Pavement Design Overview

Rebecca S. McDaniel

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Plan

- Review types of pavements
  - Features
  - Advantages and Disadvantages
  - Typical Distresses
- Common design techniques/considerations
  - AASHTO
  - Mechanistic-Empirical
- Resources

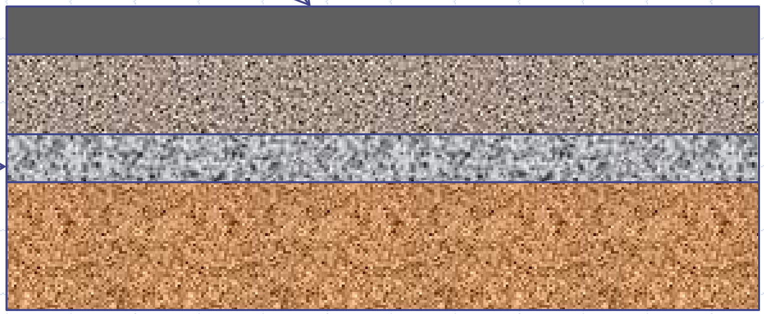
Basic Pavement Types

- Unbound
- Flexible
- Rigid
- Composite

Primary difference is in how loads are distributed to subgrade.

Typical Pavement Layers

- Wearing course or surface
- *Base course*
- *Subbase*
- Subgrade
  - Compacted or Stabilized
  - Natural



Subgrade

- Natural Soil
- Compacted Soil
- Stabilized
  - Lime
  - Cement
  - Fly Ash

Subbase/Base Courses

May be used for:

- Drainage
- Construction platform
- Controlling pumping
- Controlling frost action
- Controlling shrink and swell of subgrade

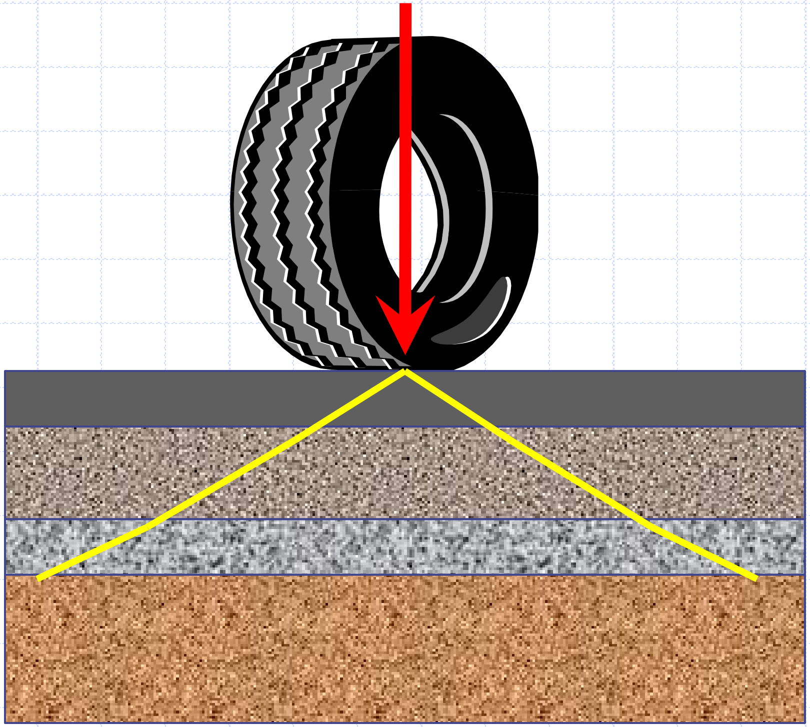
Surface Courses

- Safety
- Traffic Loads
- Environmental Factors
  - Temperature extremes
  - Moisture
- Other Considerations
  - Noise
  - Smoothness
  - Economics – Initial and Life Cycle
  - Traffic Disruptions

Flexible Pavements

- Made up of multiple, fairly thin layers
- Each layer distributes load over larger area of layer below
- Pavement deflects under load
- Typically asphalt
- Easily and routinely recycled
- Typical lives 15-20 years (to first rehab)

Flexible Pavement



- Pavement layers bend
- Each layer spreads load to next layer
- Loads over a smaller area of subgrade

Typical Applications - Flexible Pavement

- Traffic lanes (wide range of traffic levels)
- Auxiliary lanes
- Ramps
- Parking areas
- Frontage roads
- Shoulders

Advantages of Flexible Pavement

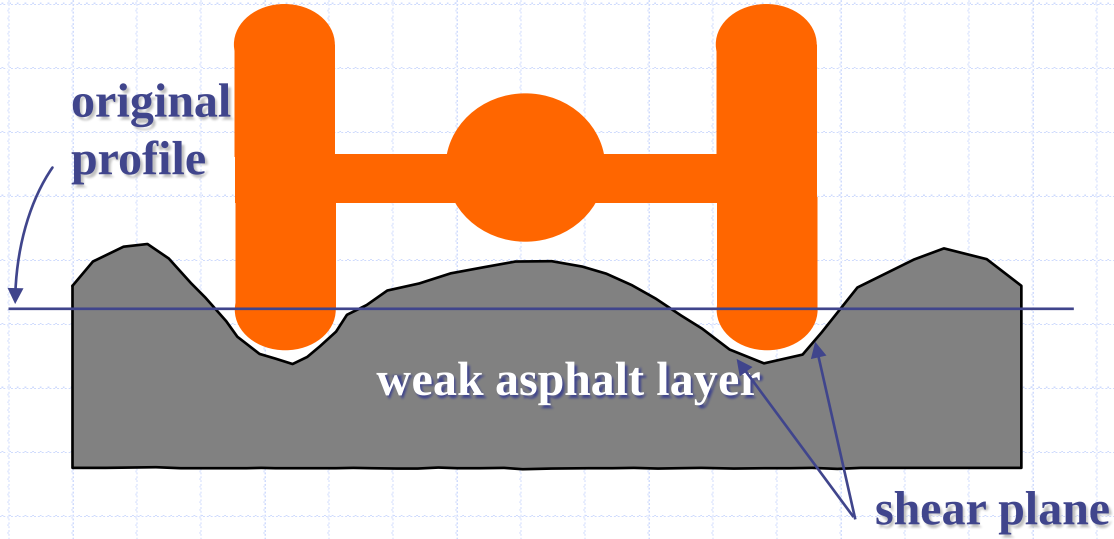
- Adjusts to limited differential settlement
- Easily, quickly constructed and repaired
- Additional thickness can be added
- Quieter and smoother (generally)
- More “forgiving”

Disadvantages of Flexible Pavement

- Properties may change over time as pavement ages
- Generally shorter service life before first rehabilitation
- May experience moisture problems

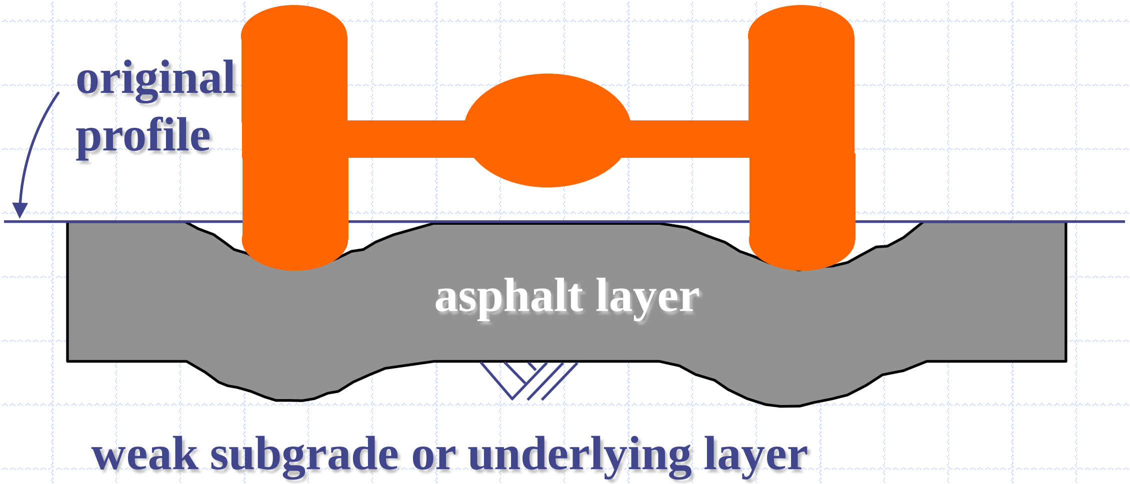
Surface Course Distress

- Rutting mainly controlled by choice of materials and design of surface mixes
- Surfaces also must be resistant to cracking

