National Trends in Pavement Design

Southeastern States Pavement Management Association

Pavement Management and Design

May 11, 2009
New Orleans, Louisiana

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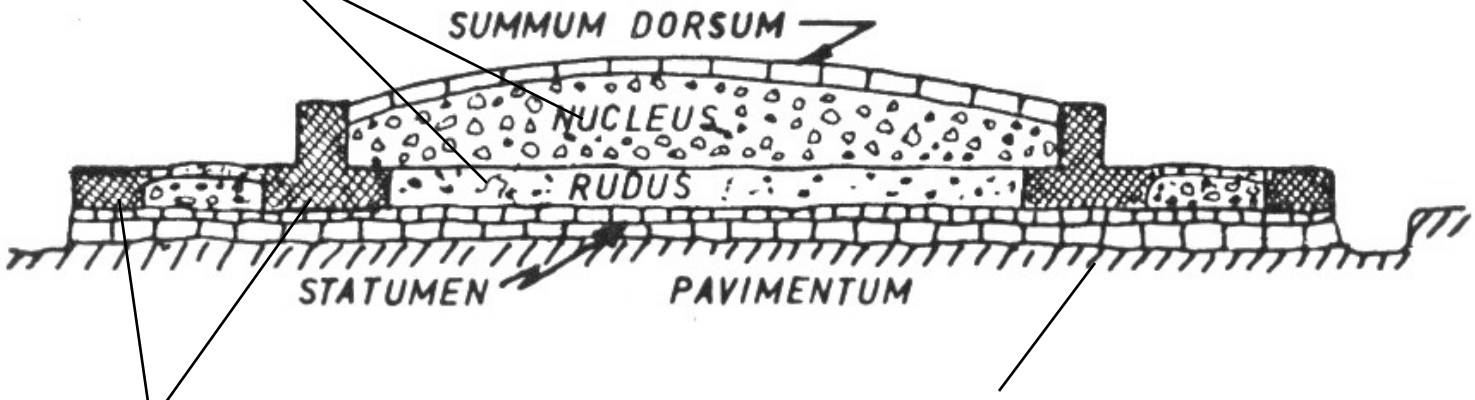
First Engineered Road

Concrete
(Stone & other
material with
Lime)



Squared Stones

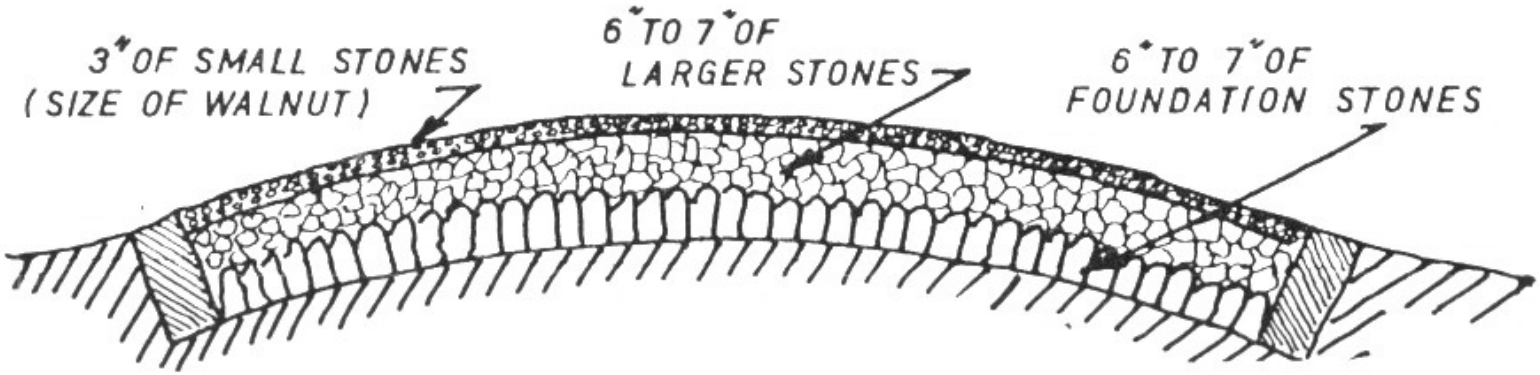
Fine Dry Soil (Well-compacted)

Roman Roads

- Roman Empire built over 3000 miles of roads in Britain alone by 200 A.D.
- Used ditches to aid in drainage
- Varied thickness over weaker soils
- Indicated that Romans had some understanding of basic soil mechanics

First Modern Roads

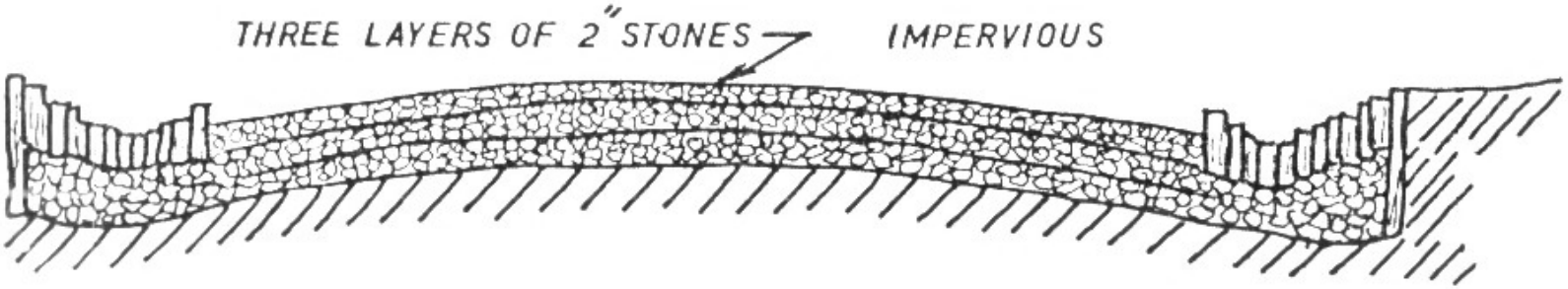
- 1764 France (Tresaguet)
- Labor costs too high; smaller stones, thinner sections



First Modern Roads

Use of Tar and Asphalt

- 1830's USA - England (McAdam)
- Impervious surface; asphalt/tar mixed hot; sand added to fill voids

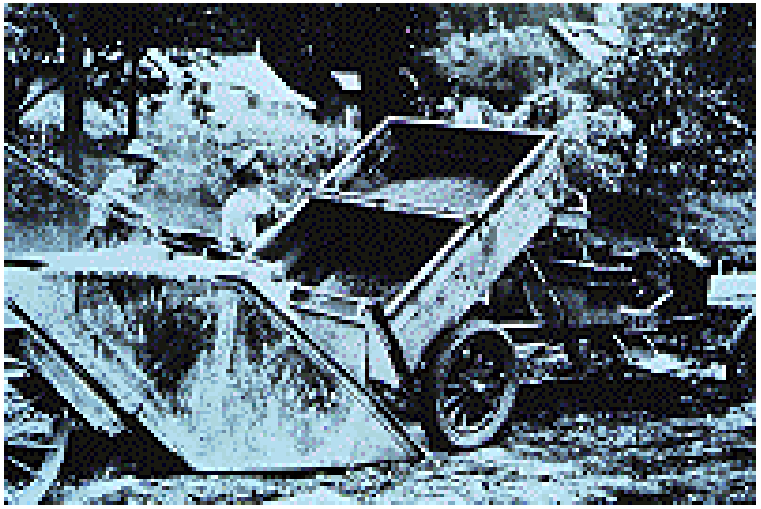


First Concrete Pavement

- 1891 George Bartholomew built first concrete pavement in Bellefontaine, Ohio
- 8-ft.-wide strip of Main Street

First Concrete Pavement

Rensselaer County, New York, 1908 -- farm-to-market thoroughfares.



Early dump truck hauls materials to paving site.

Concrete Design History

- 1916 – Typical Pavements 5 – 9”
- 1906/1918 – Patent for skewed jts
- 1920 – First CRCP in MD
- 1970 – 15 states had built CRCP sections
- <1922 - No jointed pavements, thickened center section to prevent cracking
- 1925-45 – Exp jts 50 – 120 ft, contraction jts 15-60 ft

Concrete Desing History

- 1940 to 1950 – Use of random jts.
- 1987 – 15 states using random jts.
- 1975 – 18 states using skewed jts.
- 1987 – 25 states using skewed jts.

