Pavement Design 101

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Manager, Pavement Engineering

NextLevel INDIANA

Outline

- History of pavements(road)
- Types of pavements
- Design considerations
- Pavement design methods
- Pavement distresses
- Pavement evaluations
- Pavement Rehabilitation
- Construction
- Maintenance

NextLevel INDIANA

- **History of pavements(roads)**

History of Roads

- Early Roads
  - Harappan roads
  - Wheeled transport
  - Roman Roads
  - Early tar-paved roads
  - Macadam roads

  - Modern Road

Harappan road(4000 BC)

Wheeled transport(3000 BC)

Roman roads…

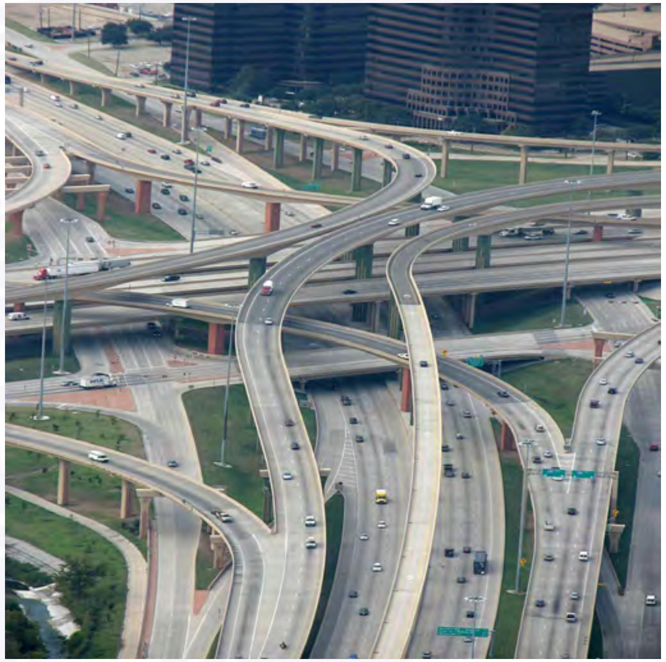
Tar road(from coal,wood,petrol

Pitch Lake, Trinidad

Pitch Lake, Trinidad

Macadamized road(1820s,30s,

Modern road



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Types of pavements

- **Types of pavements**

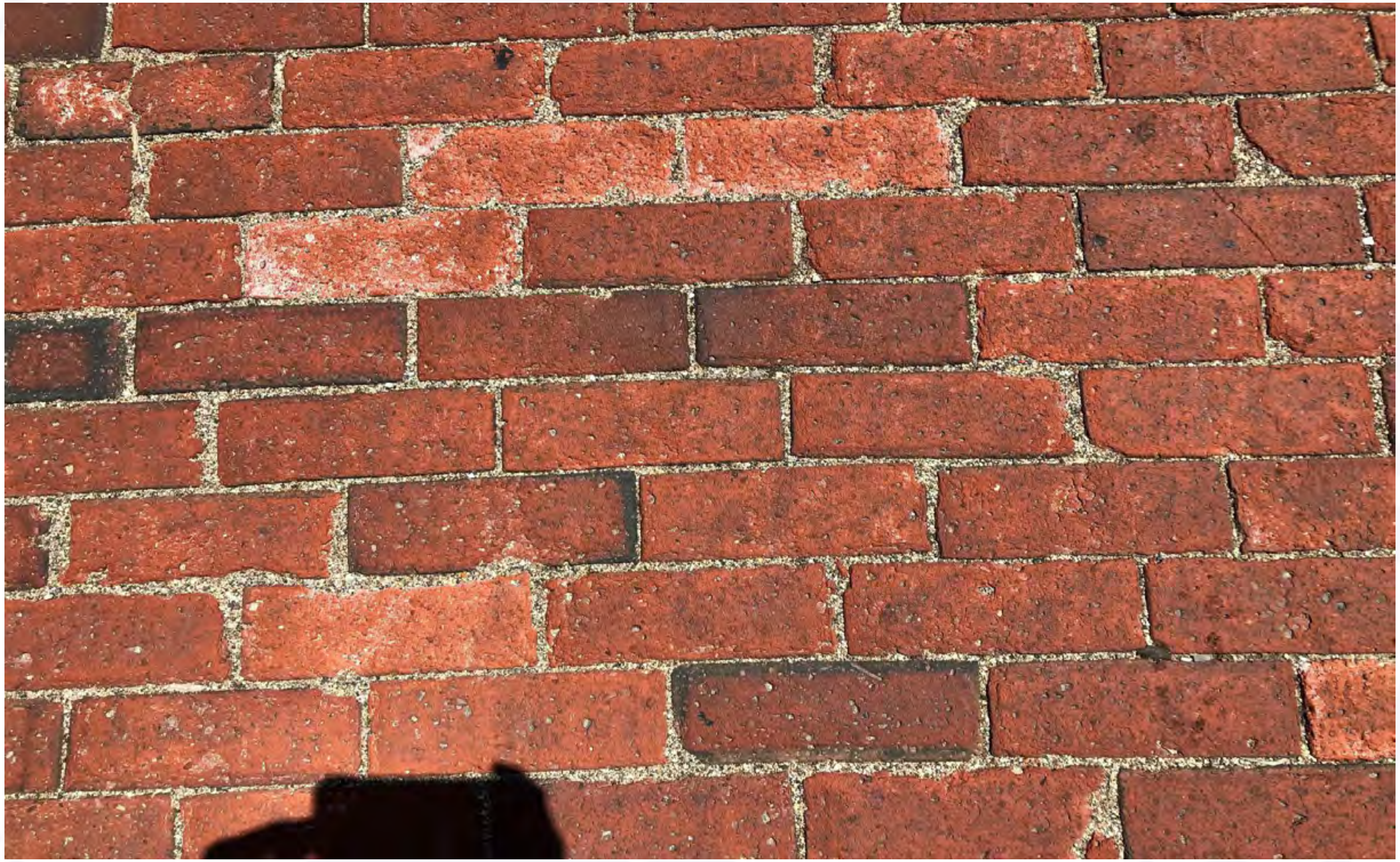
Types of Roads

- Aggregate roads
- Brick roads
- Asphalt Roads
- Concrete Roads
- Composite roads

Aggregate road

Aggregate Road

Brick Road



Asphalt Road

Asphalt Road in India

Composite Road

SR 75 in Thorntown

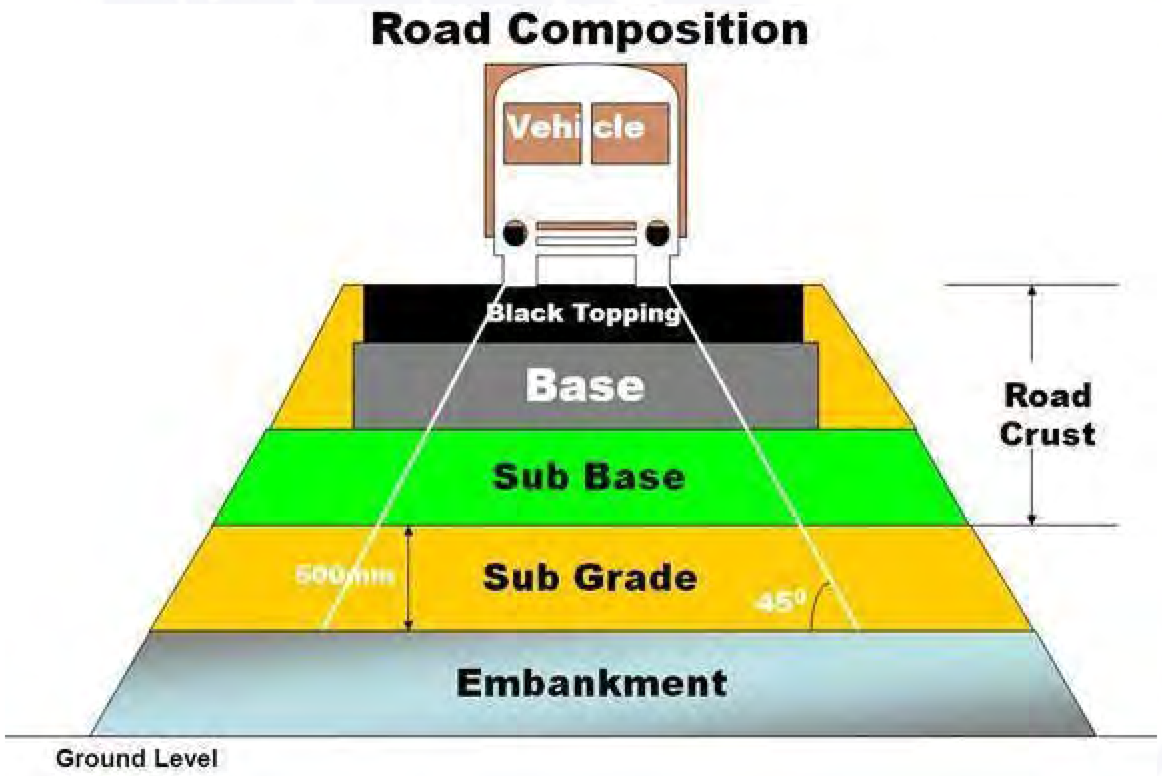

STOP


SOUTH
75

![NextLevel Indiana]