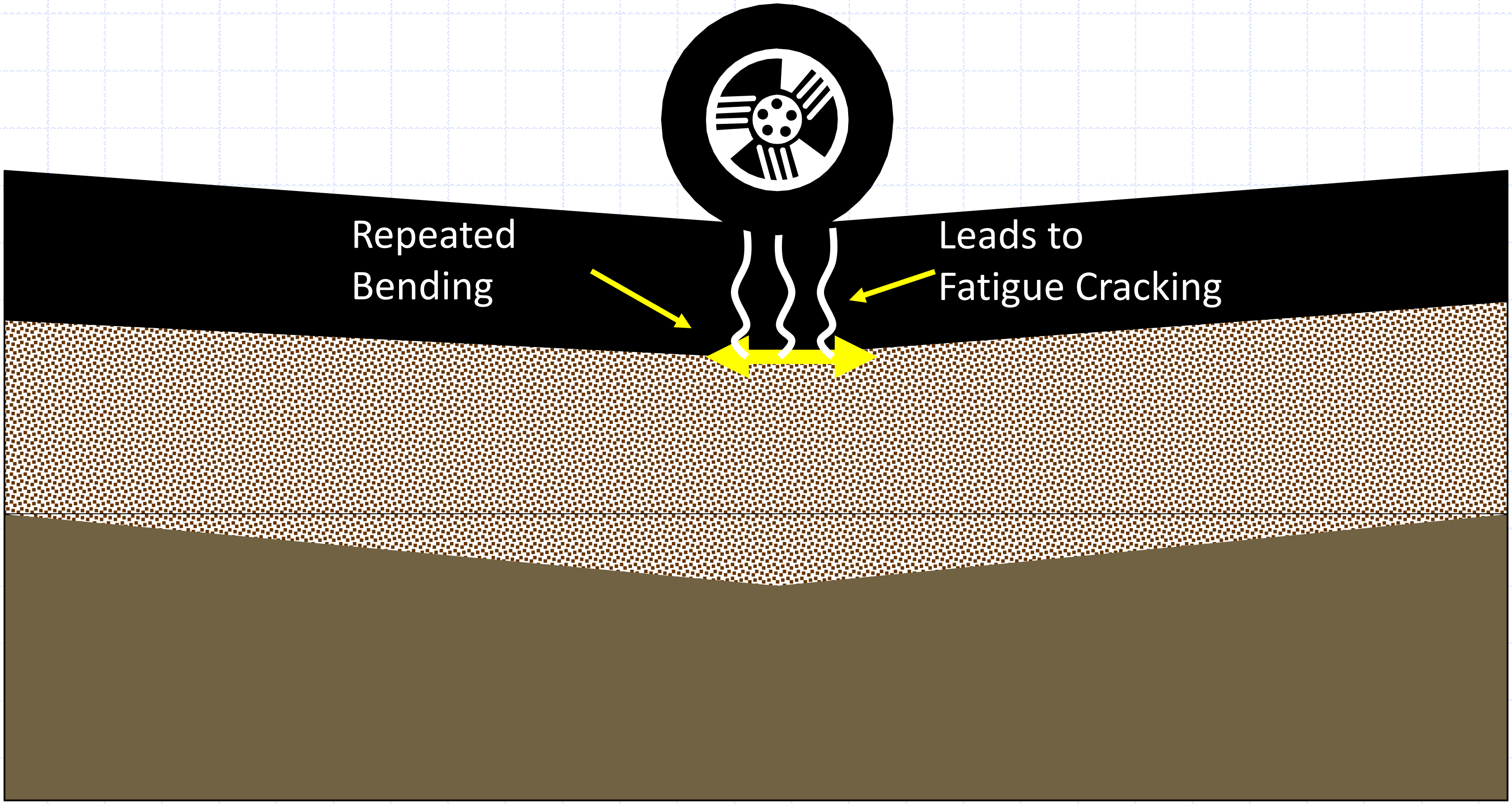


Foundation Distresses

- Poor subgrade support can cause rutting.
  - Drainage
  - Frost penetration?
  - Stabilization



Fatigue Cracking



Perpetual Pavement

- Asphalt pavement designed to last over 50 years without major structural rehabilitation needing only periodic surface renewal.
  - *Full-depth pavement* – constructed on subgrade
  - *Deep-strength pavement* – constructed on thin granular base course
  - AKA *extended-life pavement* or *long-life pavement*

Perpetual Pavement Concept

- Asphalt pavements with high enough strength will not exhibit structural failures.
- Distresses will initiate at the surface, typically in the form of rutting or cracking.
- Surface distresses can be removed/ repaired relatively easily,
  - Before causing structural damage,
  - Leaving most of pavement in place, performing well.

Perpetual Pavement Features

- Each layer designed to resist specific distresses
- Base – designed to resist fatigue and moisture damage, to be durable
- Intermediate/binder – designed for durability and stability (rut resistance)
- Surface – designed to resist surface initiated distresses (top-down cracking, rutting, other)

Surface Renewal

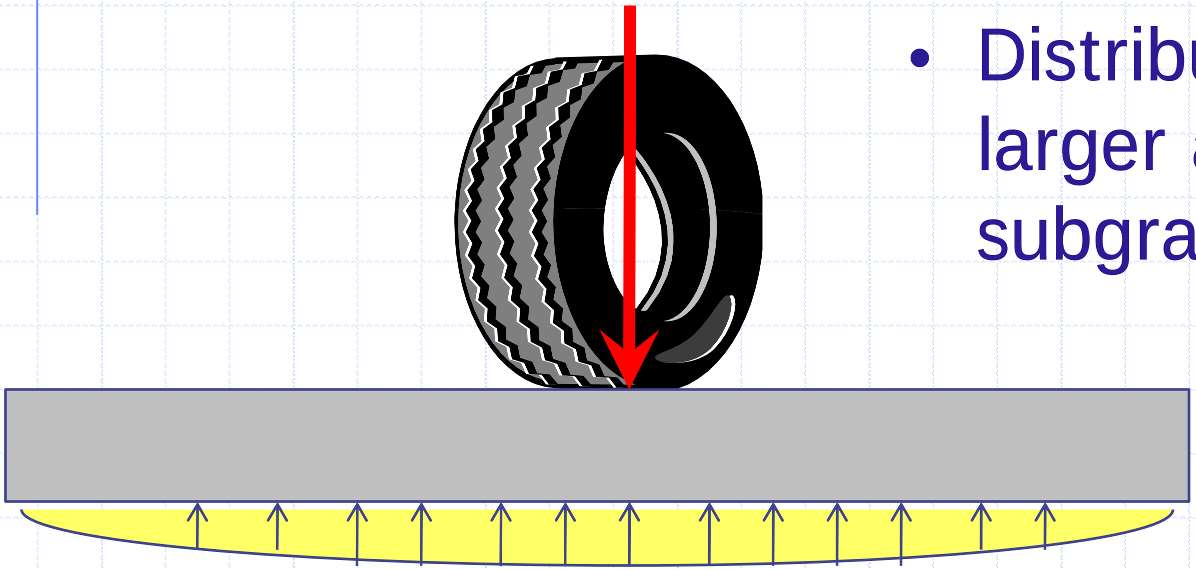
- Repair surface distresses before they become structural
  - Mill and fill
  - Thin overlay
- Quick
- Cost effective

Rigid Pavements

- Generally stiffer – may have reinforcing steel
- Distributes loads over relatively large area of subgrade
- Portland cement concrete
- Can be recycled, but less common
- Service lives 20-40 years (to first major rehab)