First Asphalt Pavement

- Paris – 1854
- Used natural rock asphalt, i.e., limestone rock impregnated with asphalt.
- Pavement provided a quiet, easily cleaned surface, but the skid resistance was very low in wet weather

First Asphalt Pavement in US

- 1870, Design by Edmund DeSmedt
- Sand Mix placed in front of City Hall in Newark, New Jersey

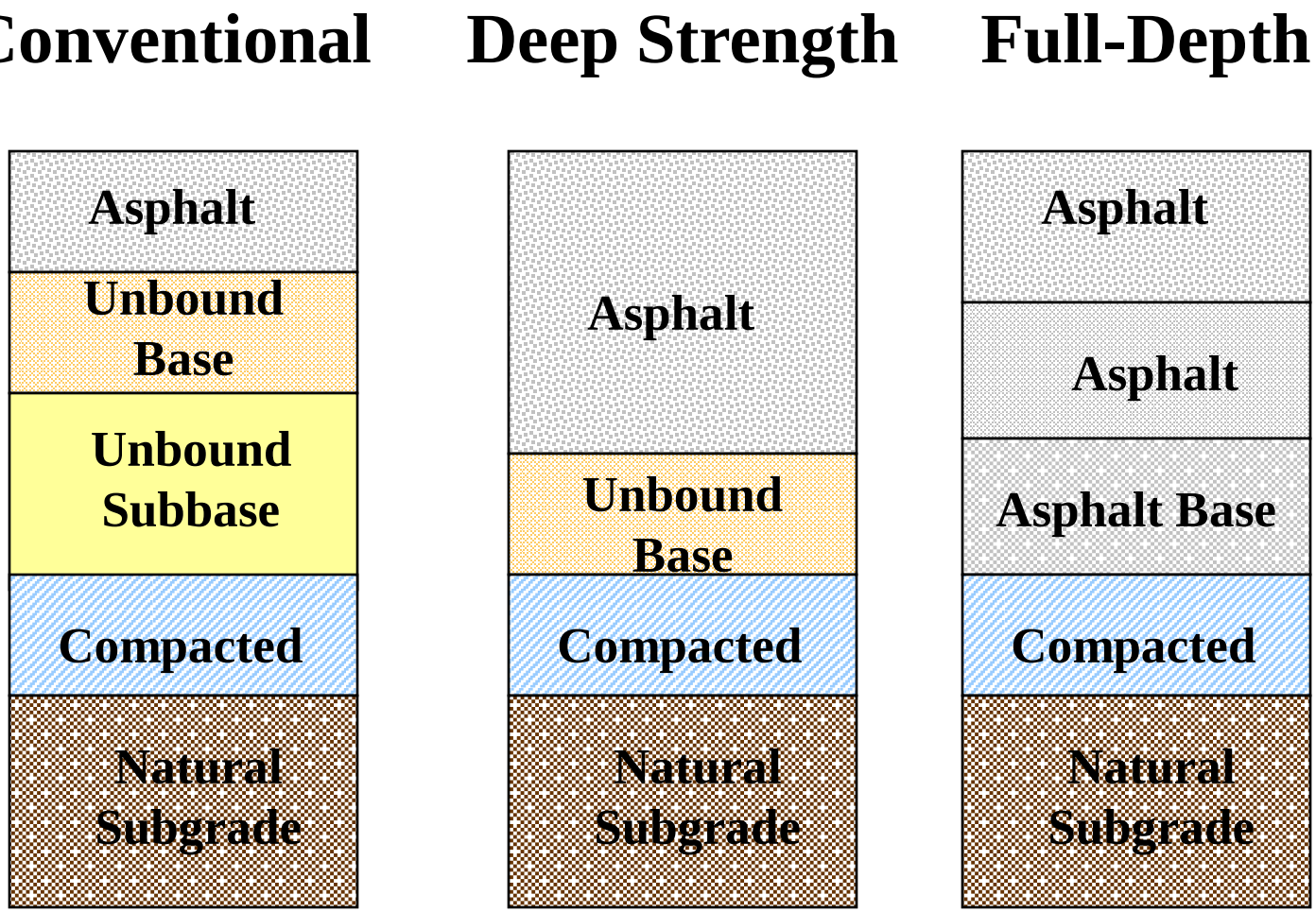
First Asphalt Pavement

- First asphalt concrete specifications appeared in the US in the 1890's.
- Concurrently, coal tar/aggregate mixtures were being used in Europe.
- First hot-mix asphalt plants were developed in the late 1920's

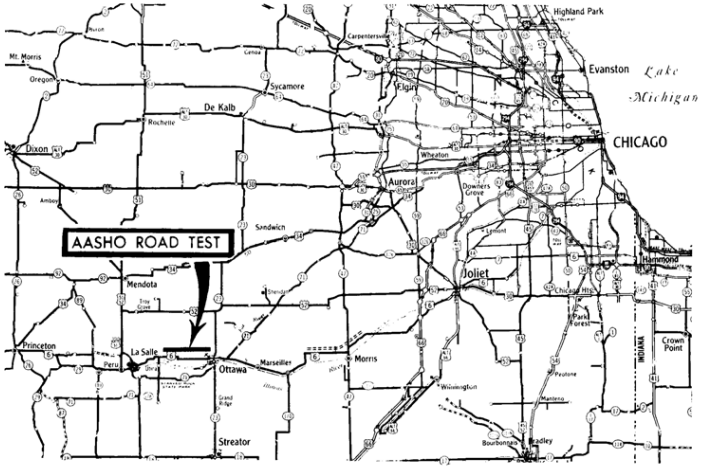
Early Construction

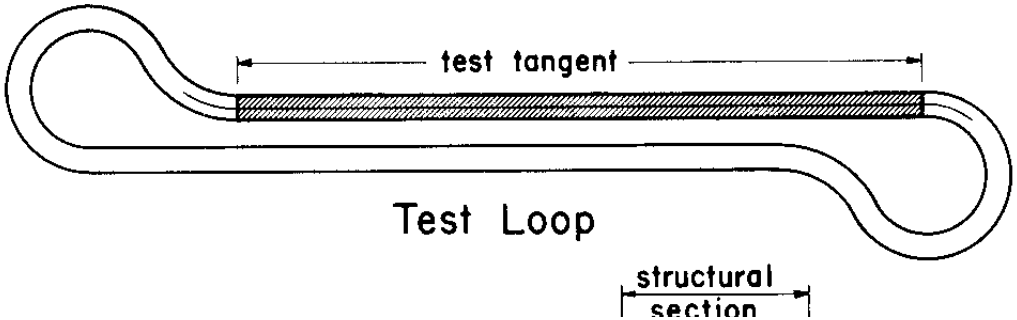
- First modern asphalt paver introduced mid-1950's
- Prior to 1950's, asphalt was placed by form-riding finishers similar to PCC

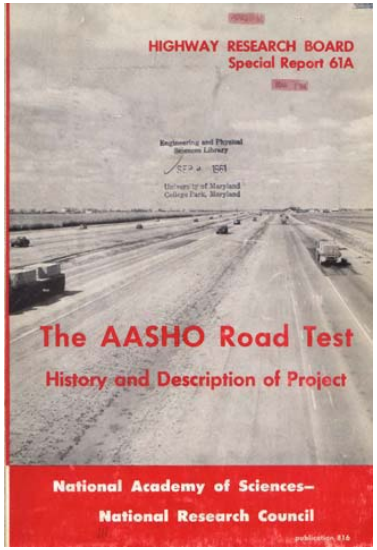
Flexible Pavements



AASHO Road Test (late 1950's)



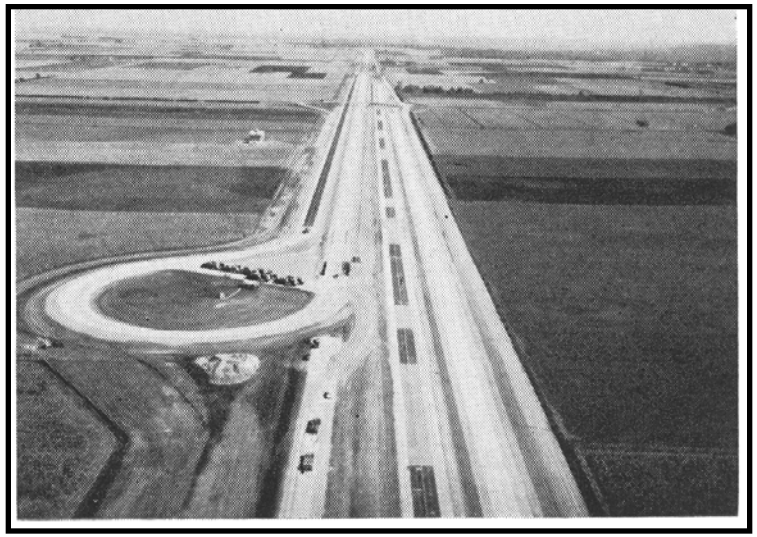


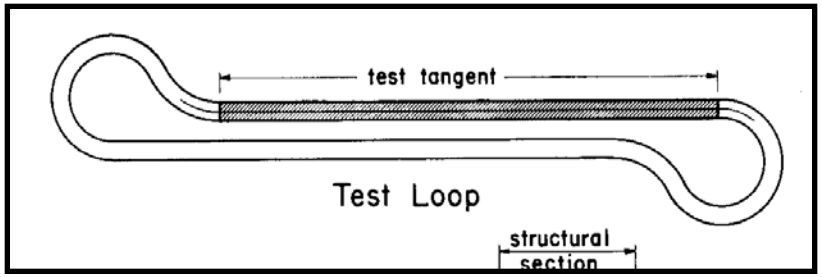


AASHO, 1961)

AASHO Road Test Achievements

- Serviceability concept
- Traffic damage factors
- Structural number concept
- Empirical Process
- Simplified Pavement Design





(AASHO, 1961)

1950s Vehicle Loads…

Figure 23. Test vehicles, showing typical axle arrangements and loadings.

(AASHO, 1961)

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 version
    - refined material characterization
  - 1993 revised version
    - More on rehabilitation
    - More consistency between flexible, rigid designs
    - Current version for flexible design procedures
  - 1998 Supplemental Guide for rigid pavement design

Why is pavement design SO HARD ?

- Predicting the future
- Indecision on design
- Political influence
- Funds
- Materials
- Construction quality

Figure 29. Bituminous concrete construction.