Asphalt Road

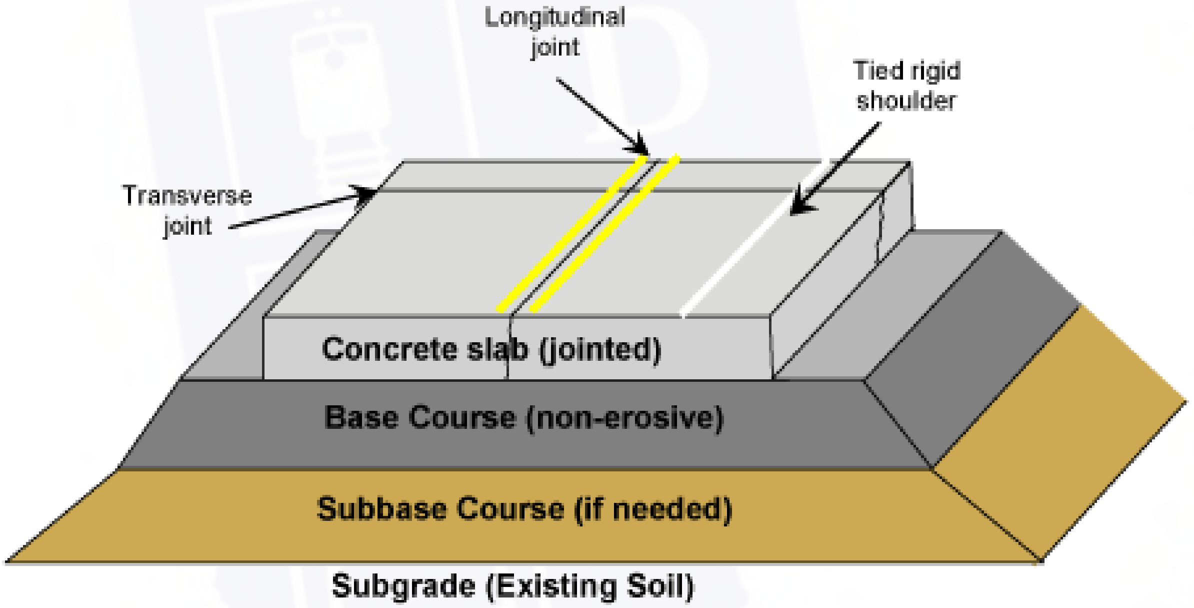
Asphalt Road composition



Concrete Road

Concrete Road

Concrete Rd composition



Asphalt & Concrete core


Valley Road Intersection
Improvement
Johnson Cou
Core No.: PC-

Pavement Coring

Composite Core

Composite Core


RB/PC
14

HMA pavement cross section

1.5” Surface

2.5” Intermediate

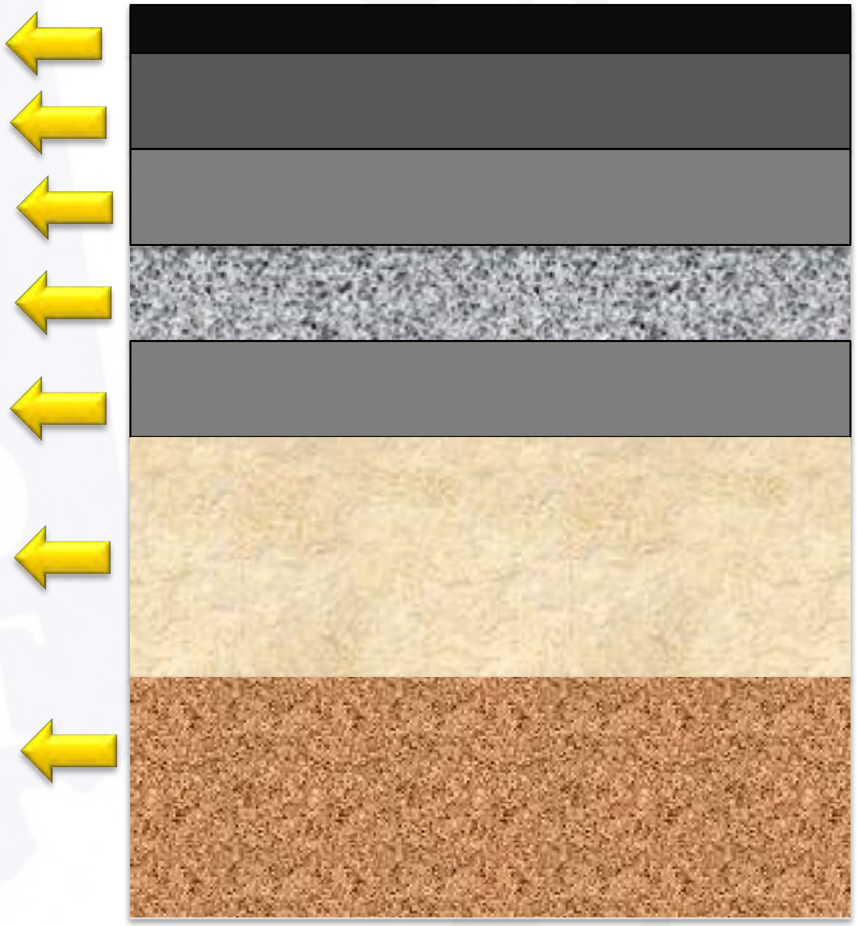
3”+ Dense graded base

3” Open graded base

3” Dense graded base

14” Soil treatment

Soil subgrade



JPCP cross section

11” – 13” JPCP

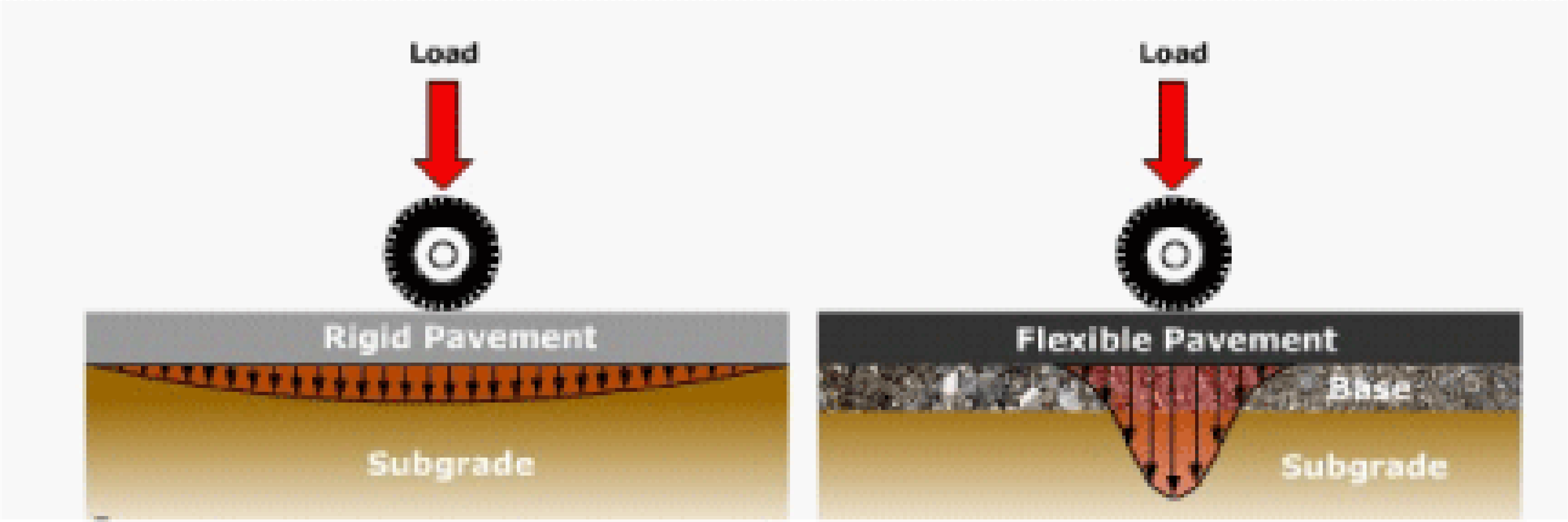
3” Open graded stone

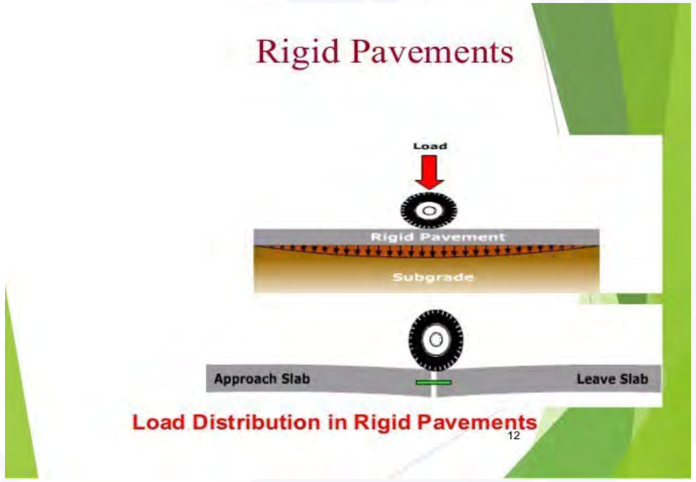
6” - 12” Dense graded stone

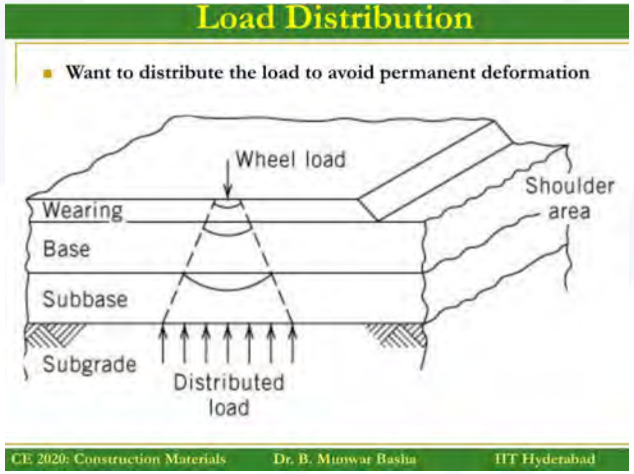
14” Soil treatment

Soil subgrade

Load distribution







Design Considerations

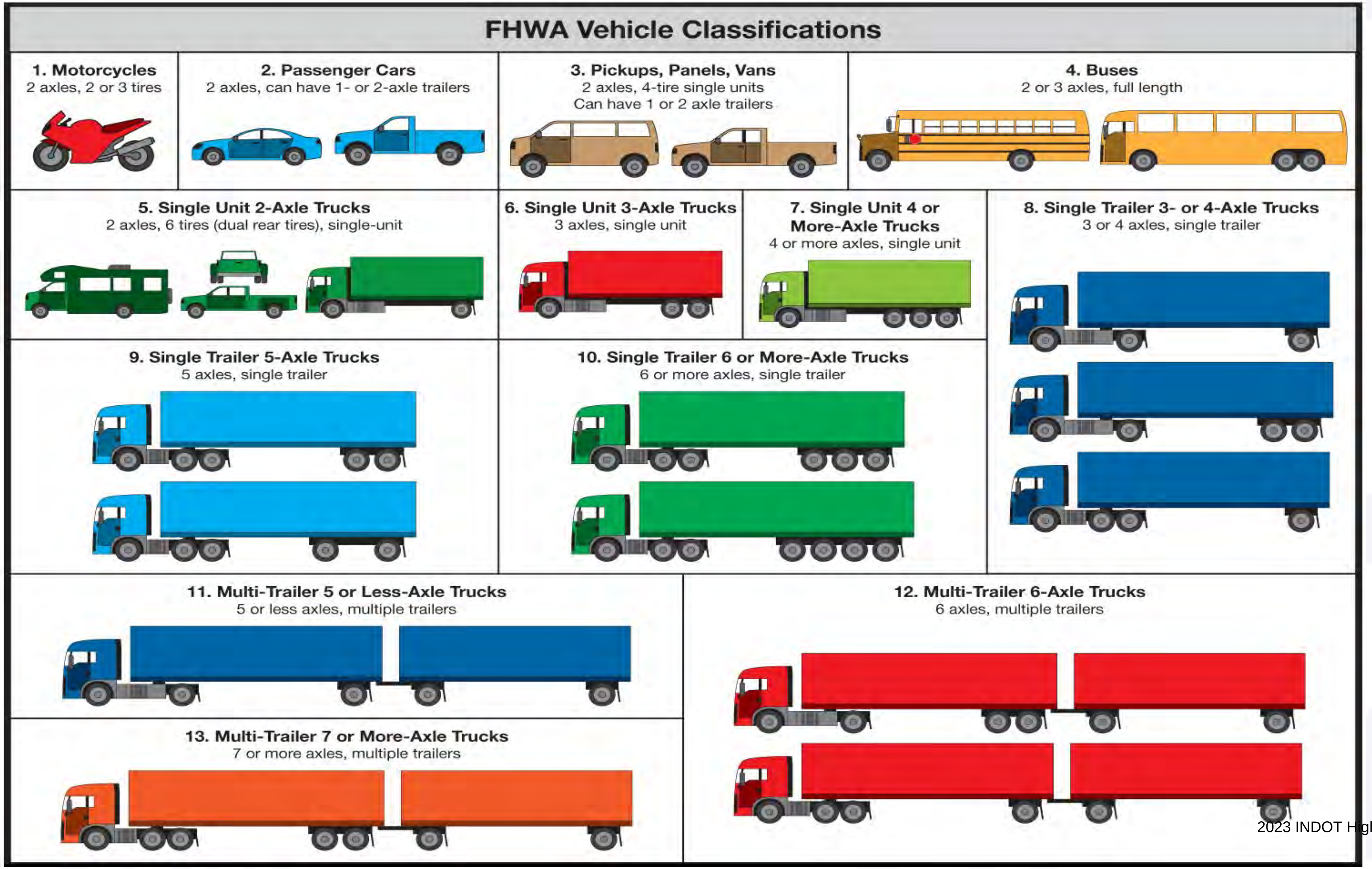
Pavement Design Consideration

- pavement performance
- traffic
- roadbed soil
- materials of construction
- environment
- drainage
- reliability
- lcpca
- Shoulder design

Pavement Performance

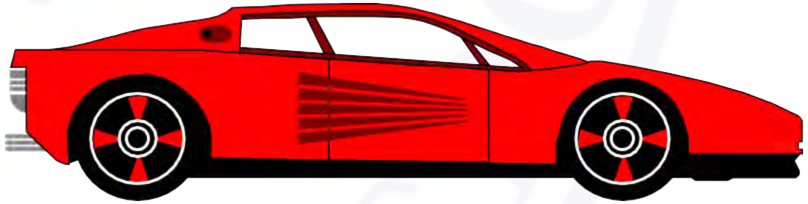
- Pavement design life=20, 30, 50 yrs.
- Asphalt road=20 years
- Concrete road=30 years

Traffic

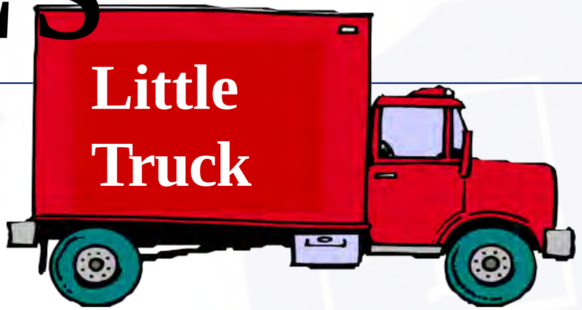

FHWA Vehicle Classifications
1. Motorcycles
2 axles, 2 or 3 tires
2. Passenger Cars
2 axles, can have 1- or 2-axle trailers
3. Pickups, Panels, Vans
2 axles, 4-tire single units
Can have 1 or 2 axle trailers
4. Buses
2 or 3 axles, full length
5. Single Unit 2-Axle Trucks
2 axles, 6 tires (dual rear tires), single-unit
6. Single Unit 3-Axle Trucks
3 axles, single unit
7. Single Unit 4 or More-Axle Trucks
4 or more axles, single unit
8. Single Trailer 3- or 4-Axle Trucks
3 or 4 axles, single trailer
9. Single Trailer 5-Axle Trucks
5 axles, single trailer
10. Single Trailer 6 or More-Axle Trucks
6 or more axles, single trailer
11. Multi-Trailer 5 or Less-Axle Trucks
5 or less axles, multiple trailers