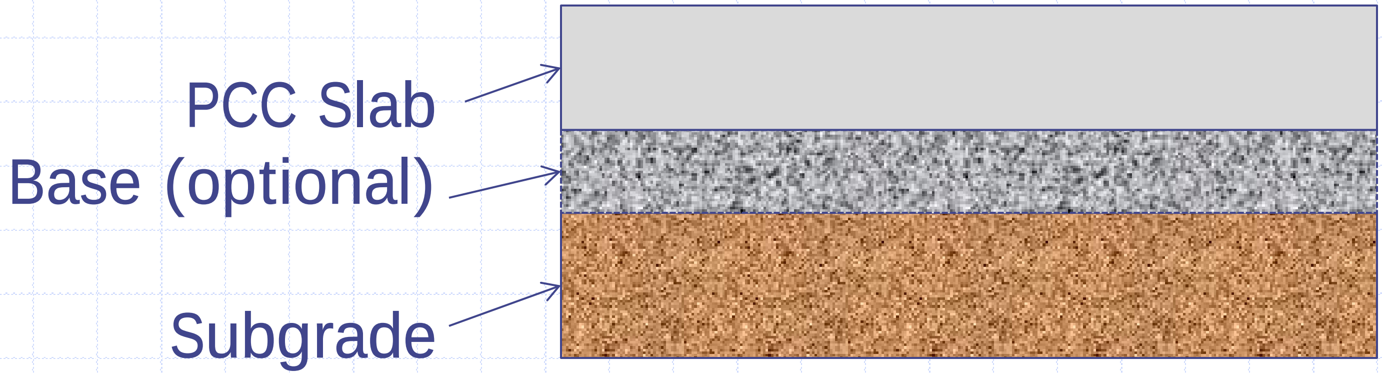
Rigid Pavement

- Stiffer pavement layer
- Little bending
- Distributes load over larger area of subgrade



Typical Applications – Rigid Pavement

- High volume traffic lanes
- Freeway to freeway connections
- Exit ramps with heavy traffic



Advantages of Rigid Pavement

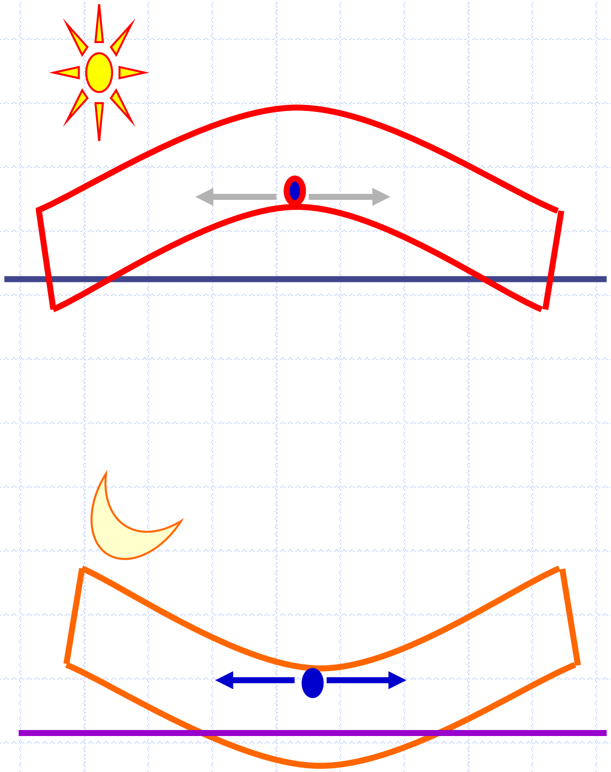
- Good durability
- Long service life
- Minor variations in subgrade strength have little effect
- Withstand repeated flooding and subsurface water without deterioration (as long as base and/or subgrade are resistant to moisture damage)

Disadvantages of Rigid Pavements

- Distresses may be harder/more expensive to repair
- May polish (lose frictional properties) over time
- Needs even subgrade support
- Generally (but not always) considered more expensive to construct

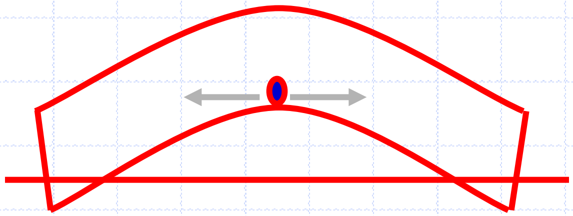
Concrete Slab Temperature and Moisture Gradients

Curling

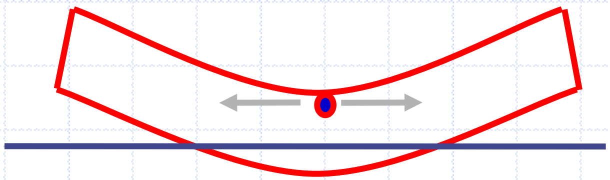


Warping

Slab wetter on top



Slab dryer on top



Choosing a Pavement Type

- Many states have guidelines or policies
- Driven by engineering and economic considerations (preferred)
- Sometimes influenced by other considerations

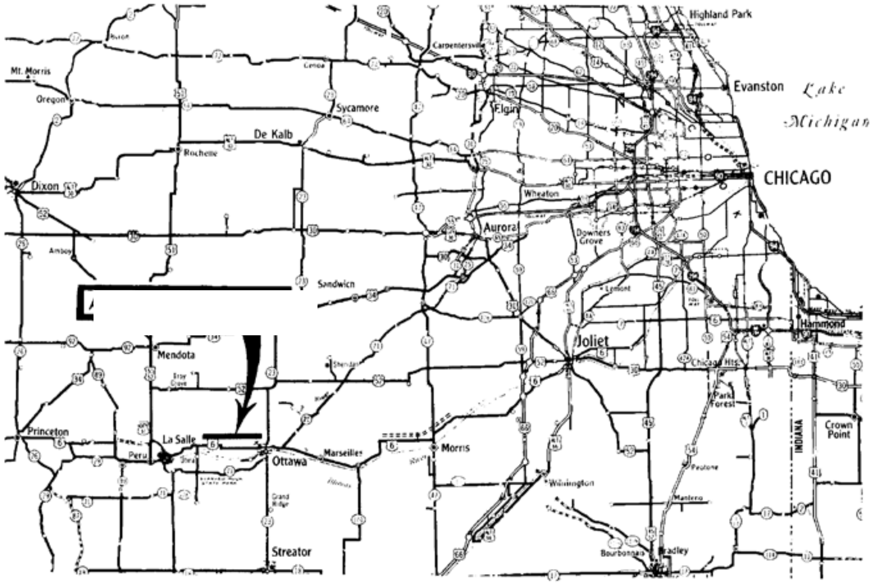
Pavement Design Considerations

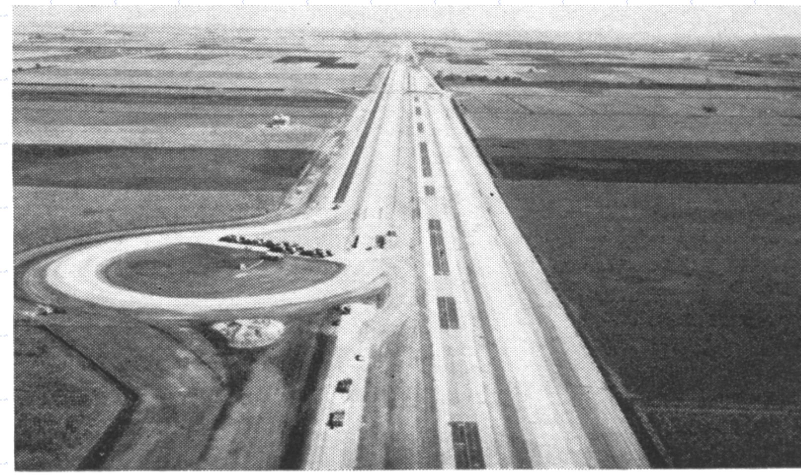
- Pavement Performance
- Traffic
- Subgrade Soil Conditions
- Availability and Cost of Materials
- Environment
- Drainage
- Reliability
- Life Cycle Costs
- Shoulder Design