Design Methodologies

- Experience
- Empirical
- Mechanistic-Empirical
- Mechanistic

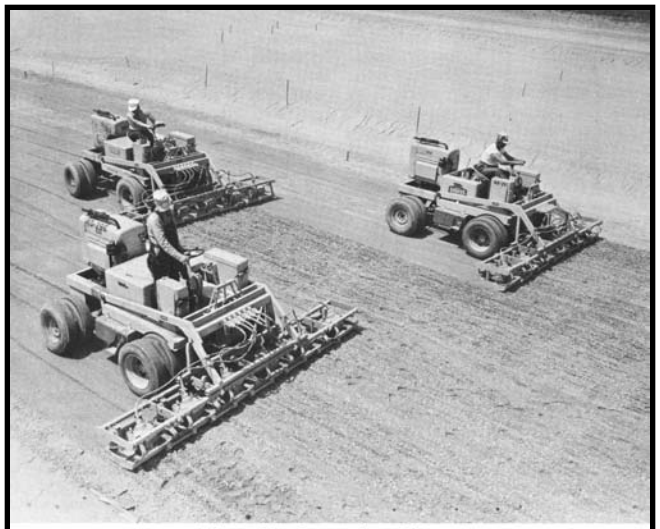
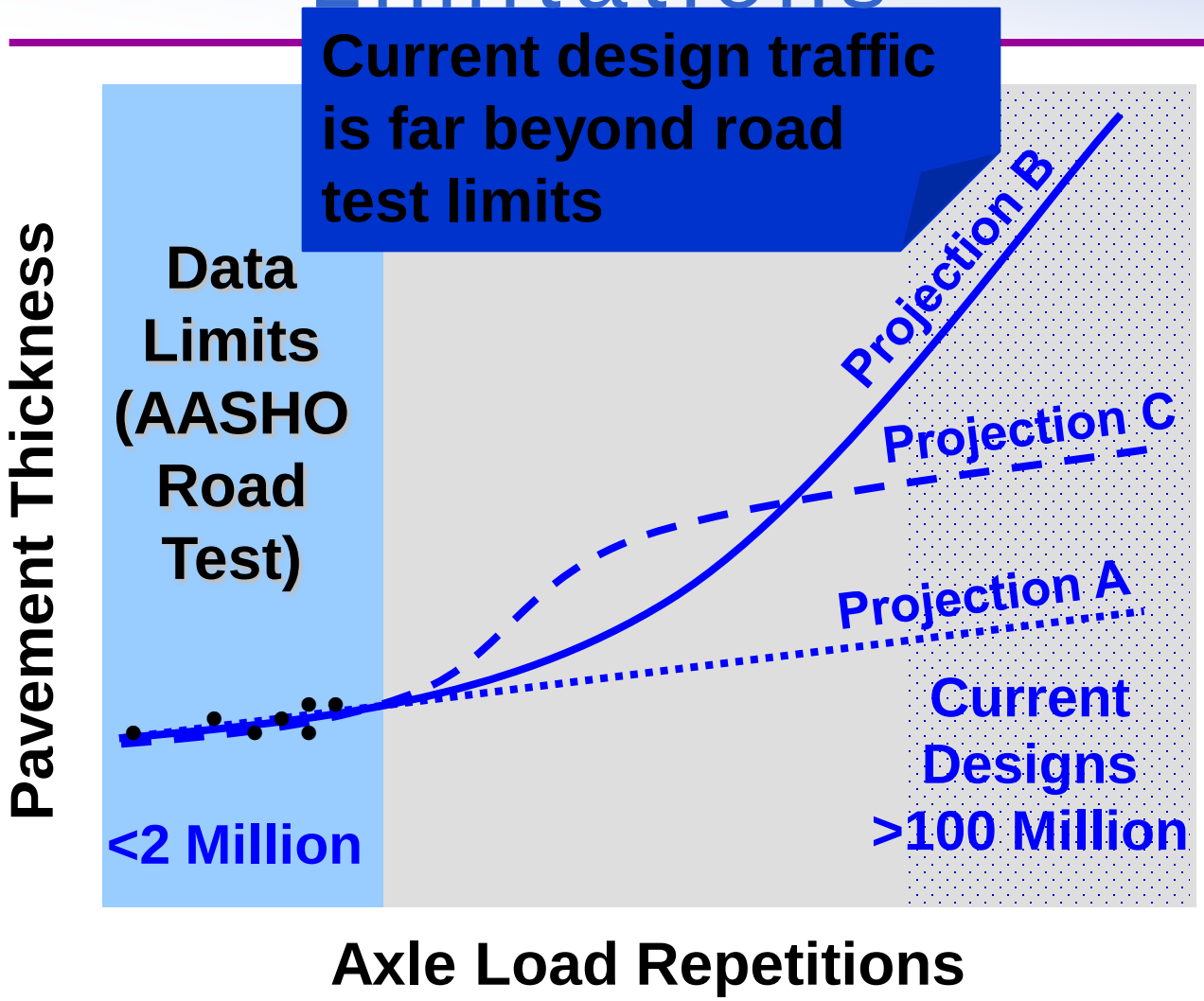


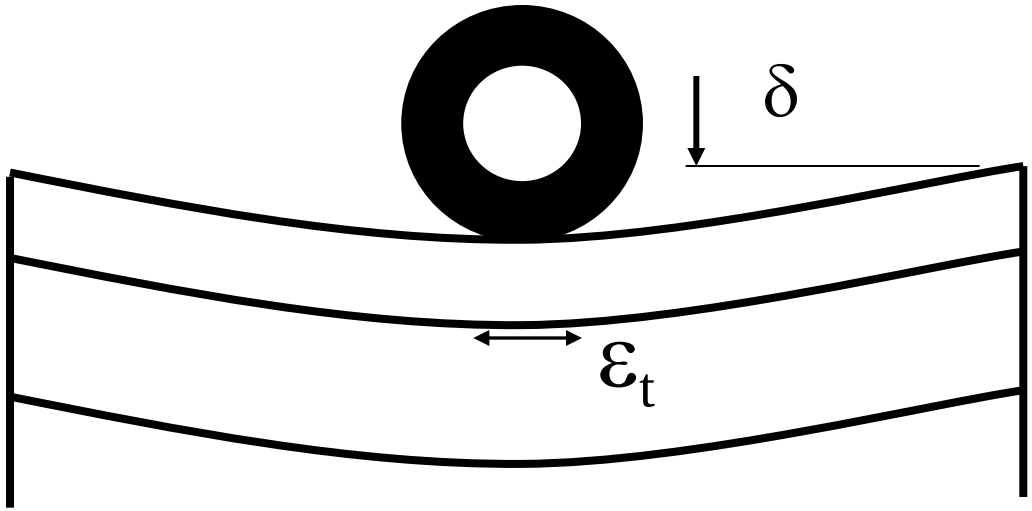
Figure 57. Compacting subbase.

AASHO Loading Limitations



The Concept of Mechanistic Design

- Fundamental engineering theories and material properties are used to calculate critical strains in the pavement due to traffic load



Major Benefits of MEPDG over AASHTO

- More defensible design procedure
- More realistic pavement thickness at high ESAL's = Cost Savings
- Ability to integrate with PRS, LCCA, warranty projects
- Not much different than AASHTO at lower ESAL ranges (<500,000)

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!

Challenges of MEPDG Method

- Many inputs required
- Availability of models representing local conditions
- Availability of required material properties
- Predicting future traffic loads and climate
- What can not be addressed?

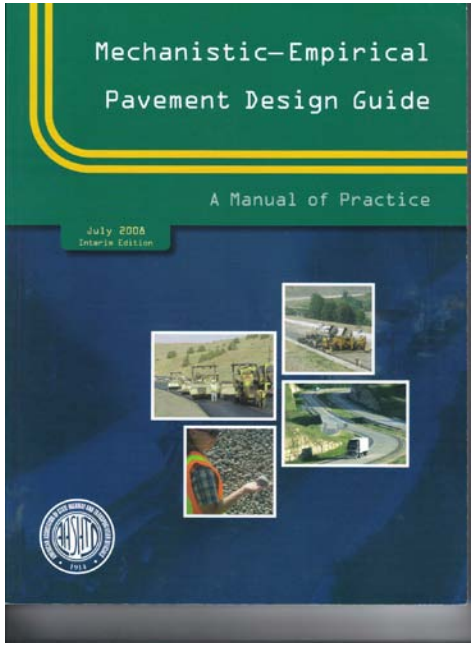
Why move to a ME based design procedure ?

- Economics
- Deficiencies in current procedures
- Political climate
- Method based on sound engineering principles

Everyone is important in the MEPDG analysis process

AASHTO MEPDG Interim Guide

- Balloted successfully in 2007
- AASHTO currently dev AASHTOWare version



What's New in MEPDG

- Topics to be covered
  - Capabilities
  - Reliability
  - Compare AASHTO Guide to MEPDG
  - Inputs
    - Climate Traffic
    - ACP PCCP
    - Unbound materials
  - Calibration
  - Testing

Capabilities

- Wide range of pavement structures
  - New
  - Rehabilitated
- Explicit treatment of major factors
  - Traffic – Over-weight trucks
  - Climate – Site specific and over time
  - Materials – New and different
  - Support – Foundation and existing pavement

