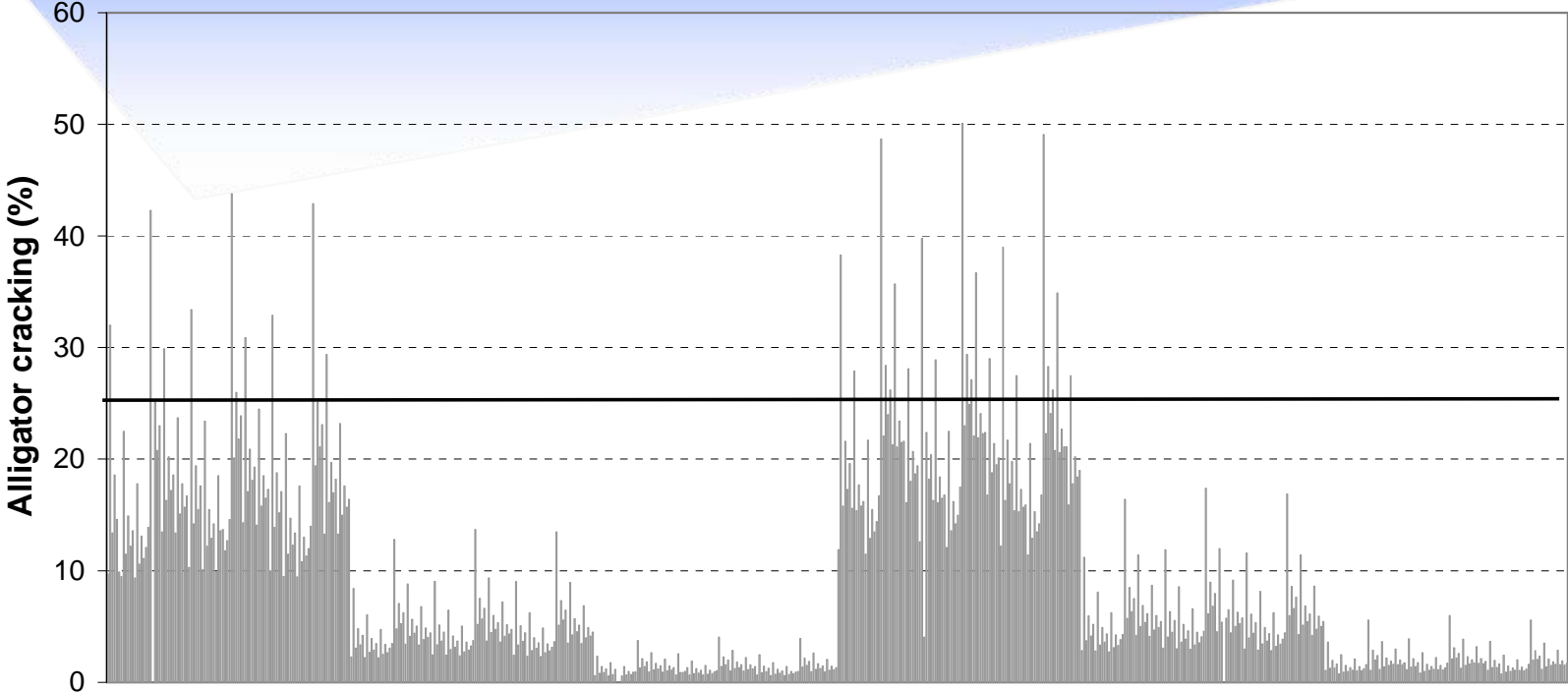
- Procedures to obtain each input
  - Traffic, climate, materials, structure, rehabilitation
- Conduct sensitivity studies
- Develop case studies of existing pavements
- Local calibration (varying climates within country) of distress & IRI models



# 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



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							
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					