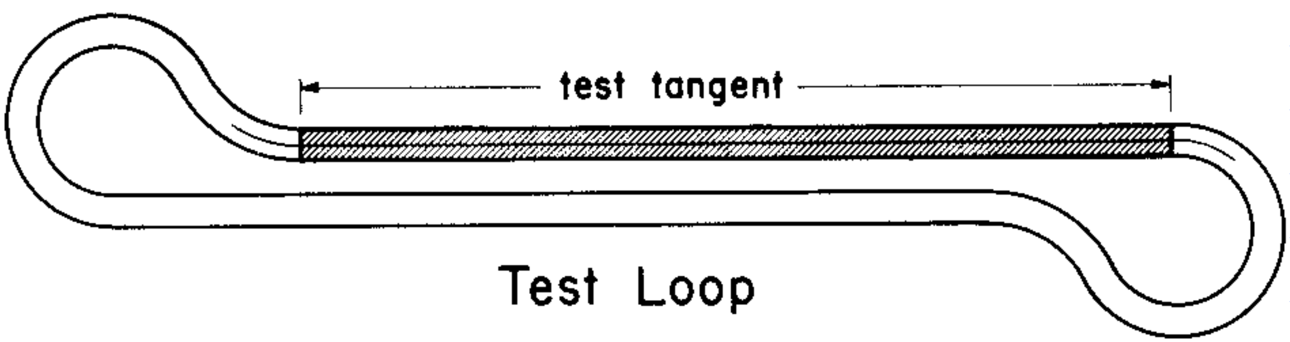
Design Methodologies

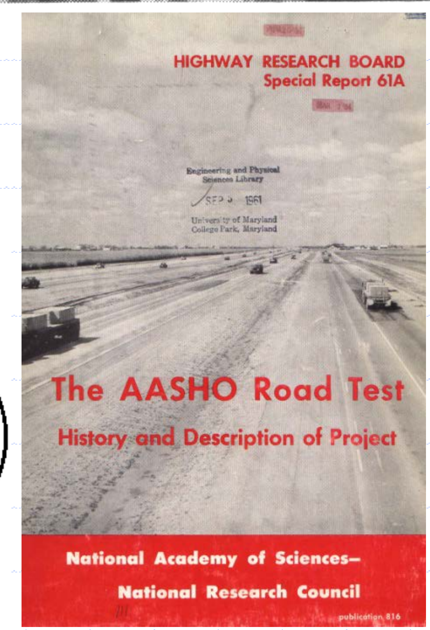
- Experience
- Empirical
  - Statistical models from road tests
- Mechanistic-empirical
  - Calculation of pavement responses, i.e., stresses, strains, deformations
  - Empirical pavement performance models
- Mechanistic

AASHO Road Test









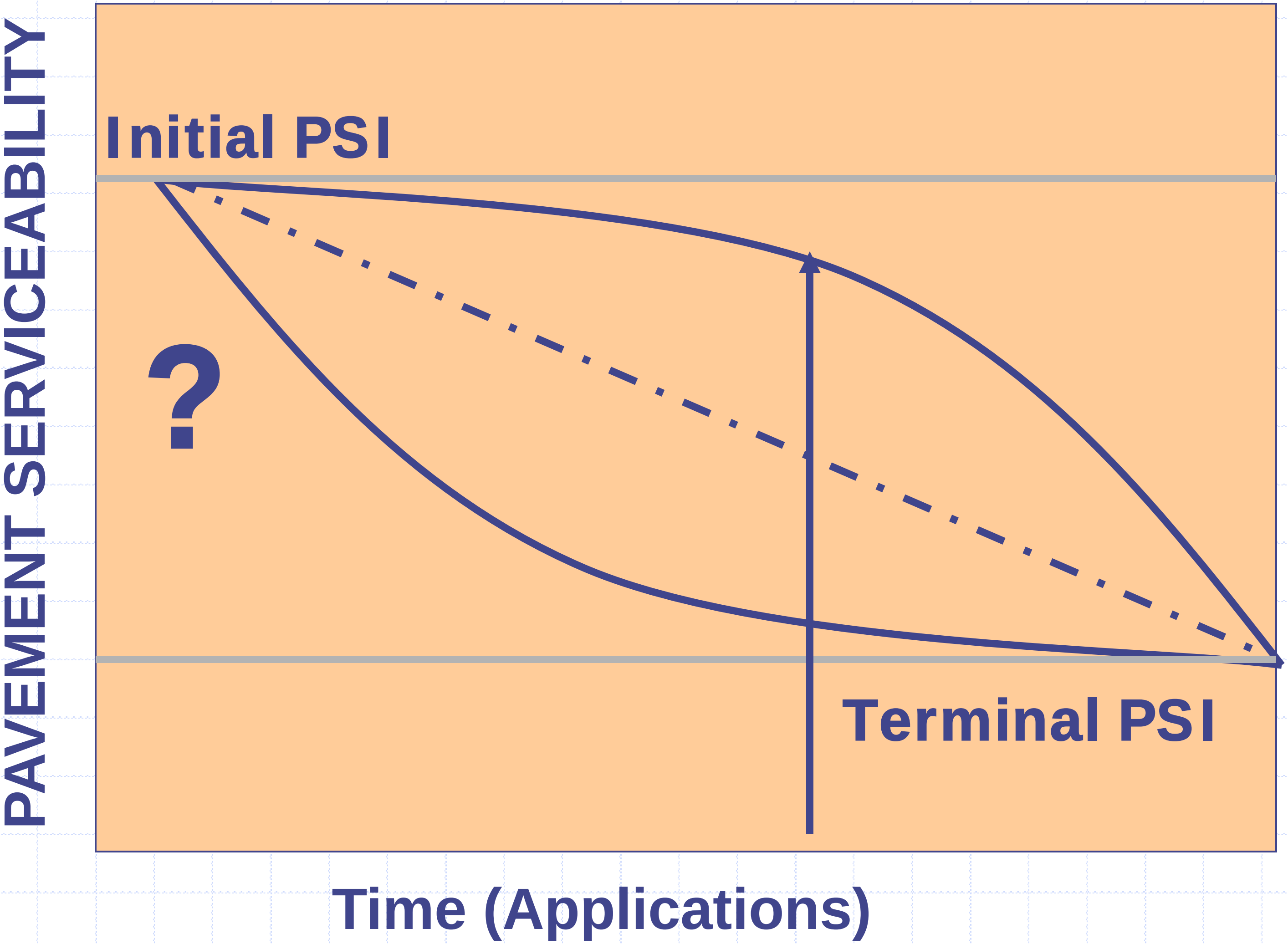
AASHO Road Test Achievements

- Serviceability concept - PSI
- Traffic damage factors – ESALs
- Structural number concept – SN
- Empirical Process
- Simplified Pavement Design
- Used for about 50 years

Serviceability

- Ability of a pavement to serve the traffic for which it was designed
- User rating of performance plus measured physical features of the pavement (such as rut depth, cracking, etc.)
- When serviceability reaches a certain level, rehab or maintenance is needed

AASHO Serviceability



Structural Number Concept

- Determine SN needed to carry the traffic over the soil conditions in the region
- Empirical layer coefficients (a_i) reflect how that material will contribute to the structural strength of the pavement
- Determine layer thicknesses (D_i) to achieve required SN

$$SN = a_1D_1 + a_2D_2 + a_3D_3 \ldots$$

Basic AASHTO Flexible Pavement Design Method

- Determine the desired terminal serviceability, p_t
- Convert traffic volumes to number of equivalent 18-kip single axle loads (ESAL)
- Determine the structural number, SN
- Determine the layer coefficients, a_i
- Solve layer thickness equations for individual layer thickness