12. Multi-Trailer 6-Axle Trucks
6 axles, multiple trailers
13. Multi-Trailer 7 or More-Axle Trucks
7 or more axles, multiple trailers

ESAL's

= 6,000



ESAL's



67 kN		27 kN	
15,000 lb	+	6,000 lb	**= 0.49 ESAL's**
0.48 ESAL		0.01 ESAL	

151 kN		151 kN		54 kN	
34,000 lb	+	34,000 lb	+	12,000 lb	**= 2.39 ESAL's**
1.10		1.10		0.19	

Roadbed soil(subgrade)

I-69 Subgrade at Martinsville

Subgrade Treatment Types


SAGAMORE

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Subgrade treatment types

- Section 207, Standard Specification
- Type I 24 in. soil compaction
- Type IBC 14 in. chemical soil modification using Cement
- Type 1BL 14 in. chemical soil modification using Lime
- Type IC 12 in. excavate & CA No.53
- Type II 6 in. excavate & CA No.53
- Type III In-place soil compaction
- Type IV 12 in. excavate & CA 53, geogrid

Materials of construction

- Soil
- Coarse Aggregate
- Fine Aggregate
- Asphalt
- Cement
- Plastic pipe
- Metal(dowel bars, tie bars etc.)
- Geosynthetic

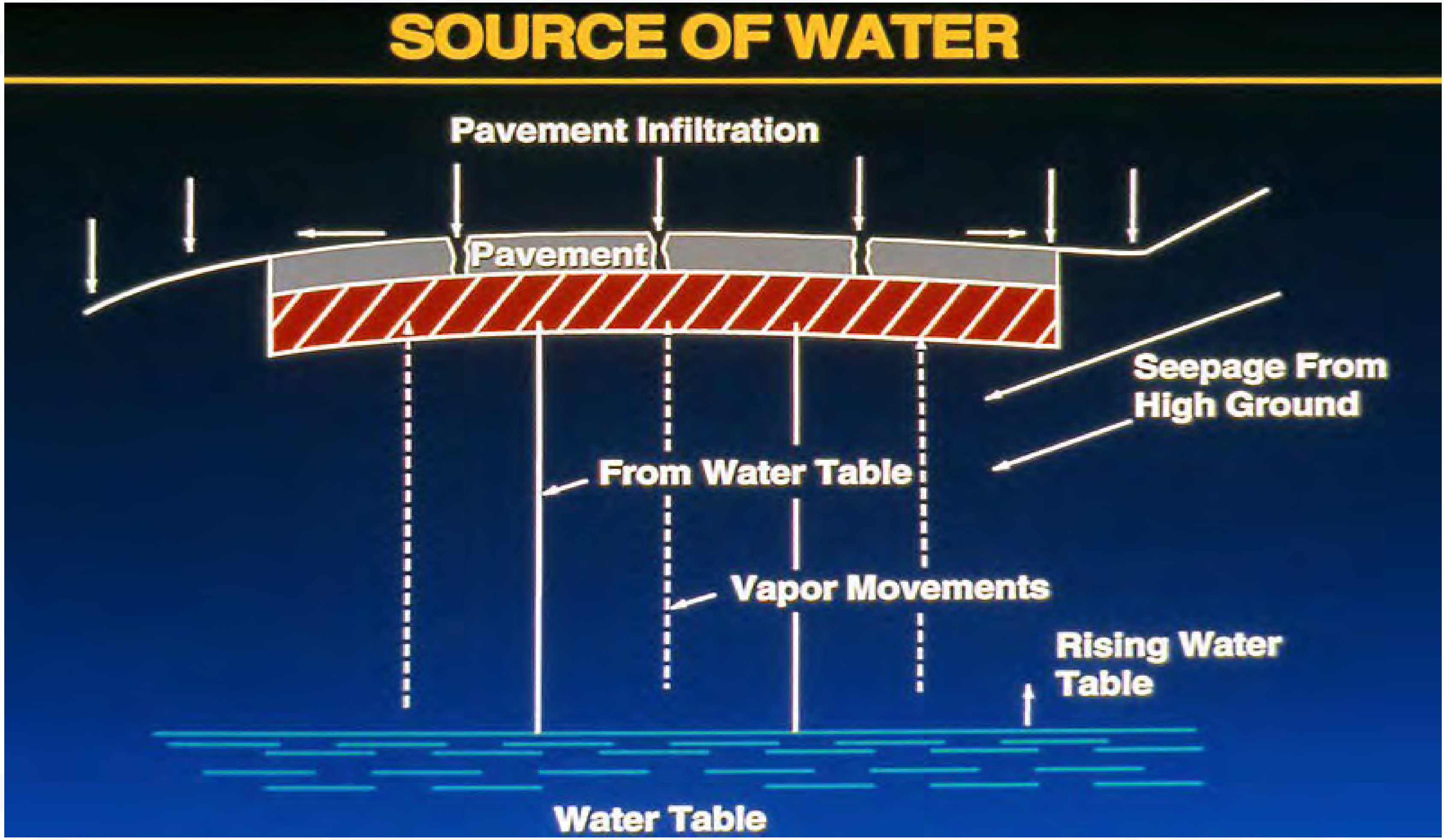

Rocks Contained in this Kit
Limestone
Dolomite
Granite
Sandstone
Shale
Marble
Gravel
Gneiss/ Schist
Blast Furnace Slag
Steel Slag

Environment

- Temperature
- Moisture
- Drainage
- Lat-Long
- Depth of water table

drainage

- Three things are imp for pavement
- drainage
- drainage
- drainage


SOURCE OF WATER
Pavement Infiltration
Pavement
Seepage From
High Ground
From Water Table
Vapor Movements
Rising Water
Table
Water Table

Drainage

Underdrain

Drainage problem

Underdrain Trench at I-74

SR 37

SR 37

SR 37

SR 37

I-69 Section 6-2

I-69 Section 6-2

Underdrains

- **Are we maintaining underdrain??????**
- **YES**
- **NO**
- **MAY BE**

Outlet Pad

Reliability

- Probability
- Varies for functional class
- 70-98%
- AASHTO
- MEPDG

LCPCA

- Economic evaluation
- Analysis Period=50 years
- Initial cost
- Future cost
- Maintenance cost
- Discount rate
- Present Worth(PW)
- Salvage Value