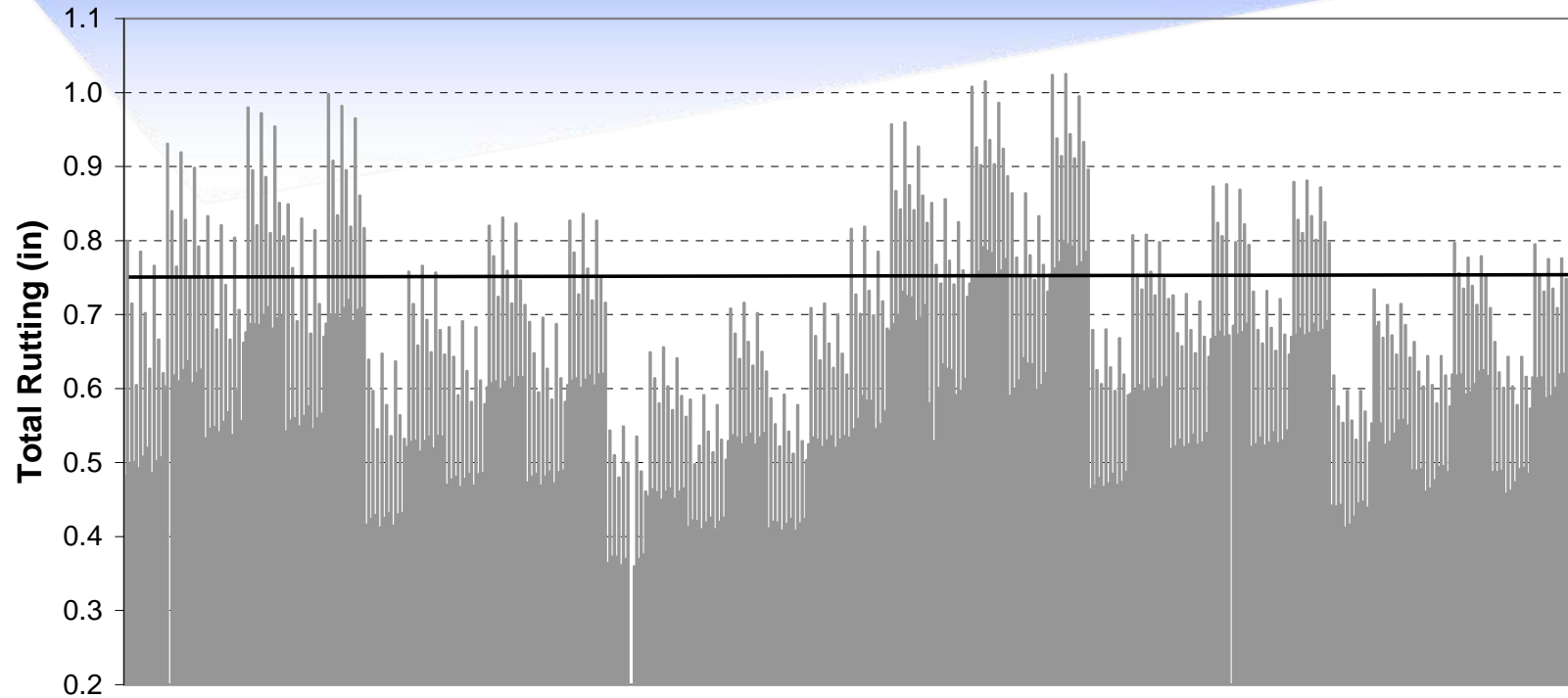
C1 = Top 50% PG 64-34 Bottom PG 58-28

C2 = Top 50% PG 58-34 Bottom PG 58-28

C3 = PG 58-34

F=Fine C=Coarse

# 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
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

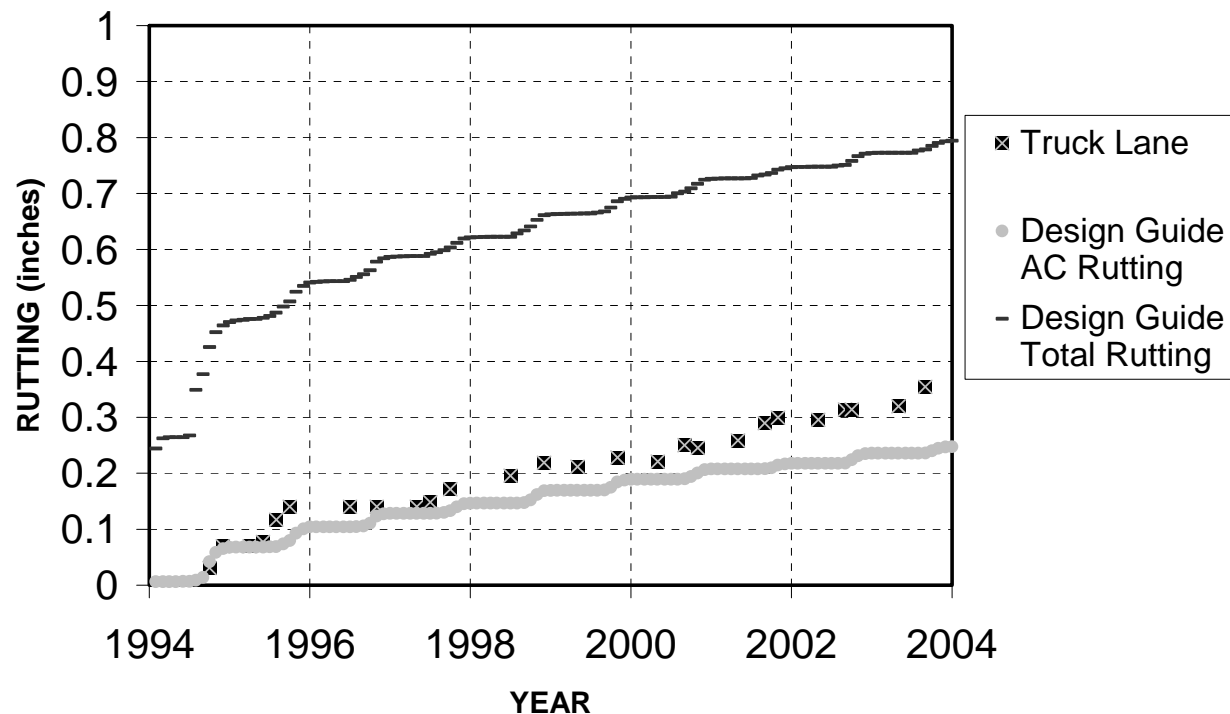
F=Fine C=Coarse



# 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)

Cell #1



# 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

- 1<sup>st</sup> 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](http://www.trb.org/mepdg)

- Guide Documentation
- Software
- Climatic database