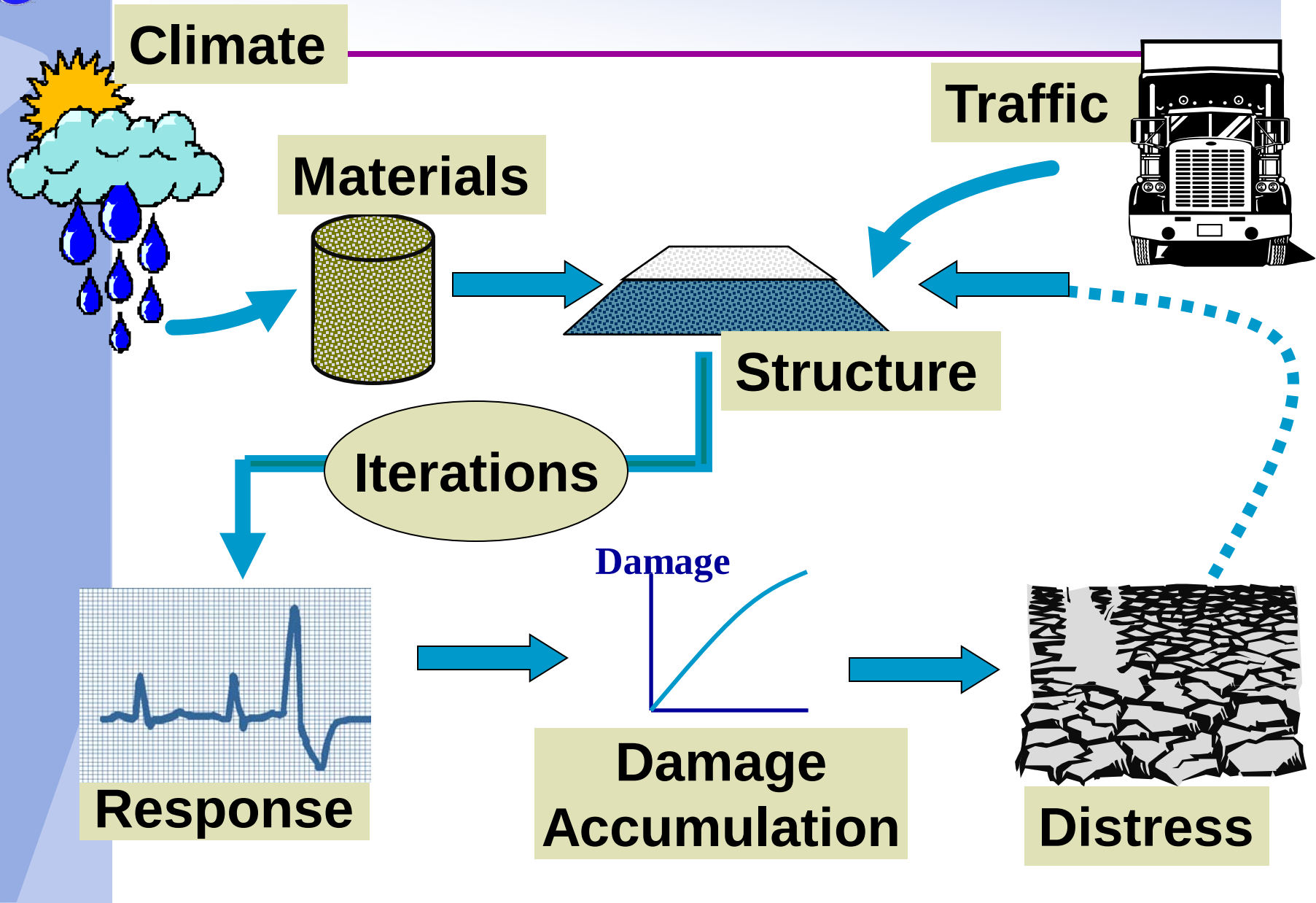
Capabilities

- Models to predict change in distress over time
- User establishes acceptance criteria
  - Distresses and smoothness

What's New in Design Reliability?

- Different than AASHTO 1986/93
- Based on predicted distress and IRI
- User selects reliability levels and performance criteria for distress and IRI

M-E Design Process



What's New About the Design Guide?

Climate

1993 Guide	**MEPDG**
Seasonal Adjustments	Inputs for EICM
Drainage Coefficients	Thermal Properties Wind Speed Air Temperature Water Table Depth Sun Radiation Precipitation

What's New About the Design Guide?

Traffic

1993 Guide	MEPDG
ESALs	Axle Load Spectra
Truck Equivalency Factors	Truck Speed Gear/Axle Configuration Axle/Tire Spacing Tire Pressure Traffic Wander Monthly, Daily Distribution Factors

What's New About the Design Guide?

	1993 Guide	MEPDG
Foundation	Resilient Modulus "k" values	Universal non-linear Resilient modulus Model

What's New in Flexible Pavement Design?

	1993 Guide	MEPDG
HMA Materials	Layer Coefficient	Dynamic Modulus - SPT (Level 1 & Master curves)
	Resilient Modulus (68°F)	Poisson's ratio

What's New in Rigid Pavement Design ?

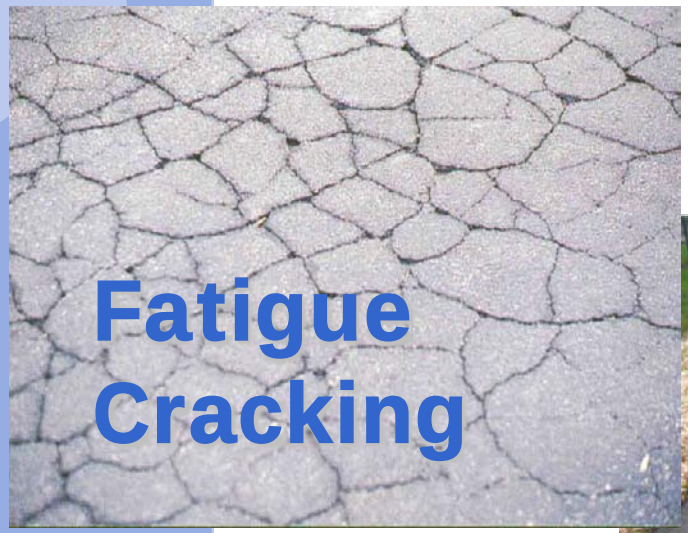
PCC Materials

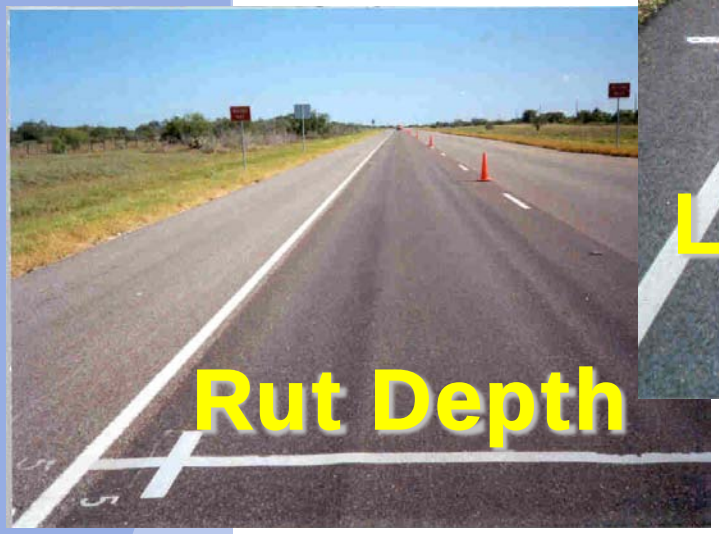
1993 Guide	**MEPDG**
Modulus, Flex Strength, Tensile Strength (28-day)	Modulus of Elasticity (7, 14, 28 & 90 day) Flexural, Tensile Strength Poisson's ratio PCC Thermal Props Drying Shrinkage Coefficient of Thermal Expansion

What's New and Different

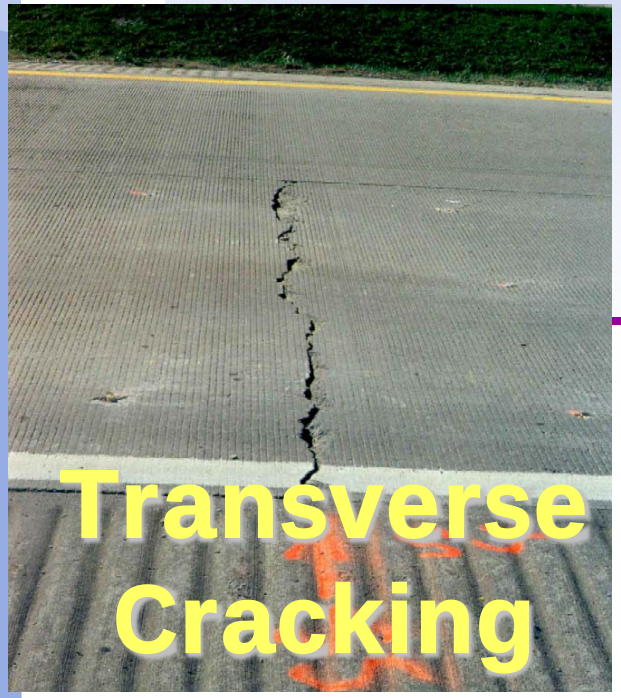
	1993 Guide	MEPDG
Outputs	Structural Number Rigid Pavement Thickness	Time Series Distress and Smoothness Prediction