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Shoulder design

- Purpose
- Varies with functional class
- MOT

Narrow shoulder

Wider shoulder

Typical divided hwy shoulder

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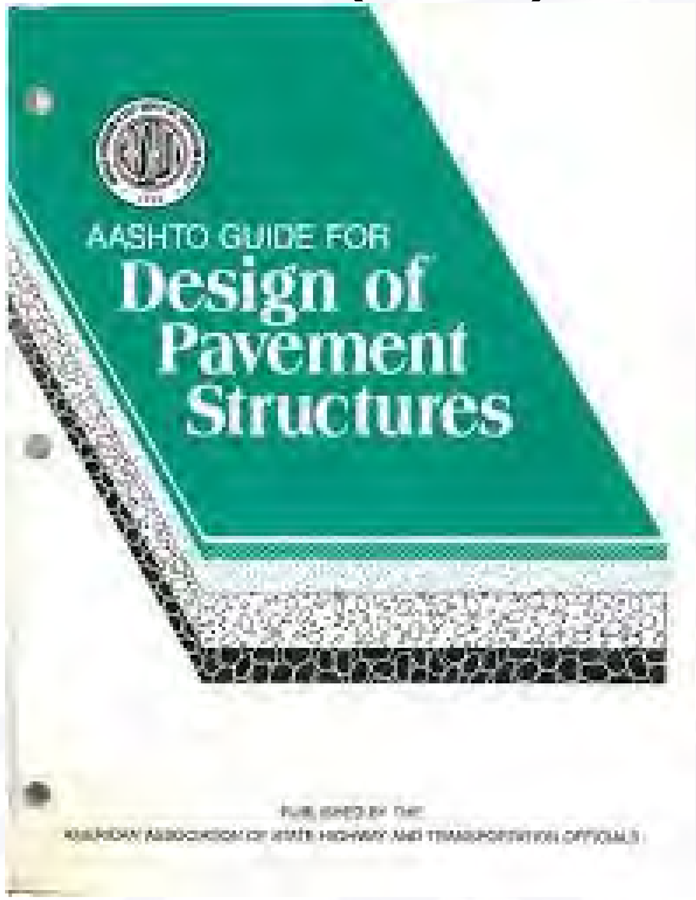
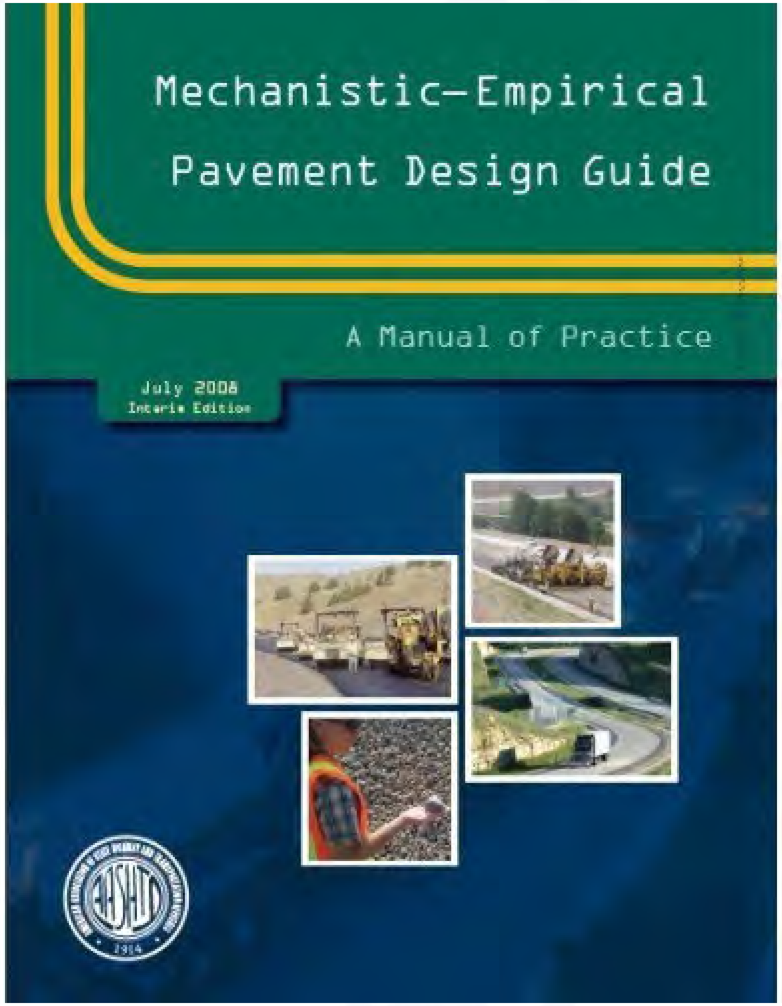
Pavement Design Methods

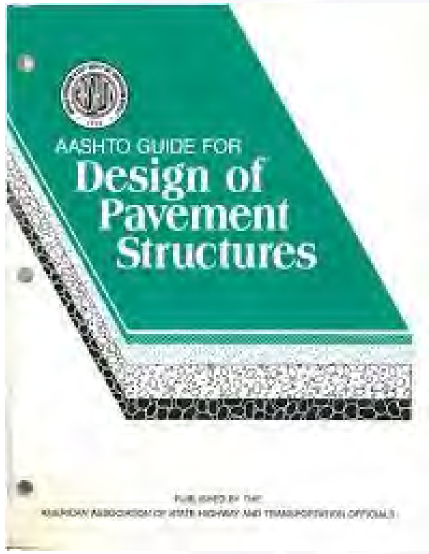
Pavement design methods

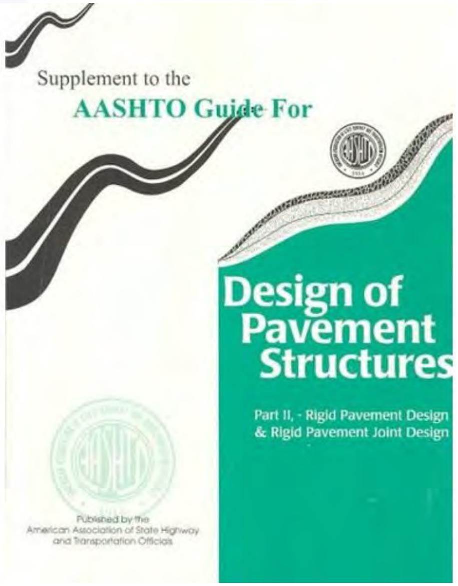
- AASHTO(Old)
- MEPDG(New)





AASHTO 1993

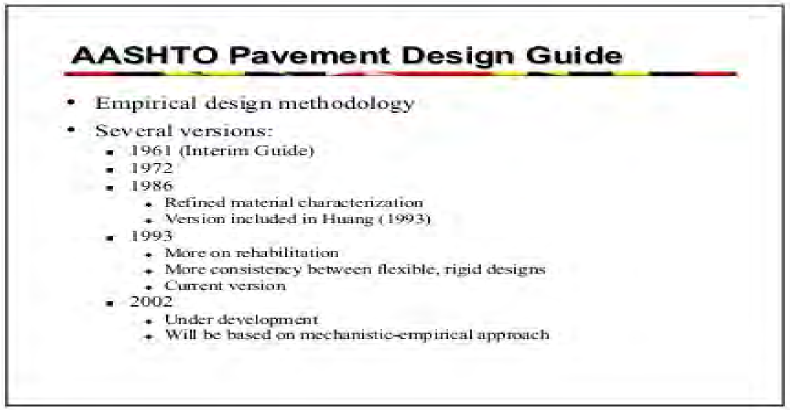

AASHTO GUIDE FOR
Design of
Pavement
Structures


Supplement to the
AASHTO Guide For
Design of
Pavement
Structures
Part II, - Rigid Pavement Design
& Rigid Pavement Joint Design
Published by the
American Association of State Highway
and Transportation Officials

AASHTO 1993

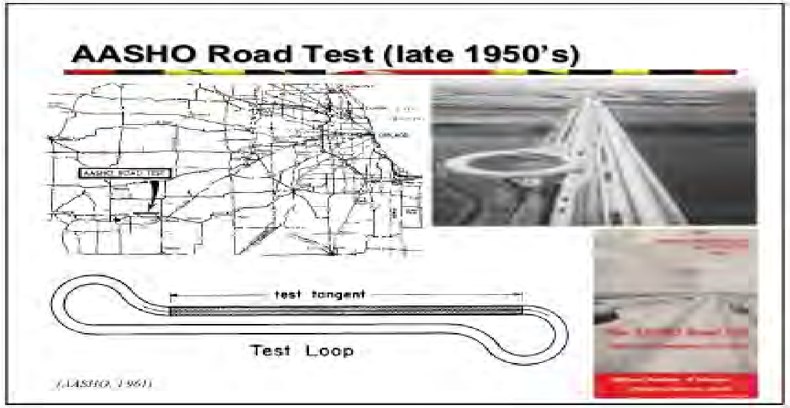
- AASHO Road test(1958)
- Flexible pavement design(Sn)
- Rigid pavement design(thickness)
- Nomograph(design chart)

AASHO Road Test



AASHTO Pavement Design Guide

- Empirical design methodology
- Several versions:
  - 1961 (Interim Guide)
  - 1972
  - 1986
    - Refined material characterization
    - Version included in Huang (1993)
  - 1993
    - More on rehabilitation
    - More consistency between flexible, rigid designs
    - Current version
  - 2002
    - Under development
    - Will be based on mechanistic-empirical approach



Empirical

- **1993 AASHTO Flexible Equation**

$$\log_{10}(W_{18}) = Z_R \times S_o + 9.36 \times \log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left(\frac{\Delta PSI}{4.5-1.5}\right)}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32 \times \log_{10}(M_R) - 8.07$$

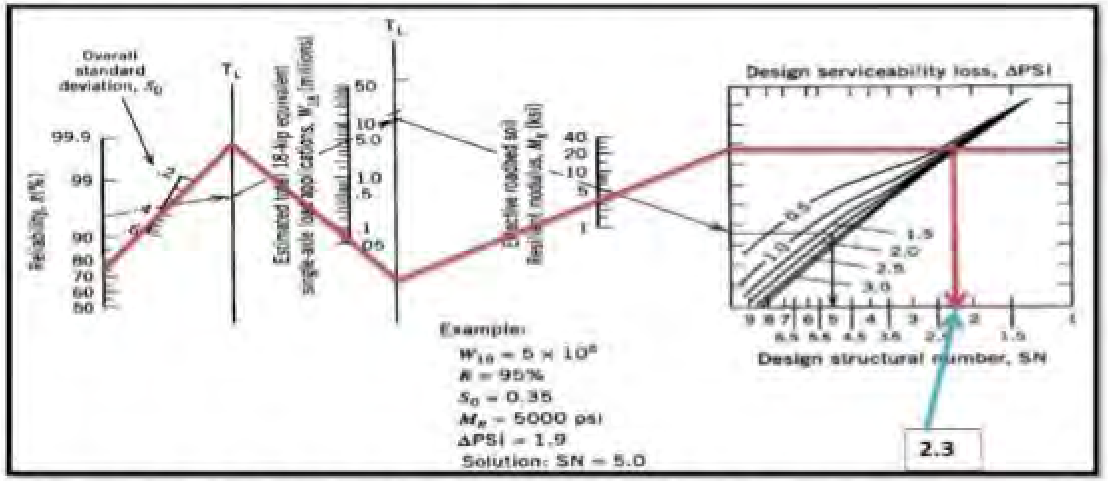
- **1993 AASHTO Rigid Equation**

$$\log_{10}(W_{18}) = Z_R \times S_o + 7.35 \times \log_{10}(D+1) - 0.06 + \frac{\log_{10}\left(\frac{\Delta PSI}{4.5-1.5}\right)}{1 + \frac{1.624 \times 10^7}{(D+1)^{8.46}}} + (4.22 - 0.32 p_t) \times \log_{10}\left[\frac{(S_c')(C_d)(D^{0.75}) - 1.132}{215.63(J)\left(D^{0.75} - \frac{18.42}{\left(\frac{E_c}{k}\right)^{0.25}}\right)}\right]$$

CEE 320
Winter 2006

DESIGN NOMOGRAPH

Required Structural Number



Design Chart for Flexible Pavements used for Estimating the Structural Number Required

Design of Flexible Pavement (contd.)