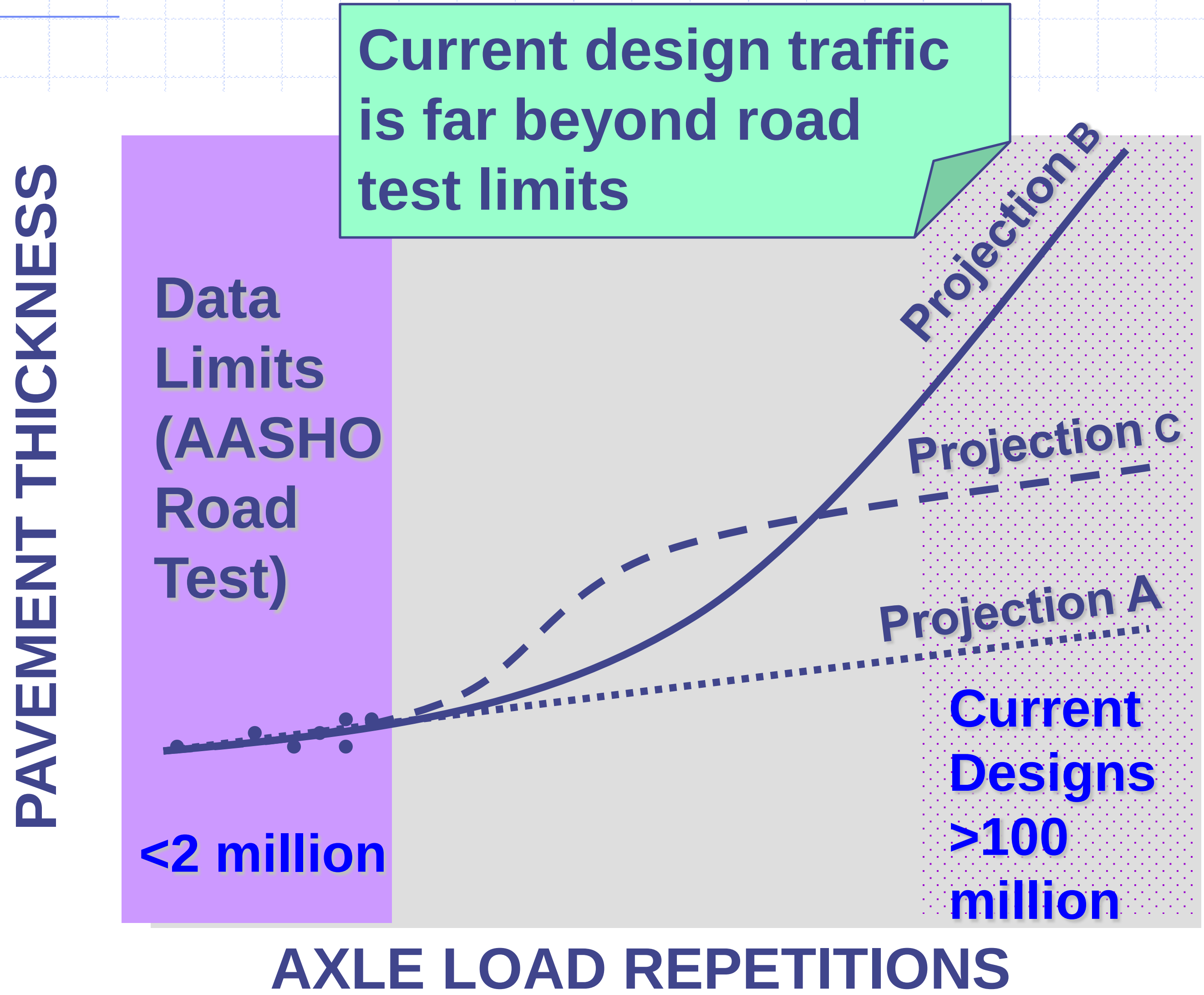
Basic AASHTO Rigid Pavement Design Method

- Select terminal serviceability
- Determine number of ESALs
- Determine the modulus of subgrade reaction
- Determine the slab thickness

Limitations of AASHO Road Test

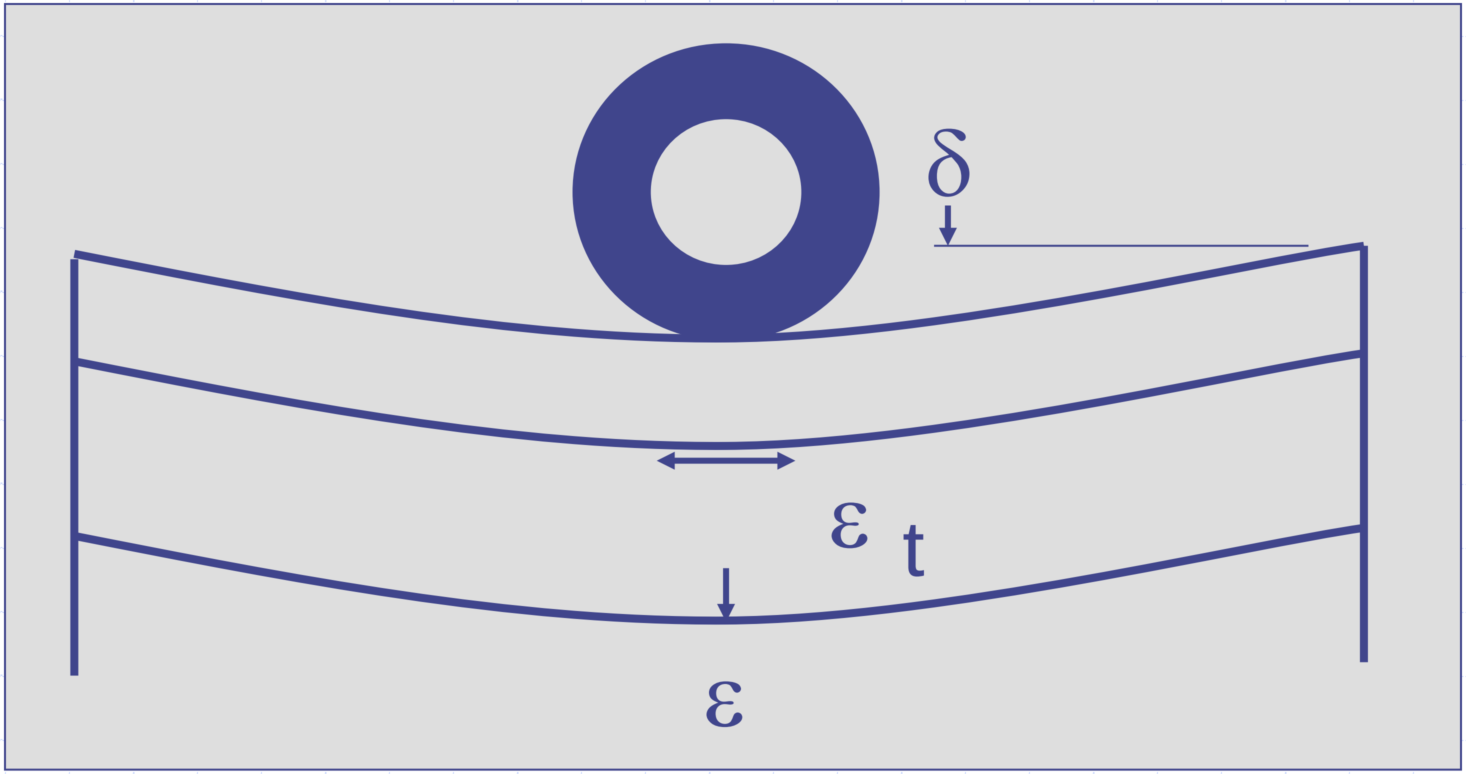
- One climate – Ottawa, Illinois
- Limited Span – two years
- Limited Traffic – generally < 2 million
- 1950’s vehicles
- 1950’s materials and construction
- Only new construction

What Is Wrong with Present System?