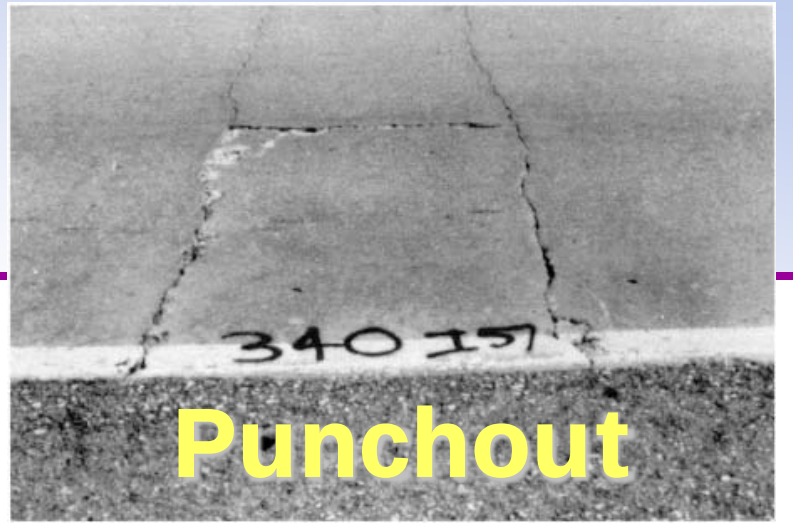
MEPDG Outputs – Flexible





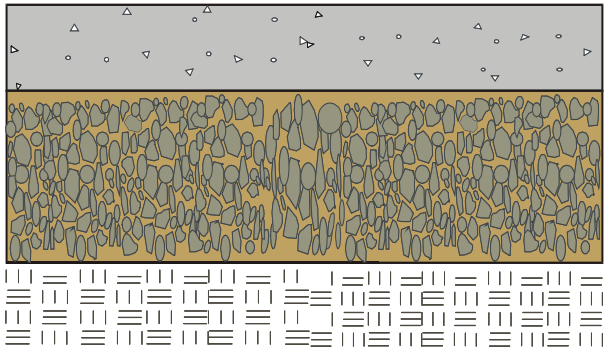
MEPDG Outputs - Rigid





MEPDG is an Analysis Program

Trial design



What's New and Different

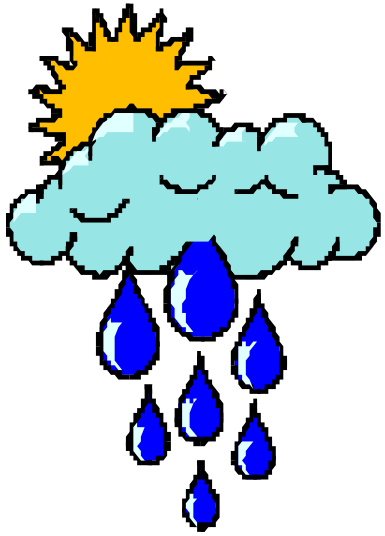
	1993 Guide	MEPDG
Input Levels	Single Value	Level Three Level Two Level One

Design Inputs - Hierarchical Levels

Input levels can be mixed and matched

Damage calculations are exactly the same regardless of design input level

Climatic Data

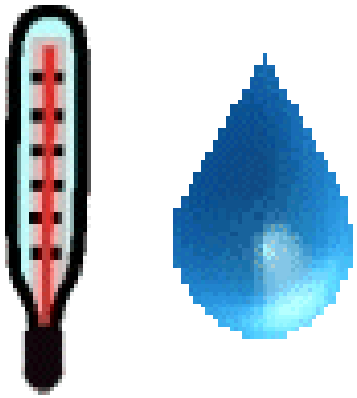


Climatic Inputs

Input Level	1	2	3
	√	√	√

- Identify weather station
  - Pick from one of 800 site
  - Create virtual by averaging surrounding or similar sites
- Create EICM file
- Depth to water table

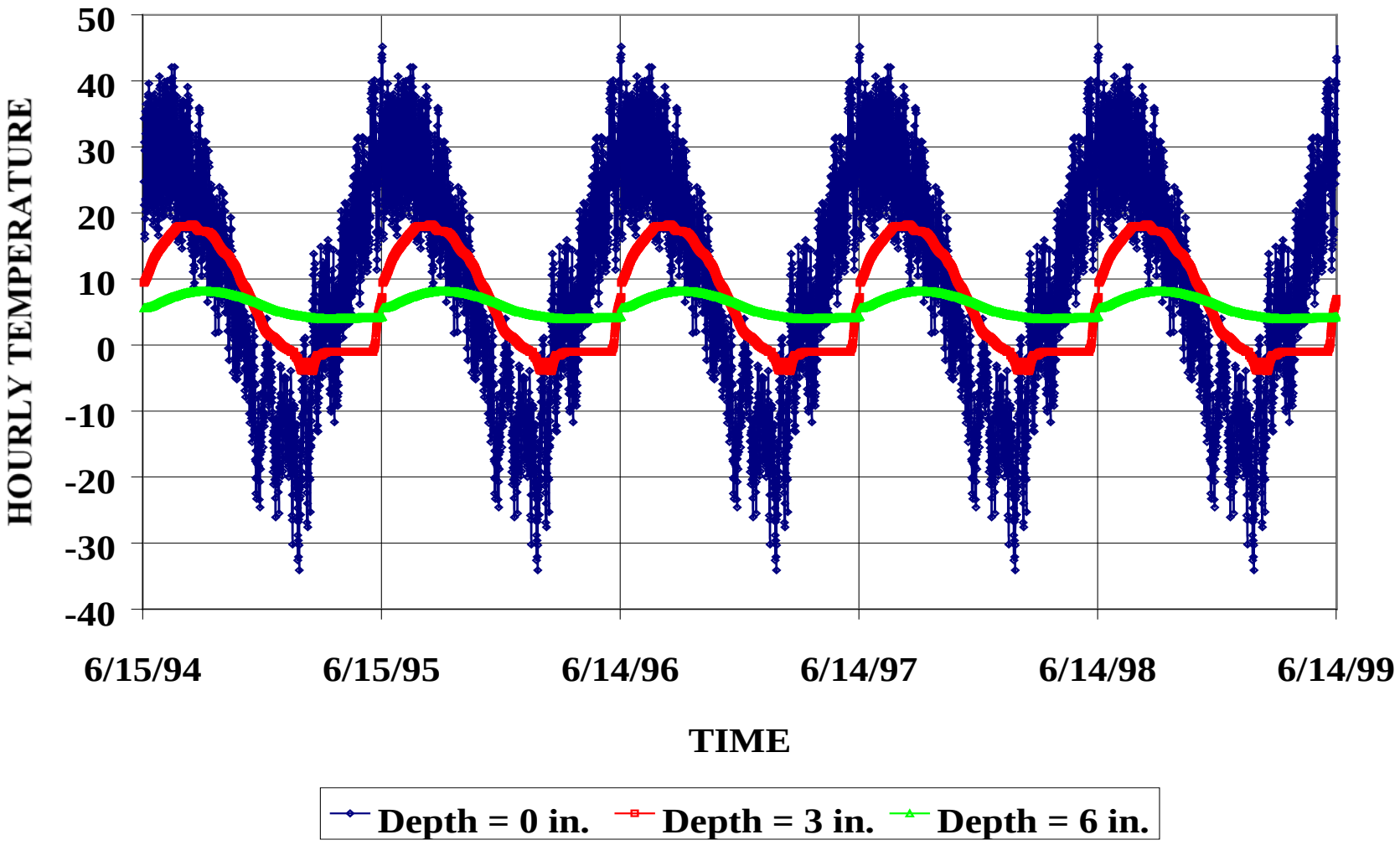
Climate Model (EICM) Asphalt Design



Adjustments:

- Unbound
  - Resilient modulus
  - Moisture content
- AC Hourly temperature profile
  - Thermal cracking
  - Rutting

Hourly Temperature Profile for AC Layers

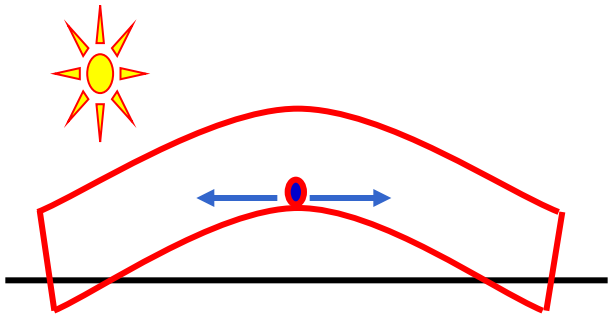


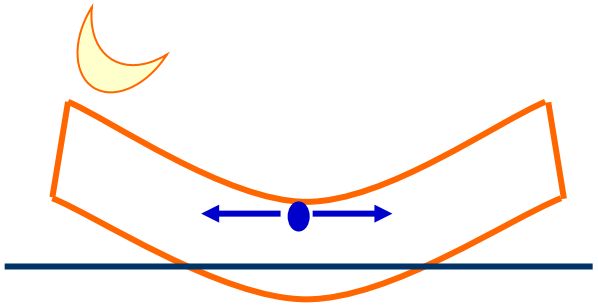
Environment
Concrete Design

- EICM used to predict
  - Hourly temperature profile
  - Monthly moisture gradient