Once SN value is set, thickness design begins…

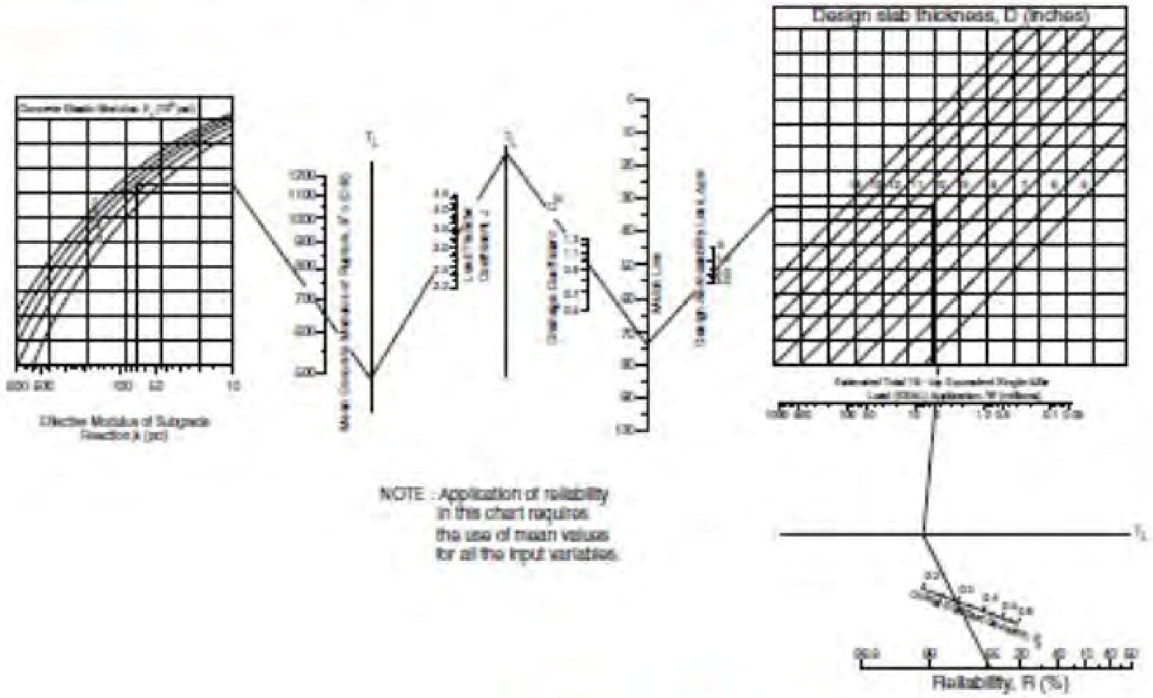
$$SN = a_1 D_1 + a_2 D_2 m_2 + a_3 D_3 m_3$$

where a_1, a_2 and a_3 are structural number coefficients obtained from nomographs for M_R values of materials used.

m_2 and m_3 are drainage coefficients obtained from table in design manual..

The depth that results in a SN value close to the SN value obtained from traffic loading, etc. is the design thickness. Thus , the design solution is not unique.

Rigid pavement thickness design chart



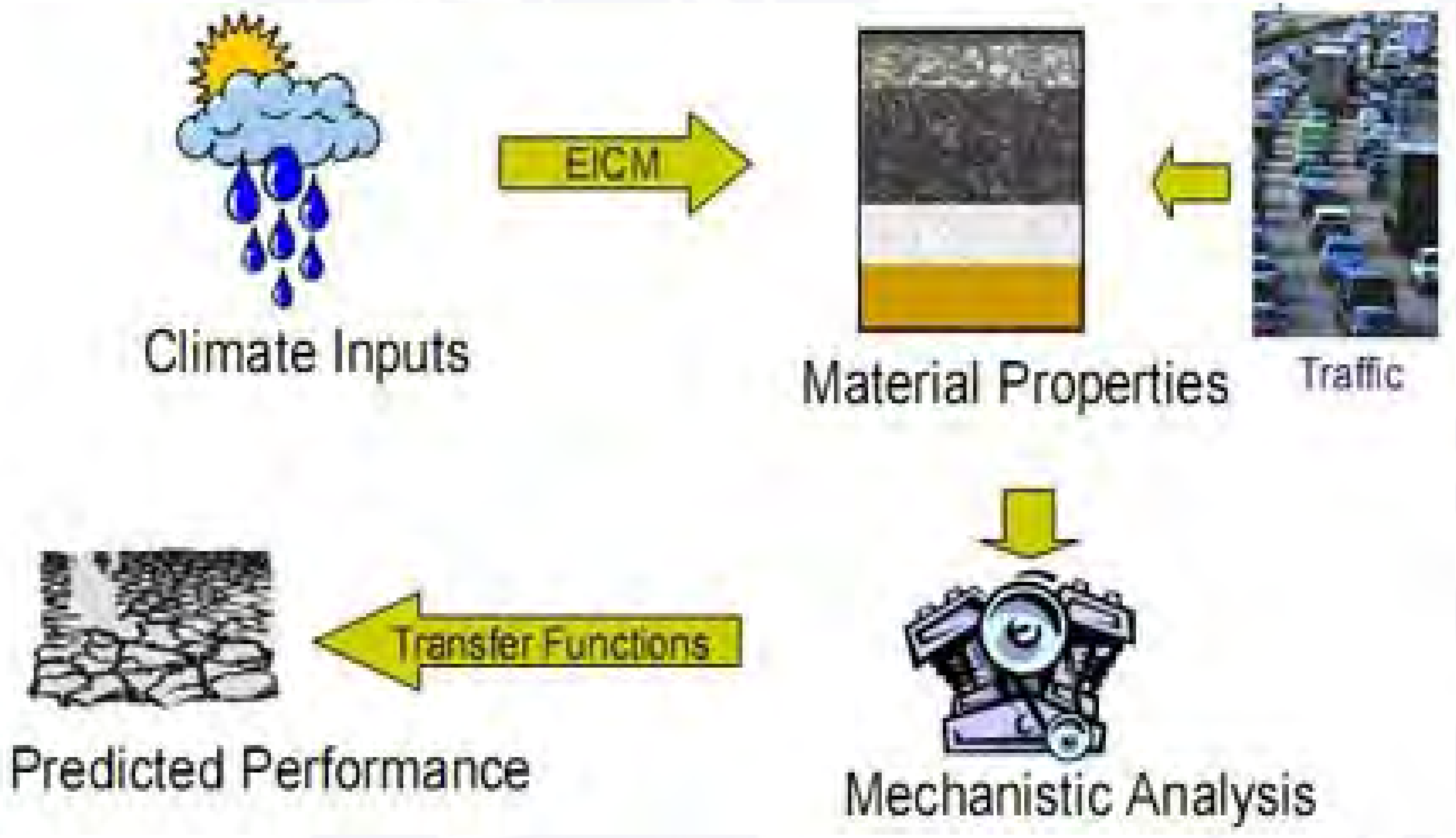
Design Example – Part 3

Design a doweled JPCP rigid pavement for this number of ESALs using the WSDOT table. Assume the following:

- Reliability = 95% (Z_R = -1.645 , S_0 = 0.40)
- ΔPSI = 1.5 (p_0 = 4.5, p_t = 3.0)
- E_{PCC} = 4,000,000 psi
- S'_C = 700 psi
- Drainage factor (C_d) = 1.0
- Load transfer coefficient (J) = 2.7
- Modulus of subgrade reaction (k) = 400 psi/in
- HMA base material