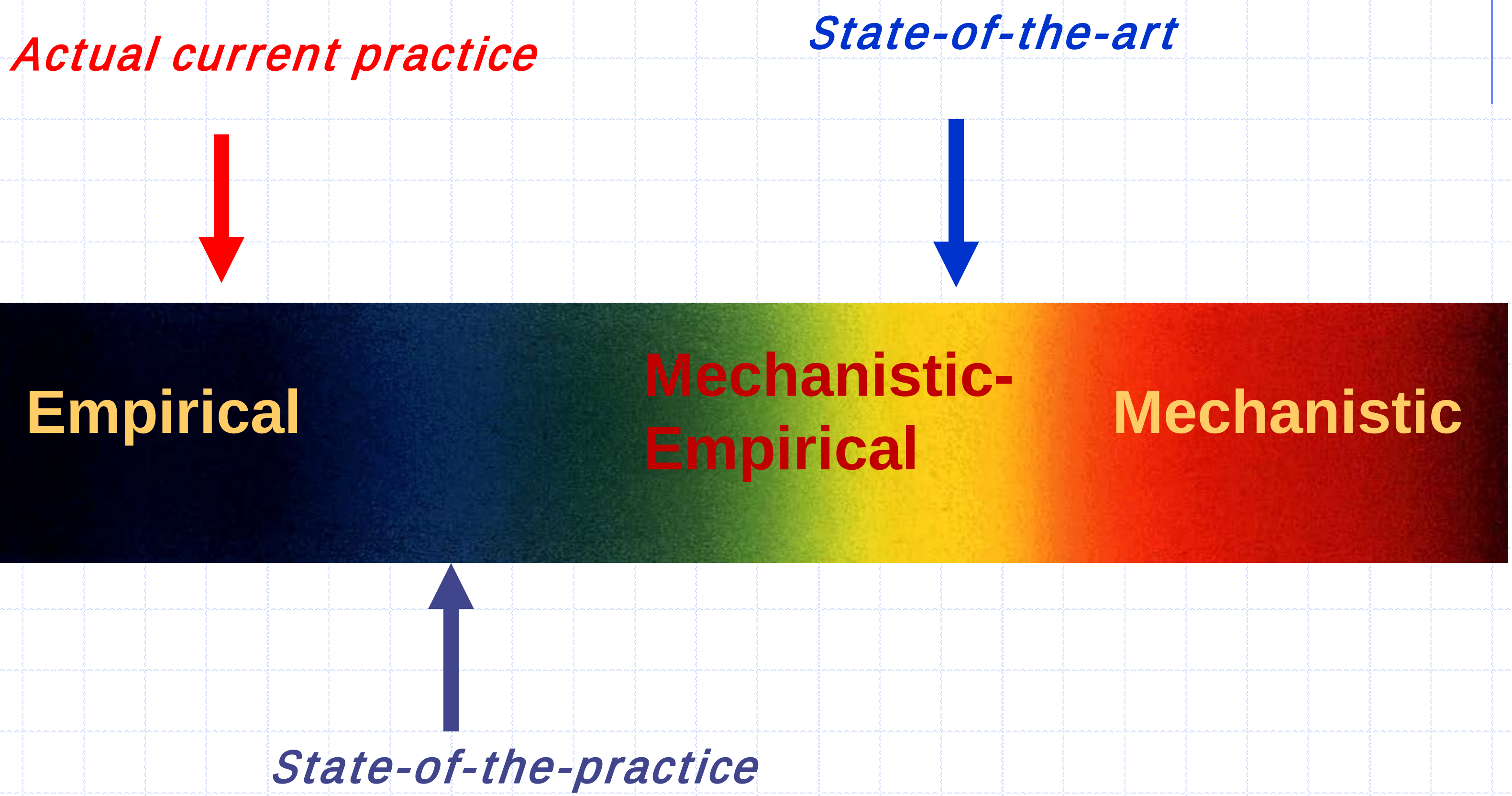


What Would be Better?

Fundamental Mechanistic - Empirical Principles



Development Continuum



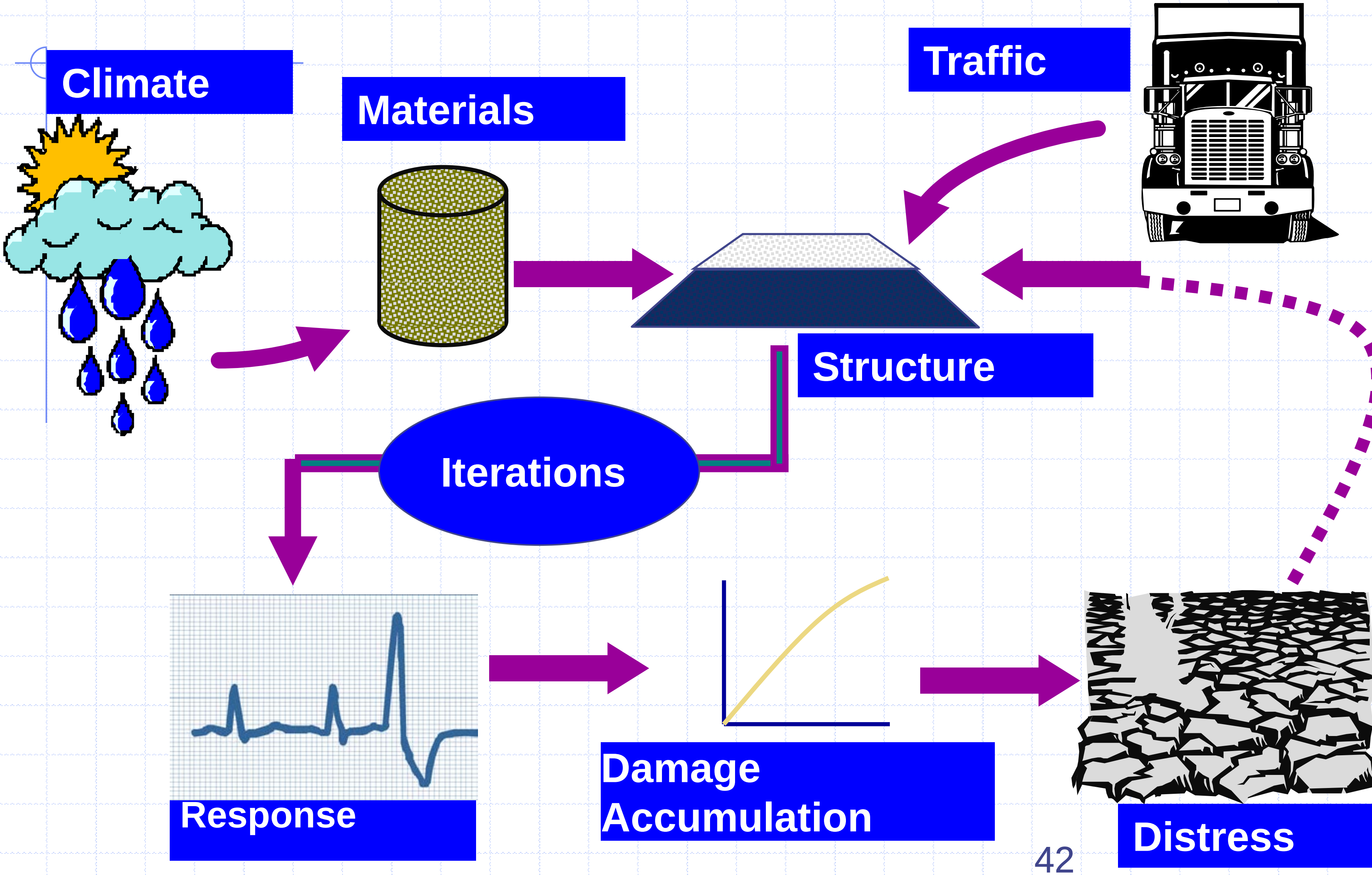
M-E Design

- Considers applied stresses and resulting strains
- Uses fundamental engineering properties that can be measured
- Computes reactions to stresses and strains and predicts distresses
- Feasible with improved computing capabilities

MEPDG

- Mechanistic-Empirical Pavement Design Guide
- Allow design of:
  - New construction (flexible and rigid)
  - Composite pavement designs
  - Rehabilitation and overlays
- Evaluates effects of specification changes
  - “what ifs”

M-E Pavement Design Process



Basic Concept Behind MEPDG

- Determine acceptable levels of distress
- Estimate traffic loading
- Determine material properties and climatic effects on those materials
- Select trial structure
- Calculate distresses in that structure based on response to traffic and climate
- Are distresses acceptable?