Concrete Slab Temperature and Moisture Gradients

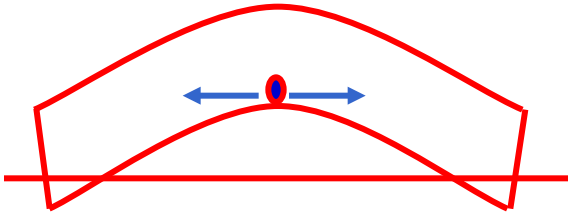
Curling



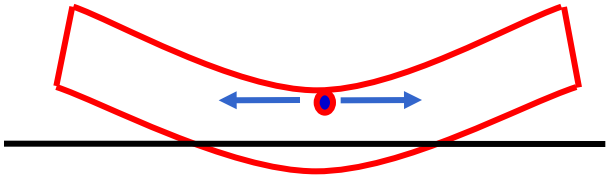


Warping

Slab wetter on top



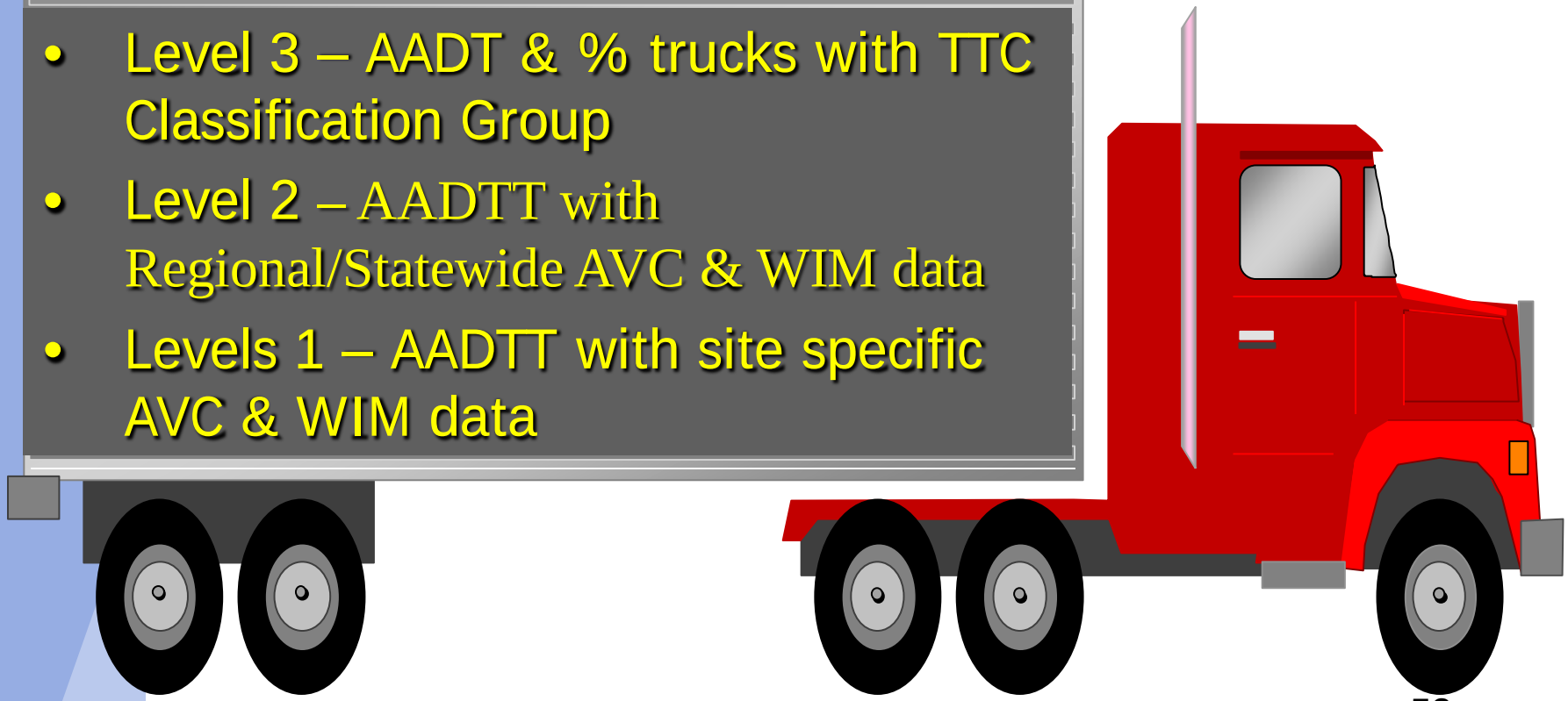
Slab dryer on top



TRAFFIC INPUTS

Traffic Hierarchical Input Levels

- Level 3 – AADT & % trucks with TTC Classification Group
- Level 2 – AADTT with Regional/Statewide AVC & WIM data
- Levels 1 – AADTT with site specific AVC & WIM data



Traffic Module Inputs - Overview

Input Parameters	Input Level		
	1	2	3
Inputs Required to Compute AADTT			
AADTT for Base Year	√	√	
AADT and Percent Trucks for Base Year			√
Directional Distribution Factor	√	√	√
Lane Distribution Factor	√	√	√
Truck Traffic Volume Adjustment Factors			
Truck Distribution Factors - Base Year	√	√	
Truck Traffic Classification (TTC) Factor			√
Axle Load Distribution Factors	√	√	
Monthly Distribution Factors	√	√	√

Traffic Module Inputs - Overview

Input Parameters	Input Level		
	1	2	3
Hourly Distribution Factors	√	√	√
Truck Traffic Growth Function/Factor	√	√	√
Axle Load Distribution Factors			
Axle Load Distribution Factors	√	√	
General Traffic Information			
No. of Axle Types per Truck Class	√	√	
Axle Spacing	√	√	
Axle Load Groups	√	√	√
Tire Spacing/Axle Configuration	√	√	√
Tire Pressure	√	√	√

Lateral Truck Traffic Wander

Input	1	2	3
Level	√	√	√

- Mean wheel location
- Traffic wander standard deviation
- Design lane width

Unbound Materials (Aggregates and Subgrade)

- Resilient Modulus
  - Level 3 Defaults
  - Level 2 Correlations
  - Level 1 Materials specific testing
- Variability
  - None
  - Seasonal Values
  - EICM

Unbound Material General Properties

Input	1	2	3
Level	√	√	√

- Unbound Material Type - select from list of:
  - AASHTO Classification (AASHTO M 145)
  - Unified Soil Classification System (ASTM D 2487)
  - Other (e.g. crushed stone, cold recycled AC)
- Layer Thickness: thickness of the layer in inches

For PCCP

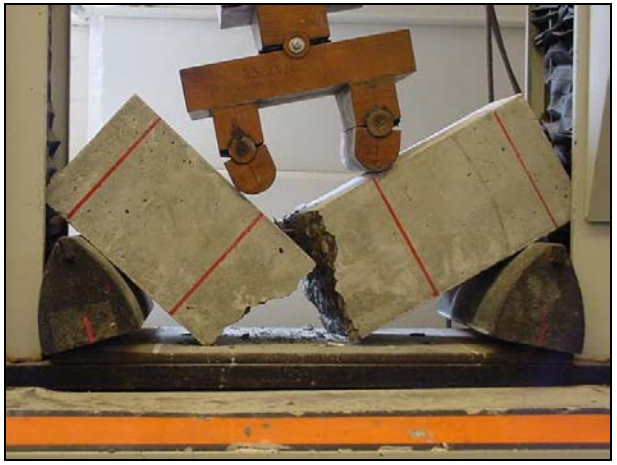
Subgrade resilient modulus is converted to a k-value that produces equivalent surface deflections for each month in year

ASPHALT MATERIAL PROPERTY AND DESIGN INPUTS

Mix Dynamic Modulus

- Level
  - 3 – Predictive equation and binder class
  - 2 – Predictive equation and binder tests
  - 1 – Laboratory mix tests
- Predictive equation
  - Gradation
  - Air Voids
  - Asphalt content
  - Binder information

PCC MATERIAL PROPERTY AND DESIGN INPUTS



CRCP Design Features - Inputs

Input	1	2	3
Level	√	√	√

- Reinforcement
  - Bar diameter
  - Spacing
  - Percent steel
- Base properties
  - Base type
  - Erodibility
  - Base/slab friction coefficient
- Crack spacing (optional)

JPCP Design Features - Inputs

Input	1	2	3
Level	√	√	√

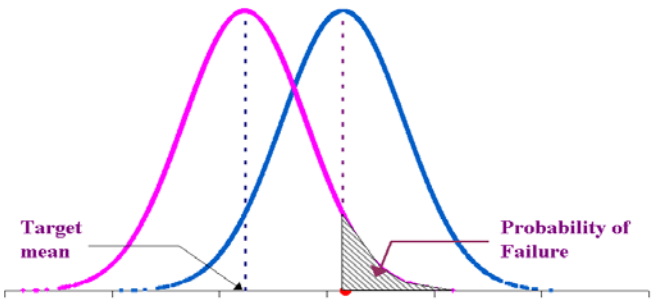
- Joint Details
  - Joint spacing
  - Sealant type
  - Dowel diameter and spacing
- Edge Support
  - Shoulder type and LTE
  - Widened slab
- Base properties
  - Base type
  - Interface type, i.e. bonded or unbonded
  - Erodibility

Three Step Process

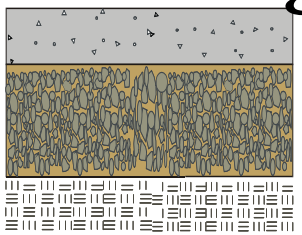
- **Verification** – assuring general reasonableness
- **Calibration** – minimize difference between predicted and observed distress
- **Validation** – confirm accuracy of calibrated model

Performance Verification

- Procedure evaluates the trial design to determine if it meets the desired performance criteria at individually set reliability levels



Trial design



MEPDG Guide Calibration

- Done with national LTPP data
- Default values also from LTPP
- Confirm/change national defaults

Implementation – Calibration

- Requires extensive experimental studies, including:
  - Field testing programs
  - Laboratory testing
  - Data analysis

Field Testing Programs

- Select test sites in each agency (LTPP and others) that includes range of:
  - Climate types and areas in the agency
  - Pavement types
    - AC (all types), PCC (all types)
    - Types of overlays and rehab.
    - Base and subgrade types
    - Joint types in PCC
  - Traffic characteristics
  - Typical preservation techniques