CEE 320
Spring 2007

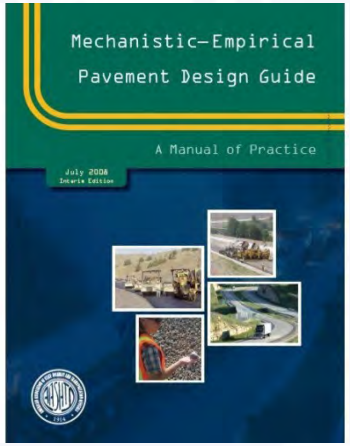
MEPDG



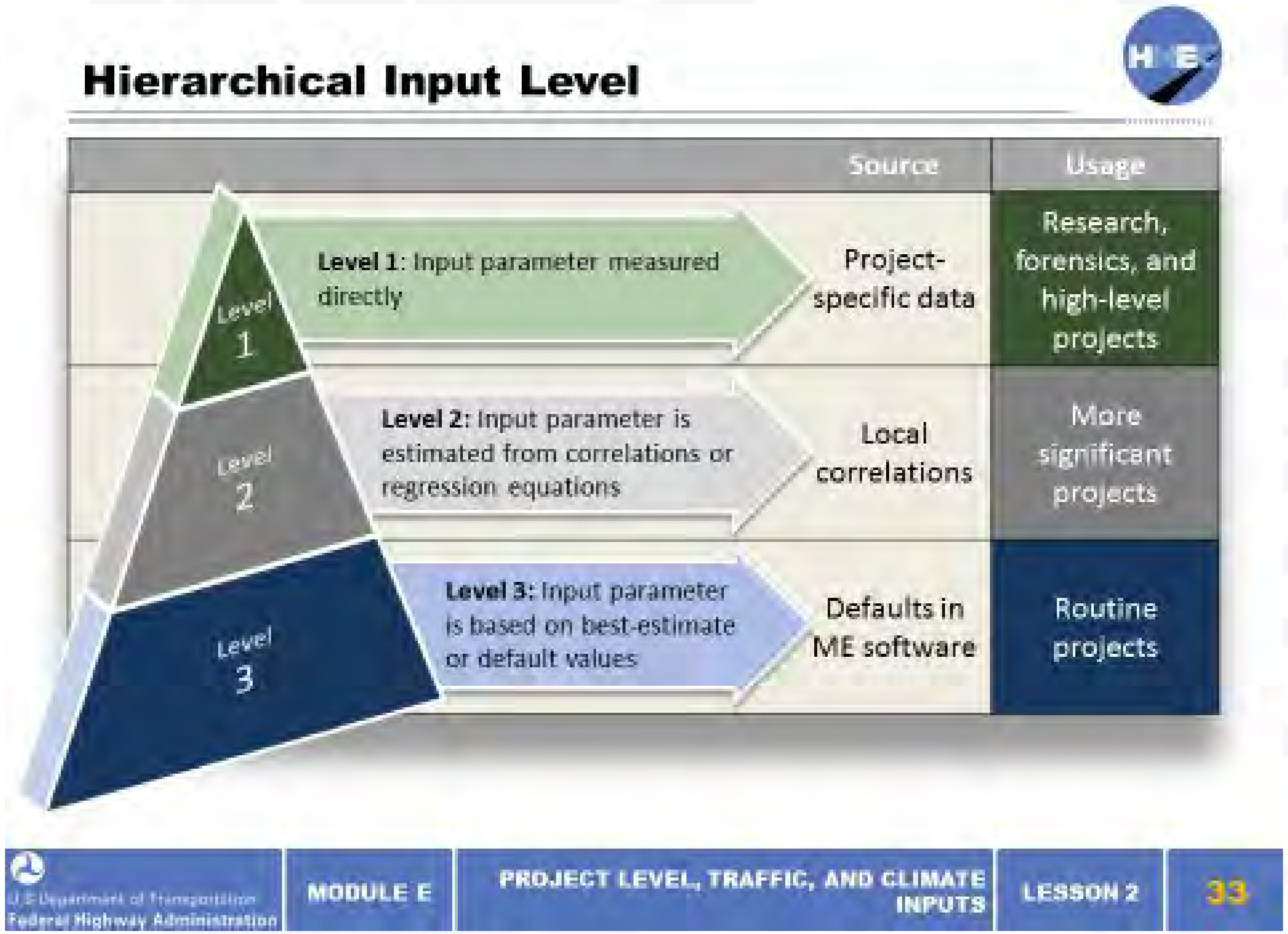
Climate Inputs
EICM
Material Properties
Traffic
Mechanistic Analysis
Transfer Functions
Predicted Performance

What is the difference between Aashto and Mepdg?

The design criterion in AASHTO 1993 is the loss in serviceability, while in MEPDG the design criterion is expressed in terms of performance (rutting, cracking, and Roughness).

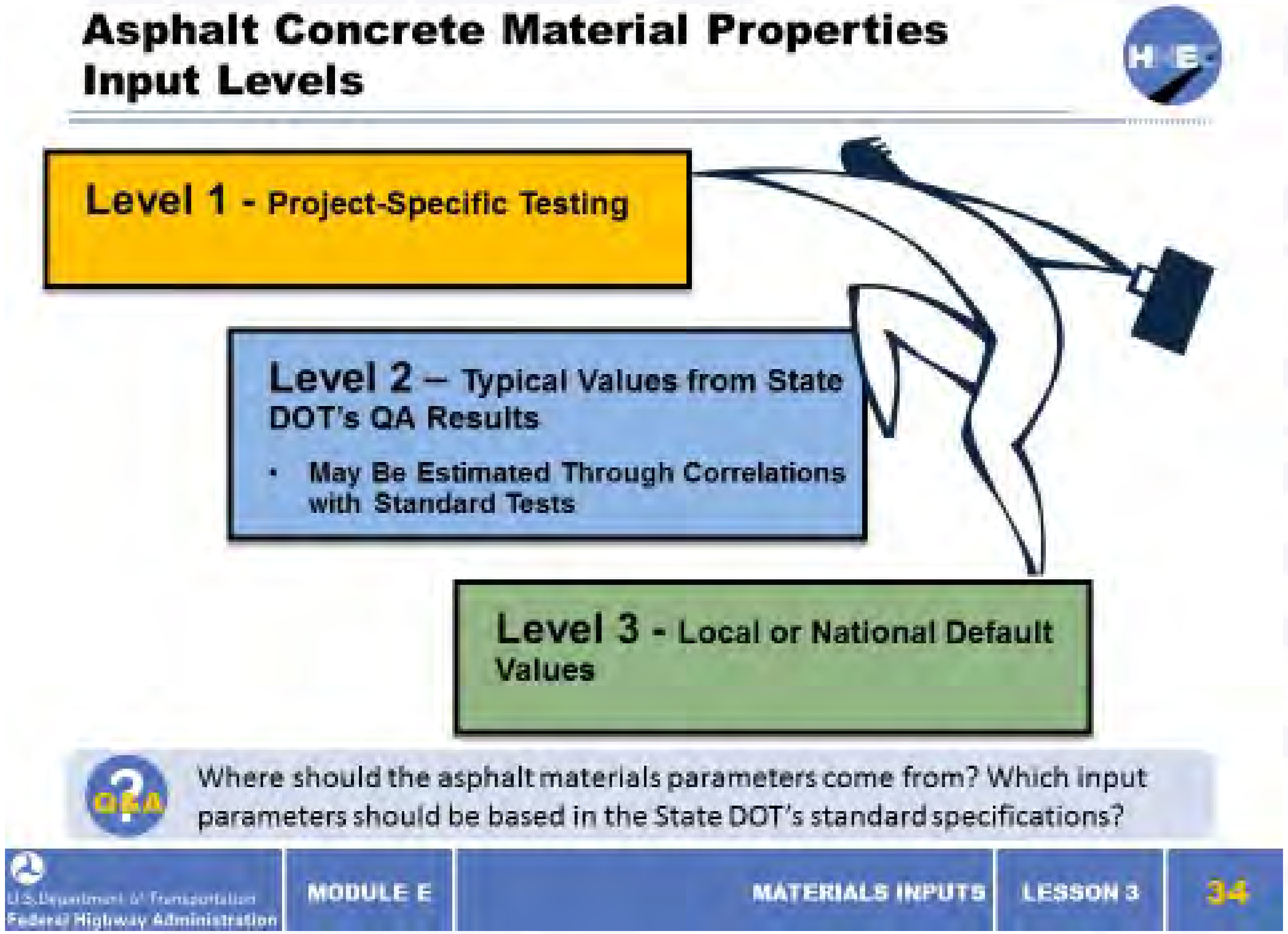


MEPDG



Hierarchical Input Level
Source
Usage
Level 1
Level 1: Input parameter measured directly
Project-specific data
Research, forensics, and high-level projects
Level 2
Level 2: Input parameter is estimated from correlations or regression equations
Local correlations
More significant projects
Level 3
Level 3: Input parameter is based on best-estimate or default values
Defaults in ME software
Routine projects
U.S. Department of Transportation
Federal Highway Administration
MODULE E
PROJECT LEVEL, TRAFFIC, AND CLIMATE INPUTS
LESSON 2
33

MEPDG


Asphalt Concrete Material Properties
Input Levels
Level 1 - Project-Specific Testing
Level 2 – Typical Values from State DOT's QA Results
• May Be Estimated Through Correlations with Standard Tests
Level 3 - Local or National Default Values
Where should the asphalt materials parameters come from? Which input parameters should be based in the State DOT's standard specifications?
U.S. Department of Transportation
Federal Highway Administration
MODULE E
MATERIALS INPUTS
LESSON 3
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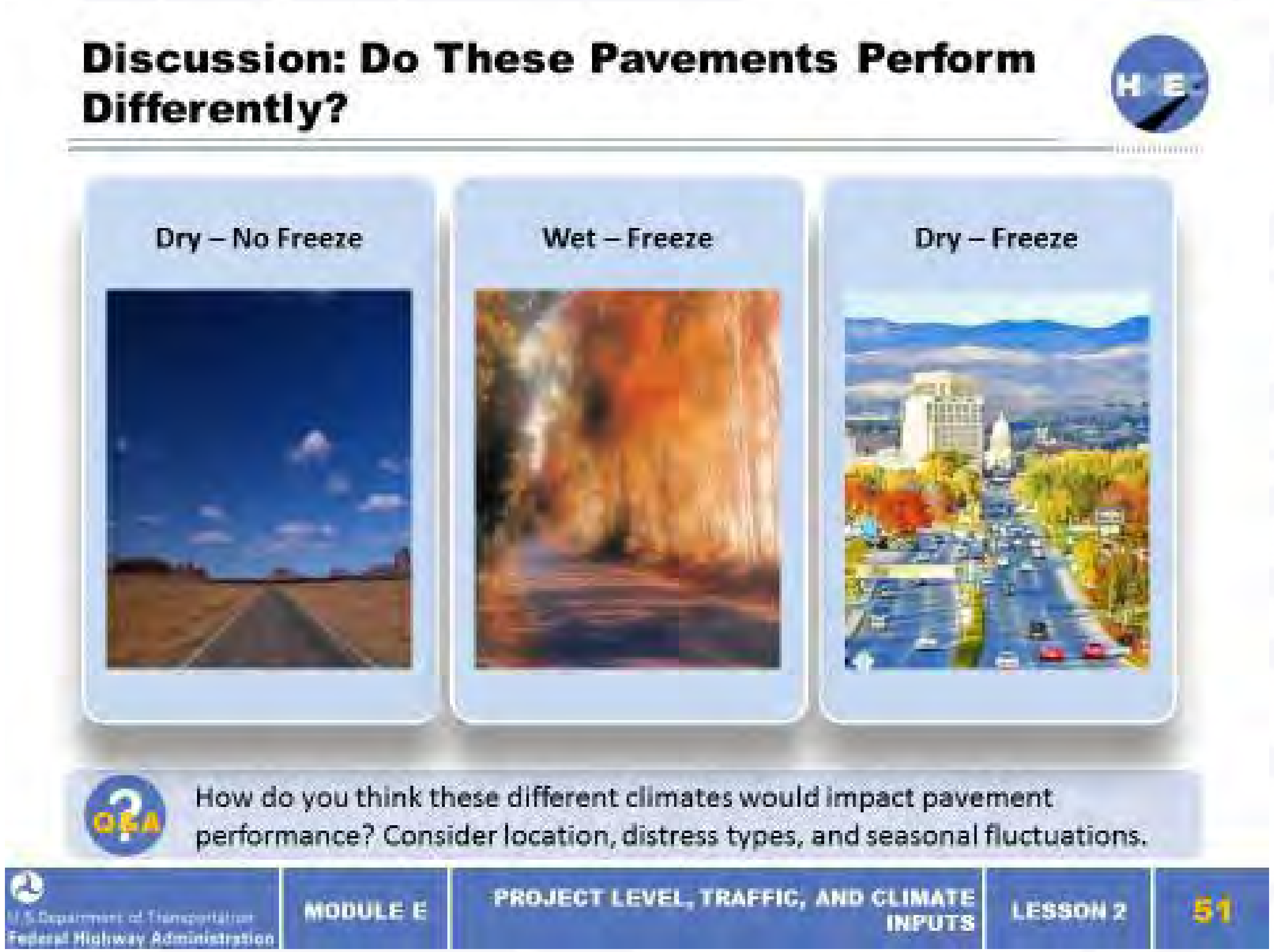
Climate