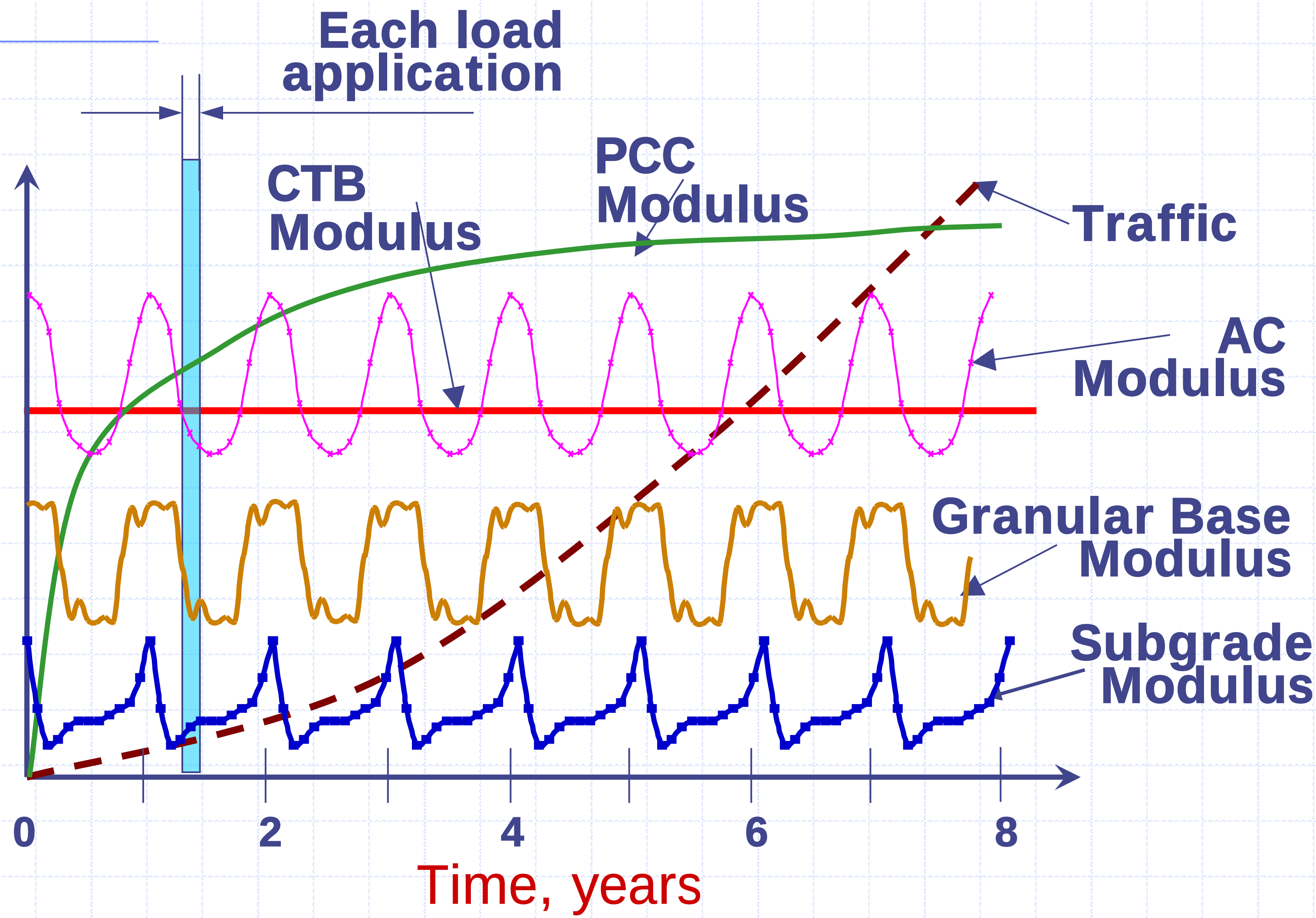
Hierarchical Levels

Level	Source	Usage
Three	Defaults	Routine projects
Two	Correlations	Routine significant projects
One	Project specific data	Research, forensics and high level projects

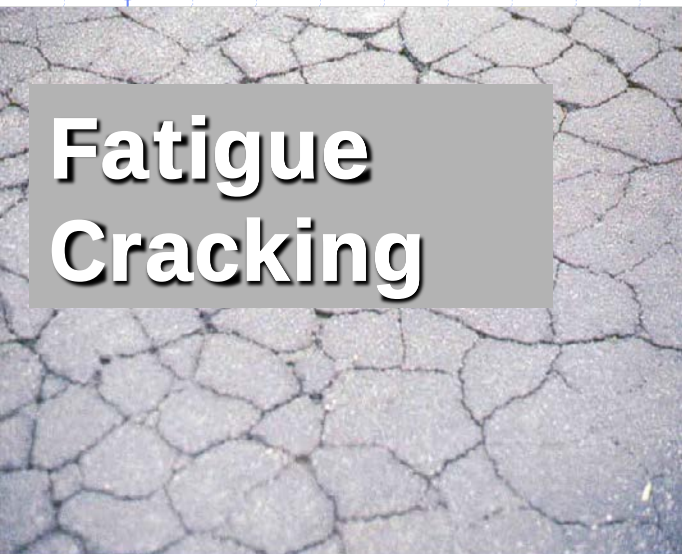
Numerous Input Parameters

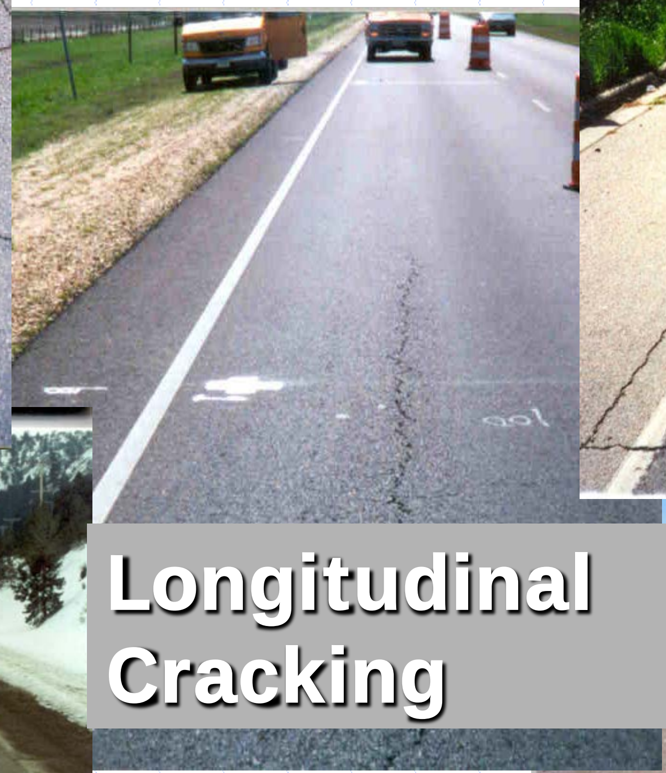
- Materials properties change with time and environment
- Calculates incremental damage for each load
- Damage is dependent upon stress-strain and material properties at time of loading