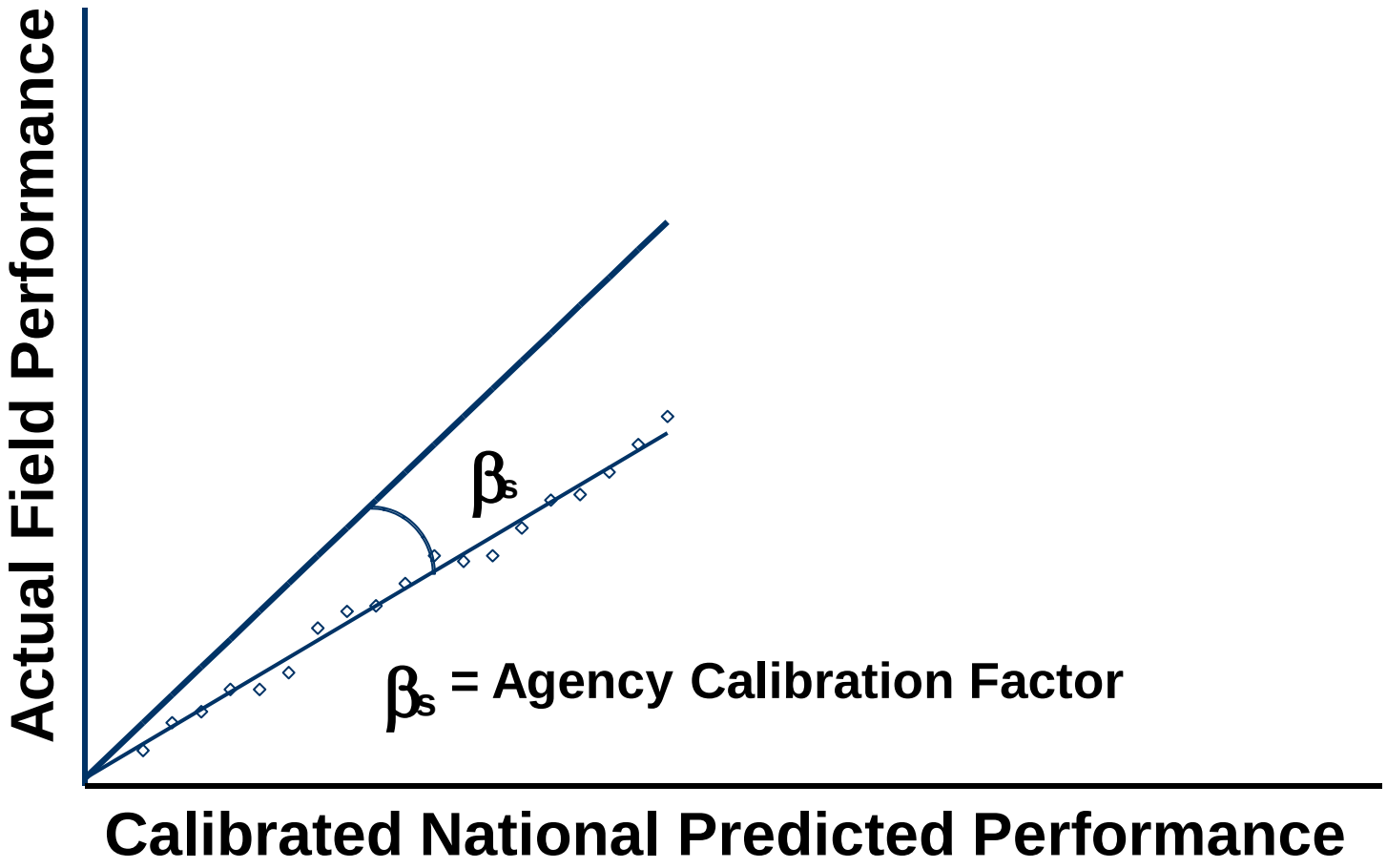
Field Testing Programs, Cont.

- Obtain pavement performance data
  - Distress surveys
  - FWD and core testing
  - Pavement profile
  - Material related distresses
- Determine in-place material properties

Data Analysis

Local calibration will involve recalibrating the distress models using data collected from the selected local sections