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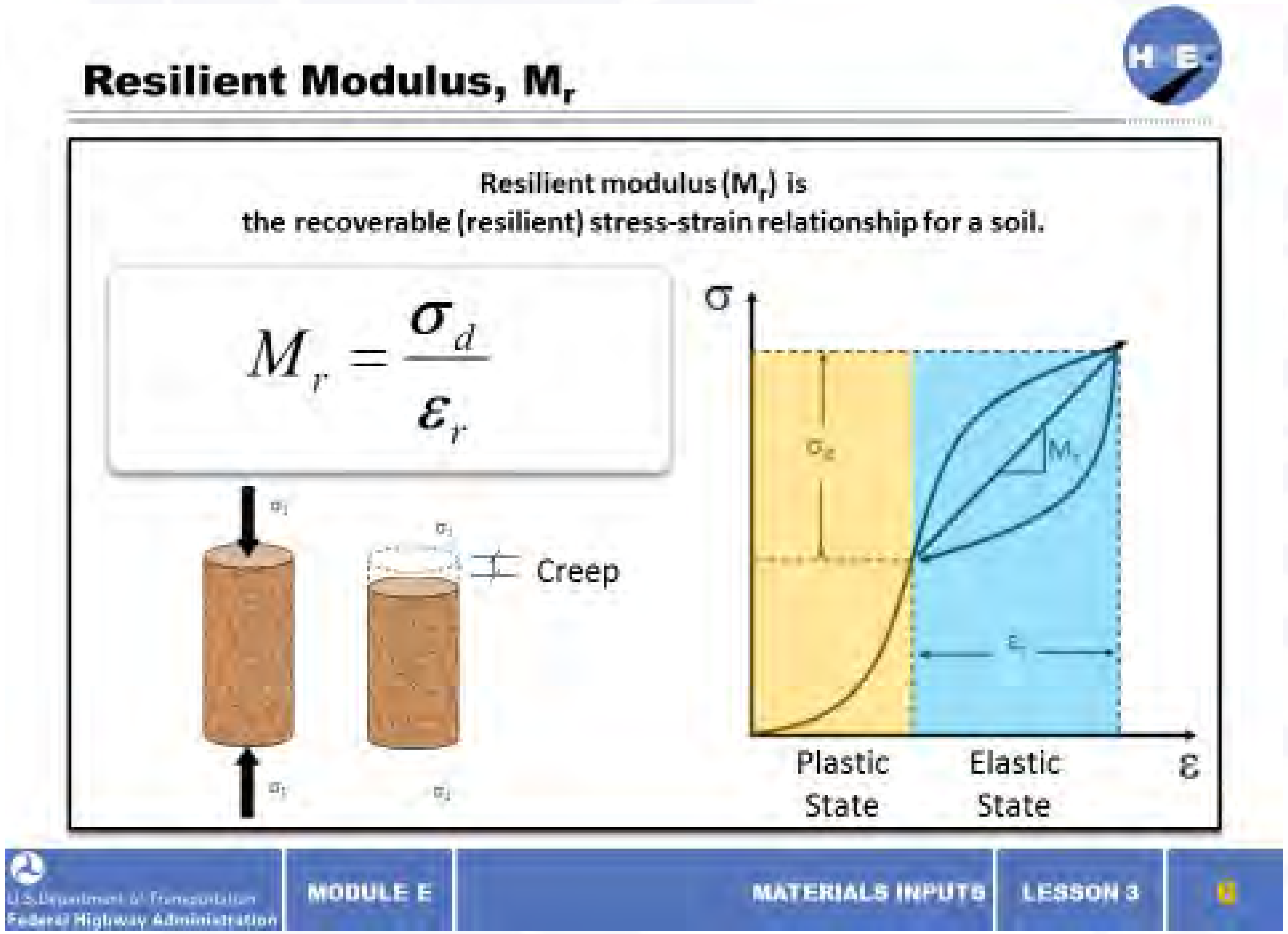
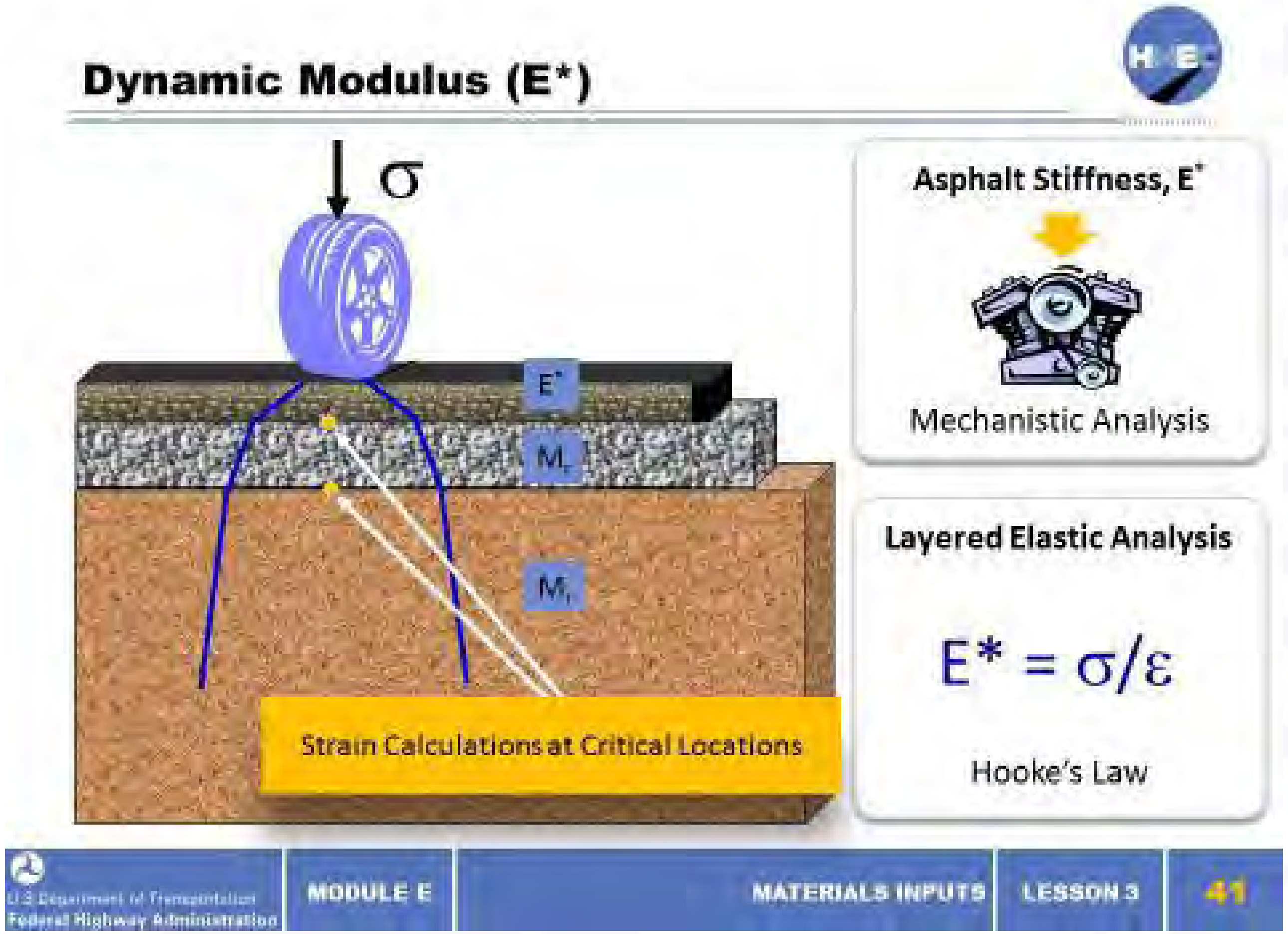
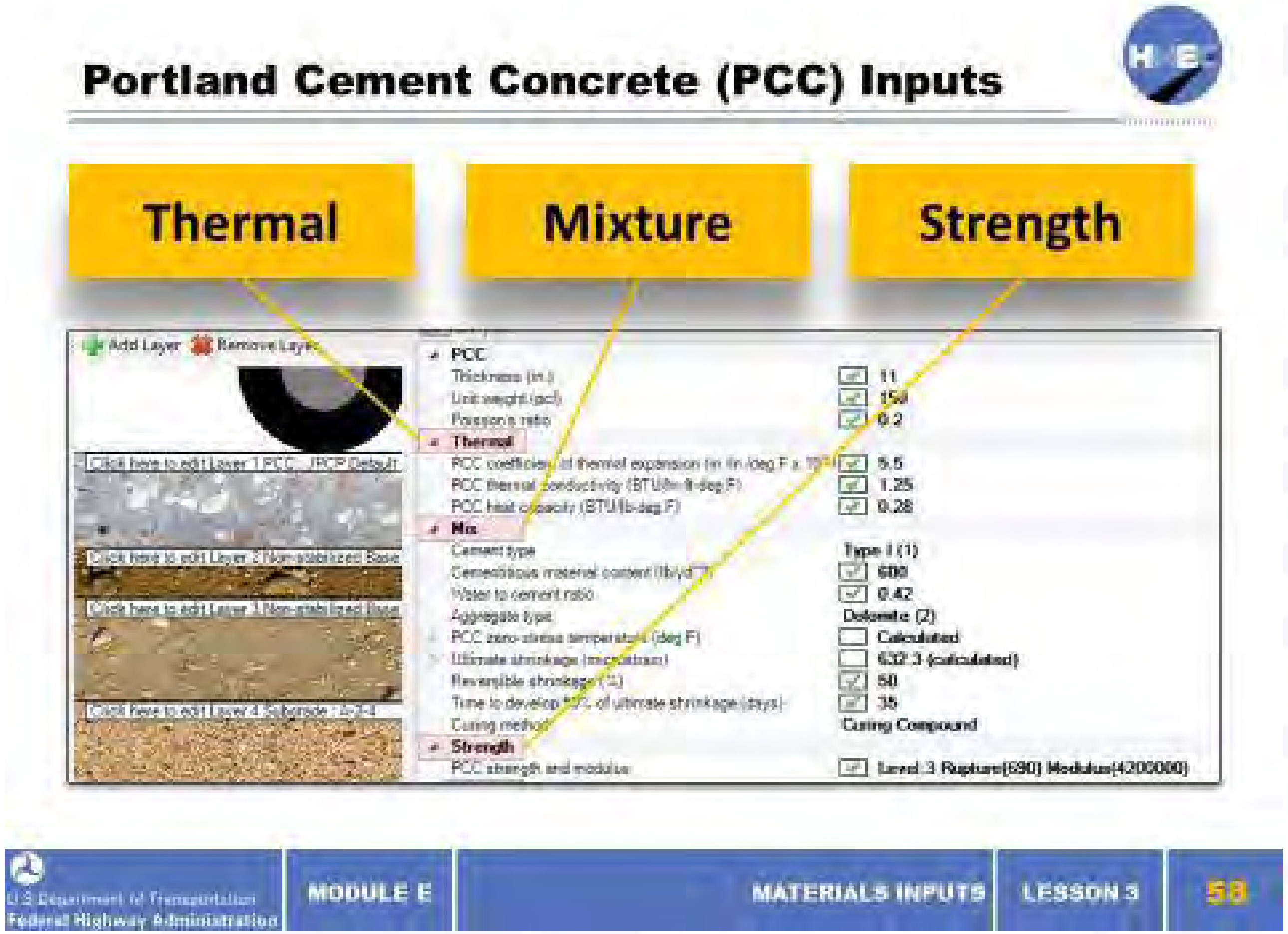
Materials testing