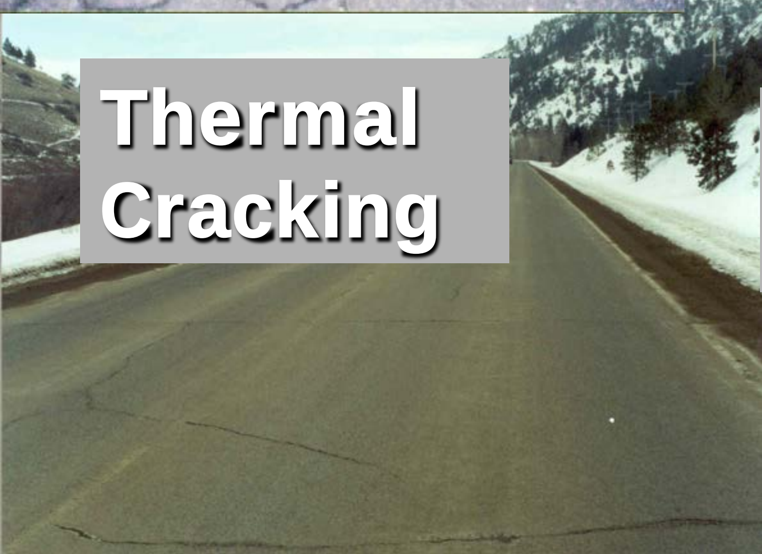
Pavement Design Variables



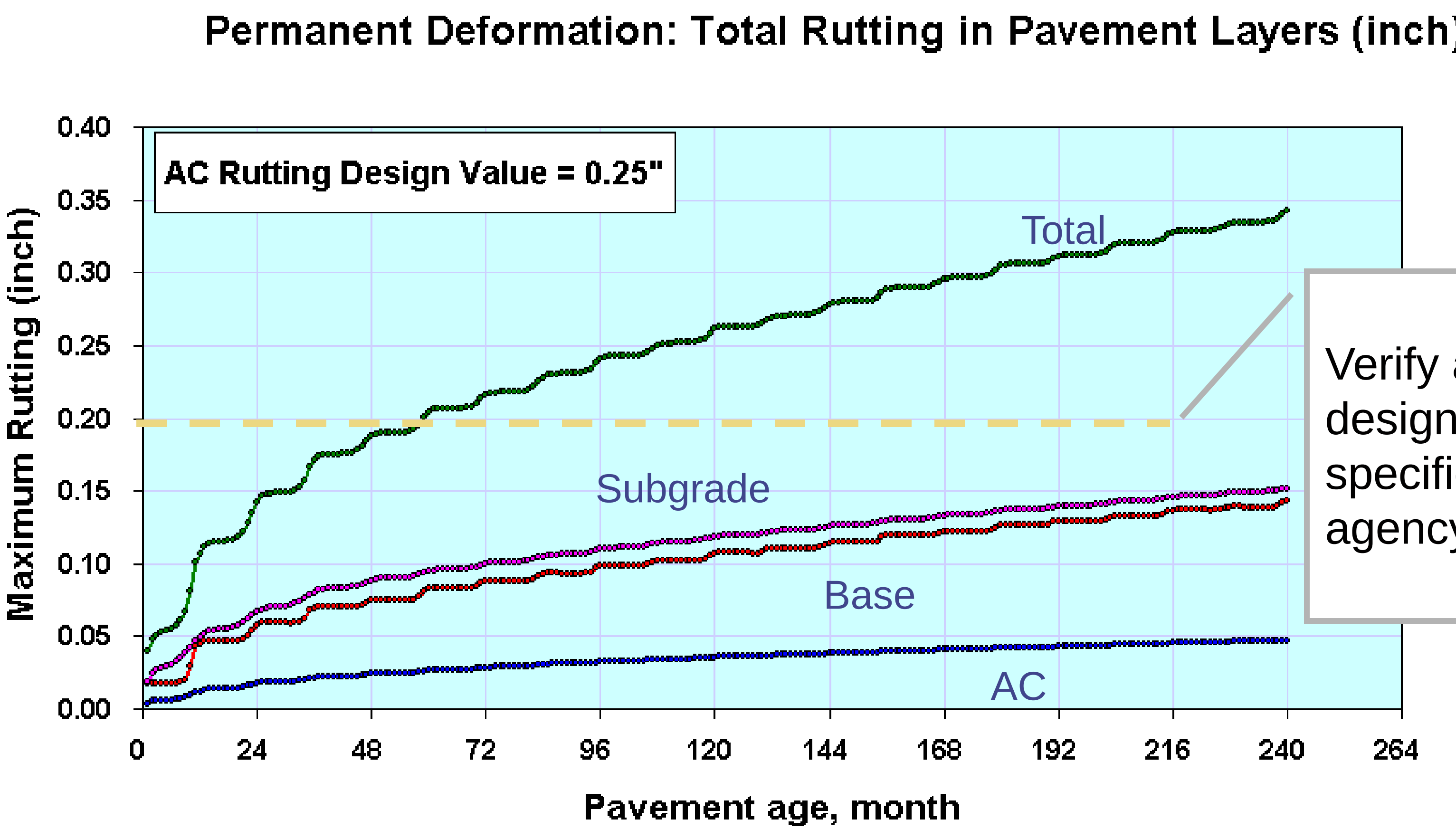
Predicted Distresses - Flexible







Graph Example Output – Rutting



Verify against design criterion specified by agency

Rigid Pavement Performance

Transverse Cracking

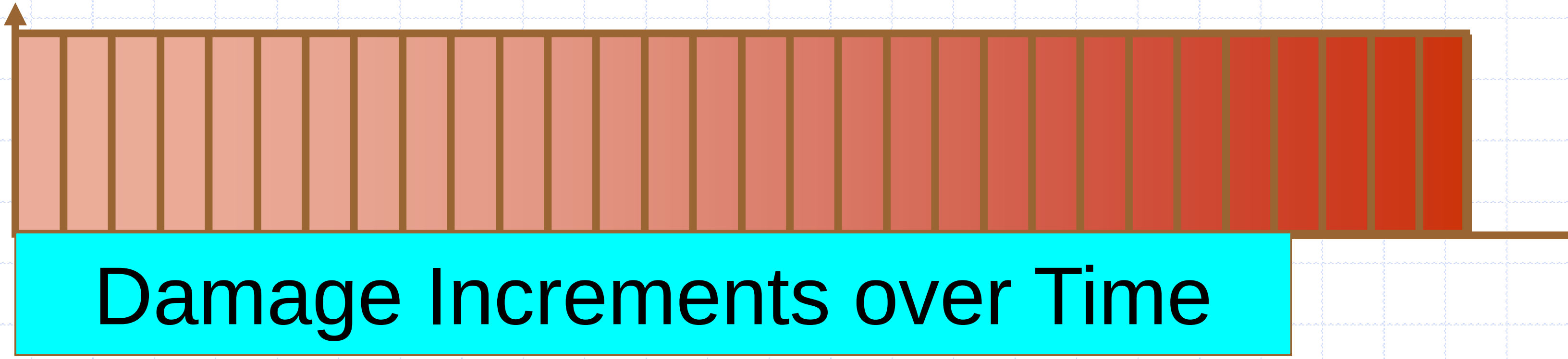
Faulting

Punchout

IRI

Incremental Damage Concept – Accumulation for PCC Pavements

- Design life divided into monthly increments
- Specific material properties, traffic and climatic data used for each increment

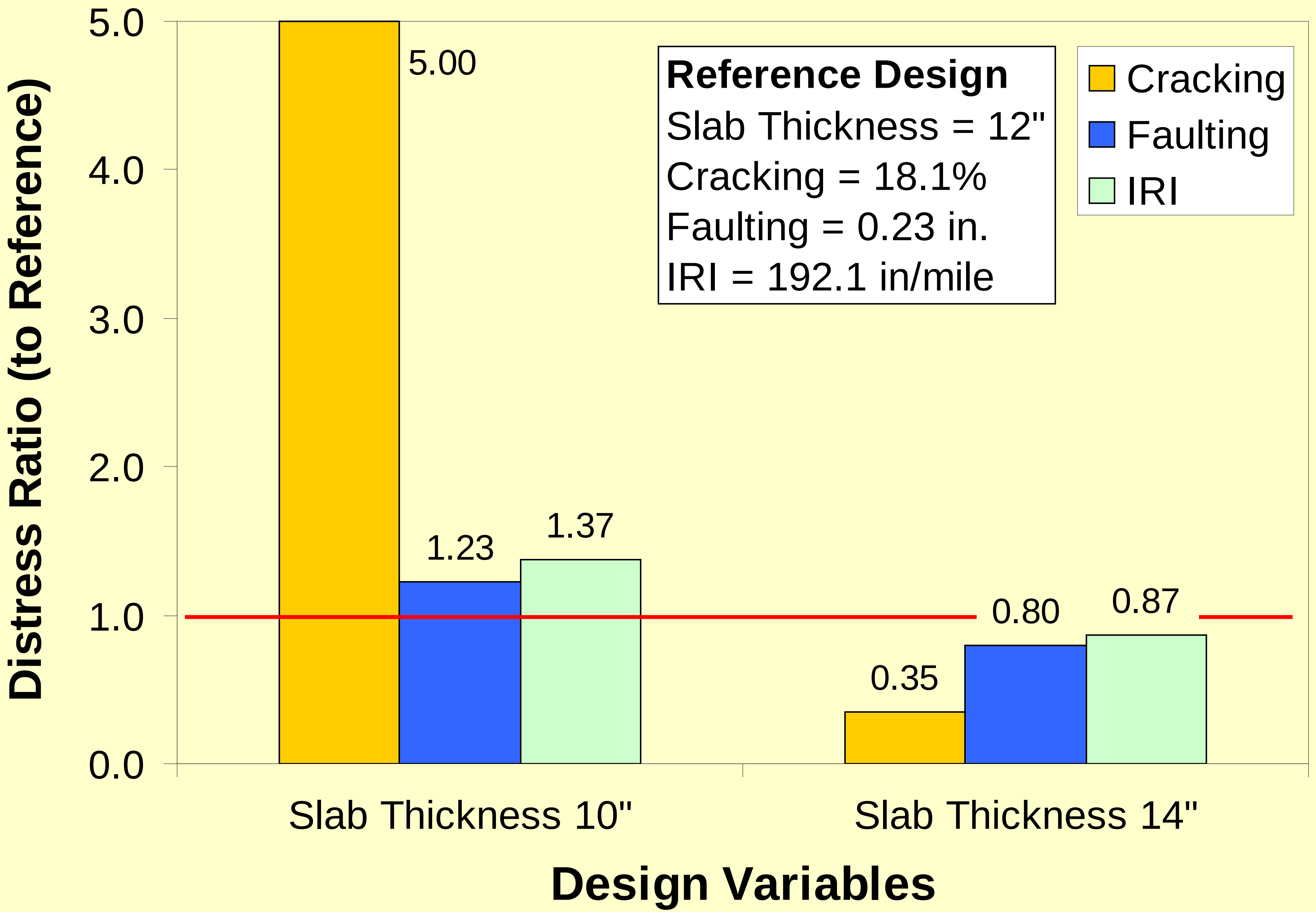


JPCP Design Features Inputs

- 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

Input Level	1	2	3
	√	√	√

Slab Thickness - JPCP



MEPDG Capabilities

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

MEPDG Capabilities

- Models to predict change in distress over time
- User establishes acceptance criteria
  - Distresses and smoothness
- Procedure evaluates the trial design to determine if it meets the desired performance criteria at individually set reliability levels

Pavement Design Resources

- MEPDG www.trb.org/mepdg/
- AASHTO 1993 Pavement Design Guide
- Perpetual Pavement Design Software – PerRoad http://asphaltroads.org/PerpetualPavement

Rebecca S. McDaniel
Technical Director
North Central Superpave Center
765/463-2317 ext. 226
rsmcdani@purdue.edu
https://engineering.purdue.edu/NCSC/