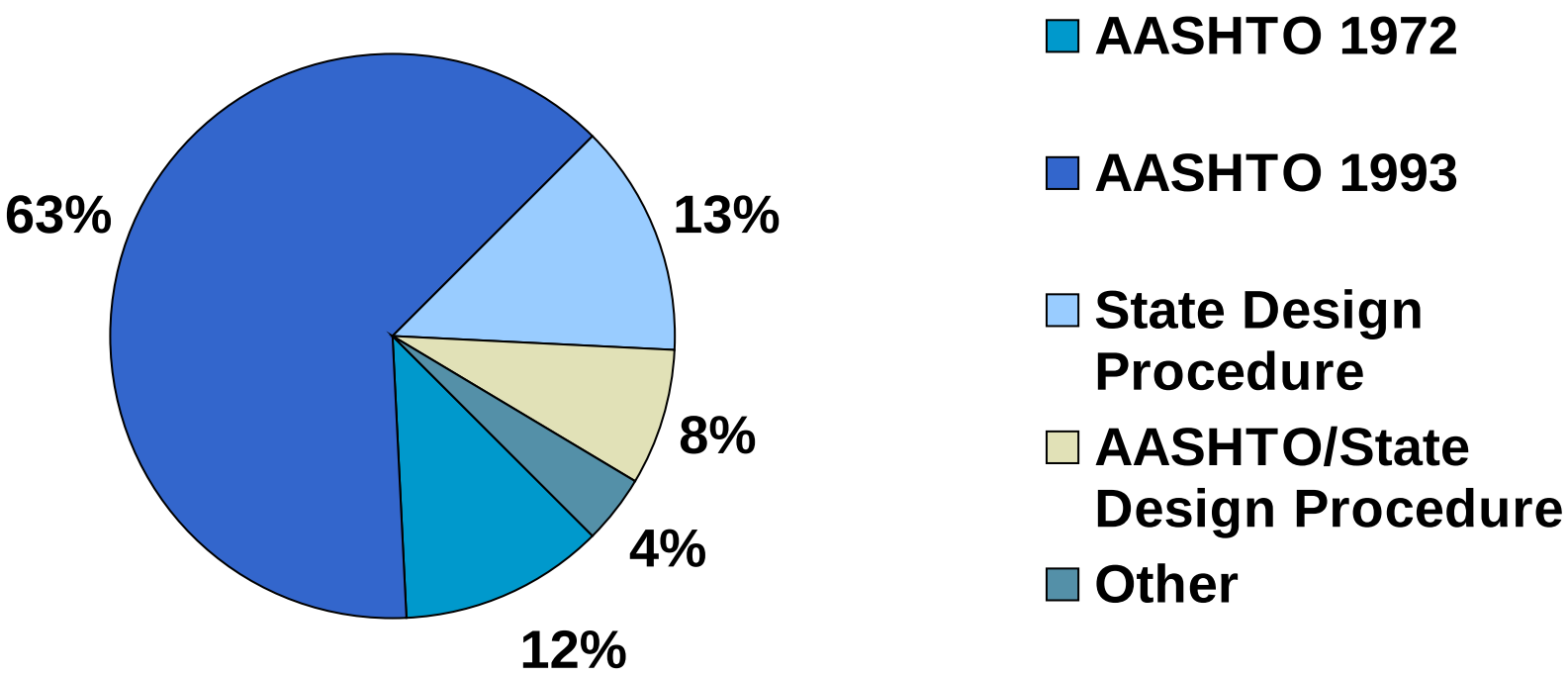
Regional/Local Calibration Process



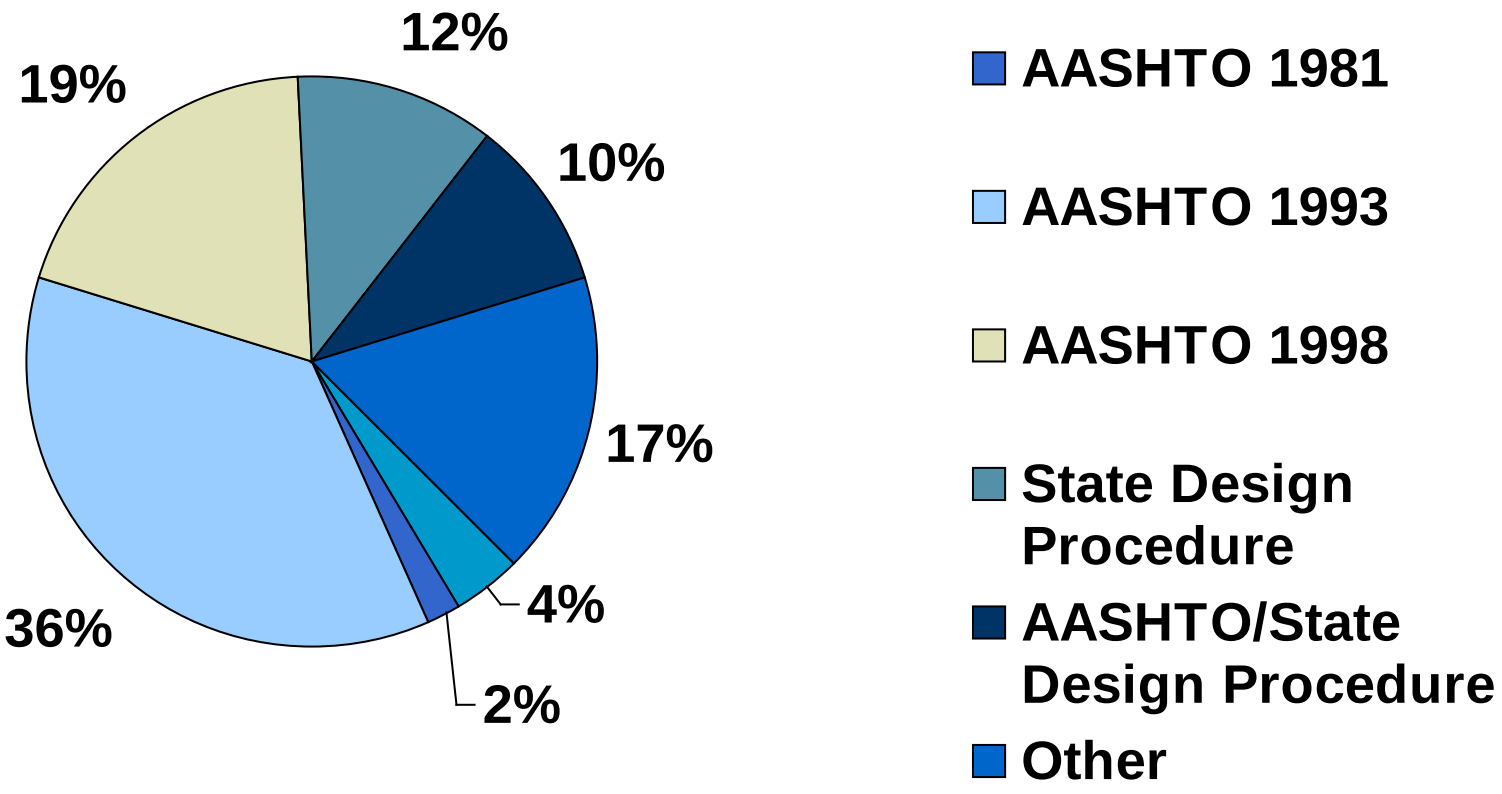
MEPDG Survey Conducted in 2007

- 52 responses, 50 states plus DC & PR
- 65 questions on:
  - Current Design Procedures
  - MEPDG Knowledge
  - Implementation Activities
  - Partnering Activities
  - Training Needs

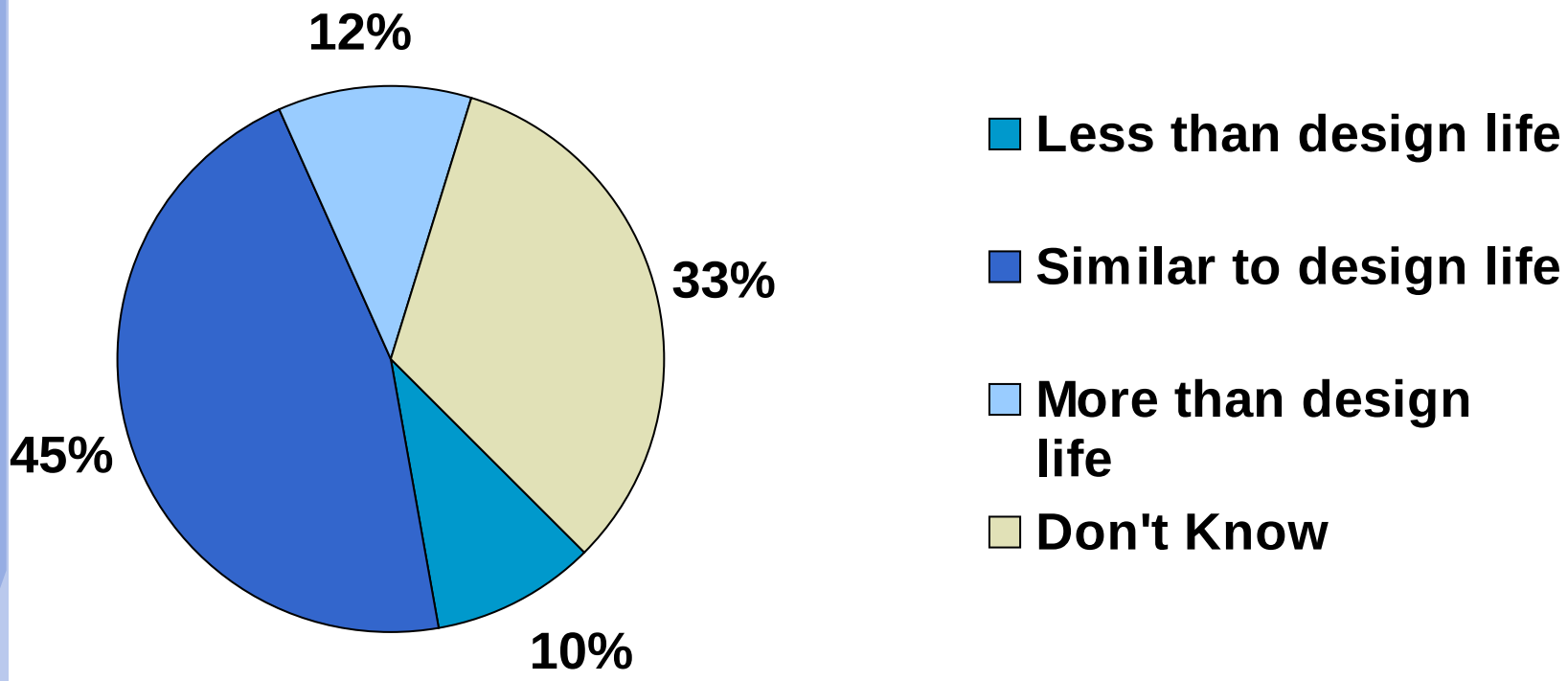
Asphalt Design Procedure



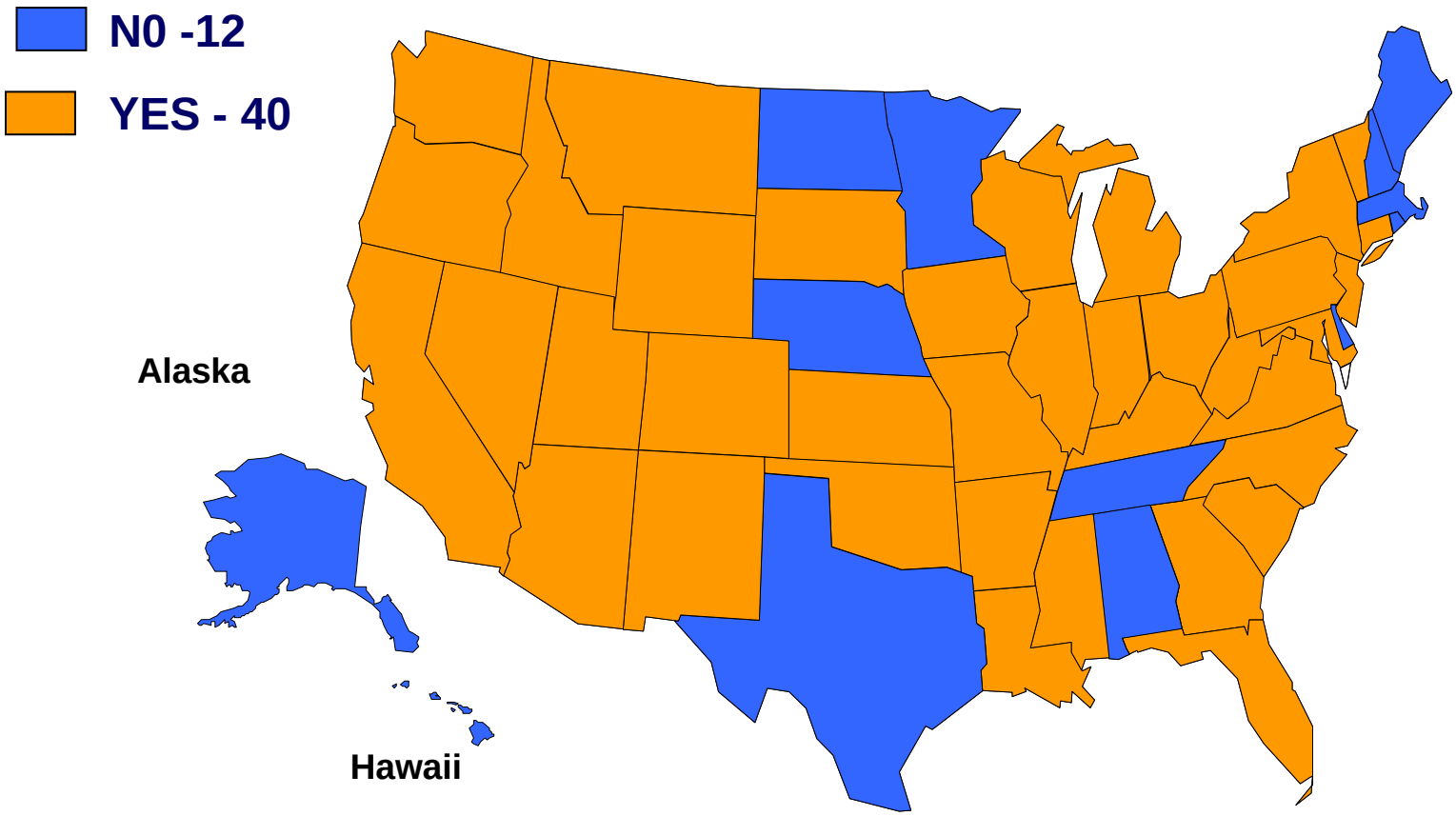
Concrete Design Procedure



How does actual performance compare to design life?



Does SHA Use or Plan to Use MEPDG?



Evolution

The MEPDG is not perfect…..BUT;

The MEPDG provides a reasonable and structured platform for continuous improvement.

Things to remember

- All pavement design systems need:
  - Quality Materials Characterization
  - Ties climate with design
  - Quality Traffic Data
  - Calibrated to local conditions
- The MEPDG is one tool for a designer
  - Focused on the structural design aspects
  - Has limitations

QUESTIONS

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