Materials testing


Dynamic Modulus (E*)
σ
E*
Mr
Mr
Strain Calculations at Critical Locations
Asphalt Stiffness, E*
Mechanistic Analysis
Layered Elastic Analysis
E* = σ/ε
Hooke's Law
U.S. Department of Transportation
Federal Highway Administration
MODULE E
MATERIALS INPUTS
LESSON 3
41

Material properties



Reliability

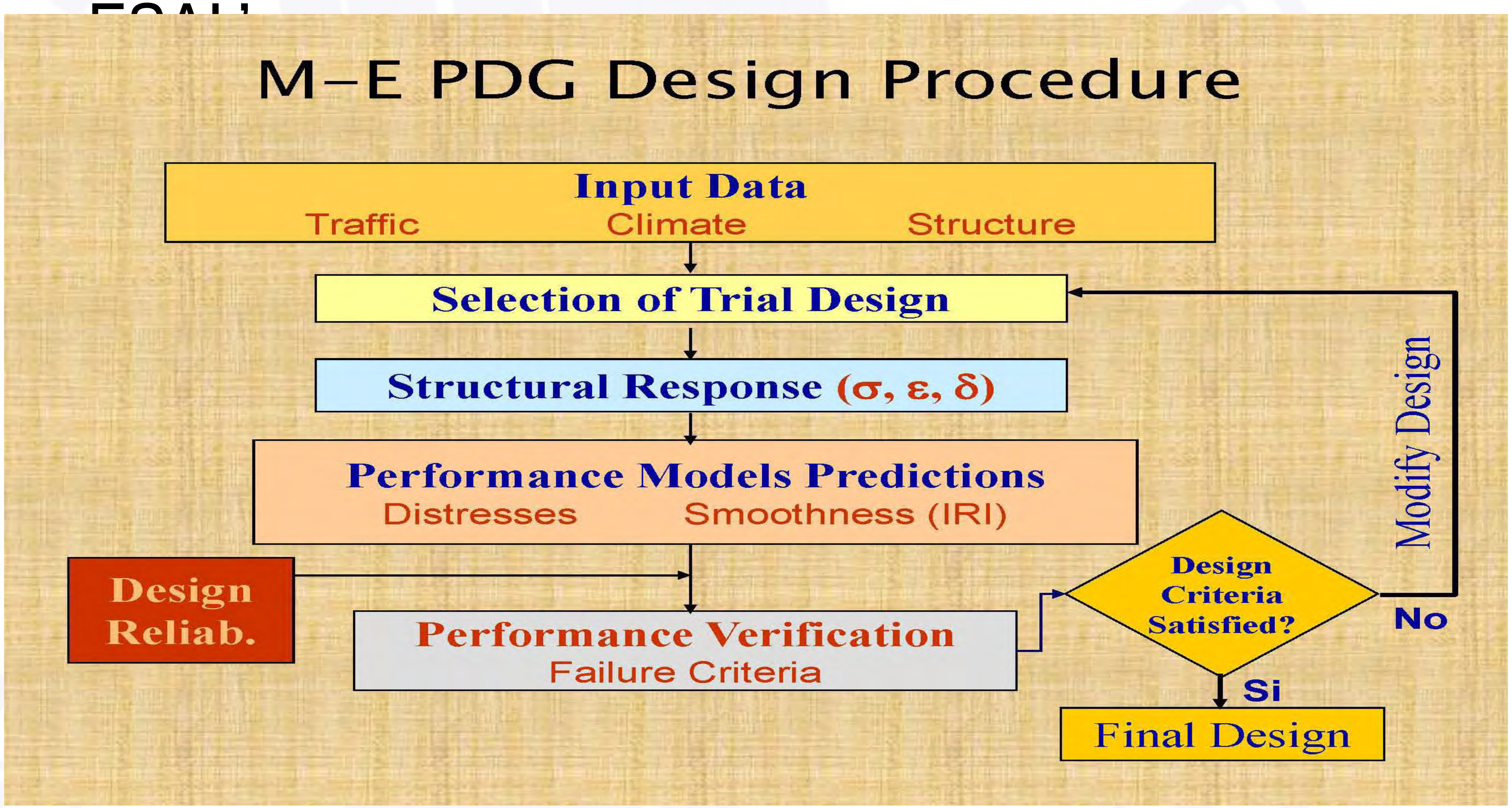
Design Reliability

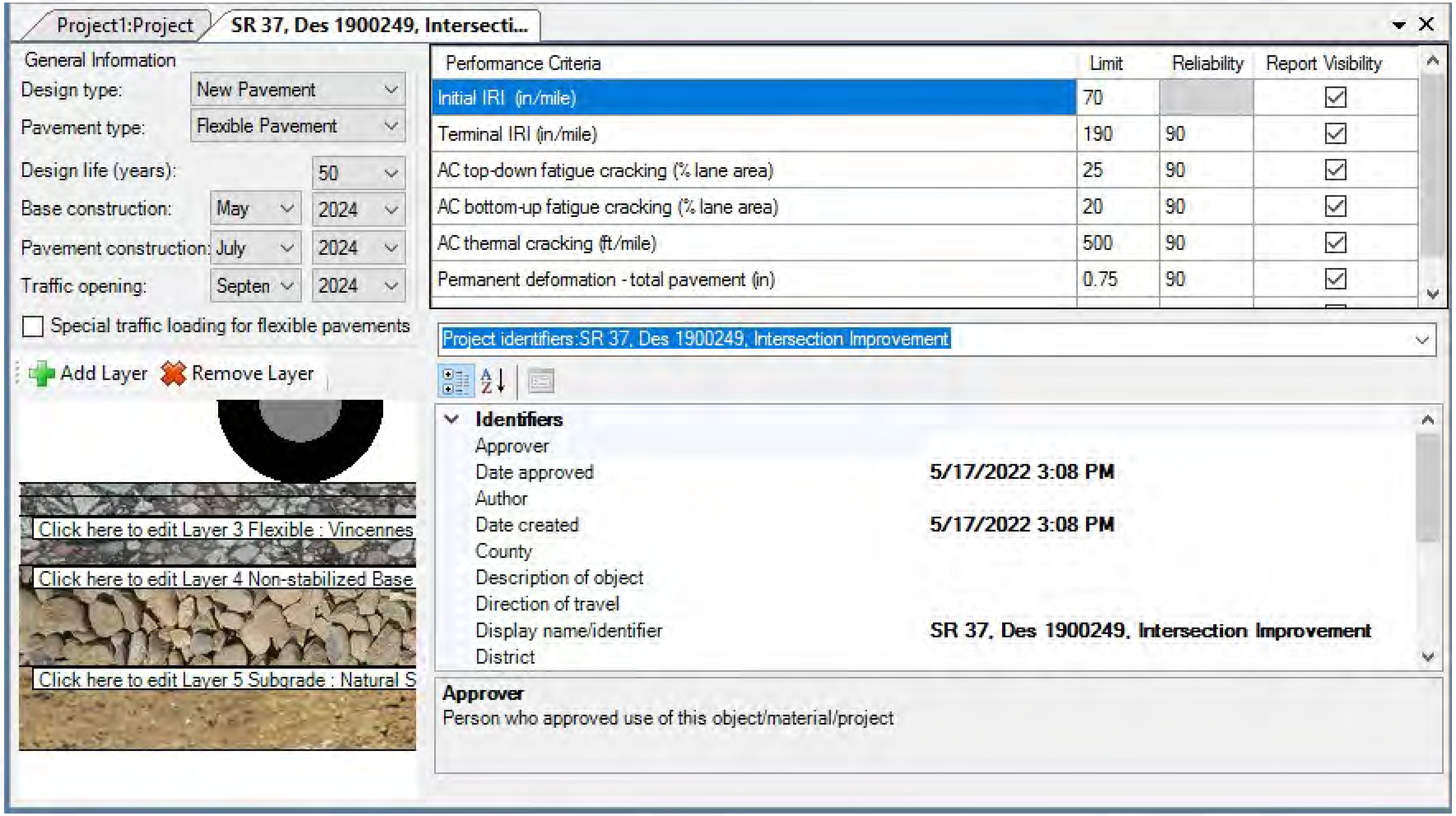
Functional Classification	Level of Reliability (%)	
	Urban	Rural
Interstate/Freeways	95	95
Principal Arterials	90	85
Collectors	80	75
Local	75	70

The greater the consequences of premature failure, the higher the design reliability.

High Reliability + Low Distress Limits

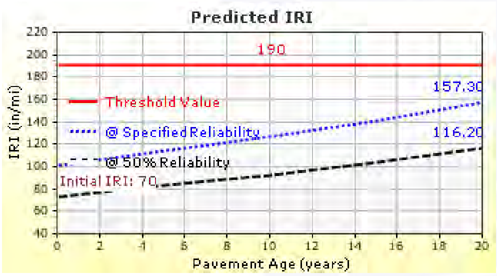
Conservative Design

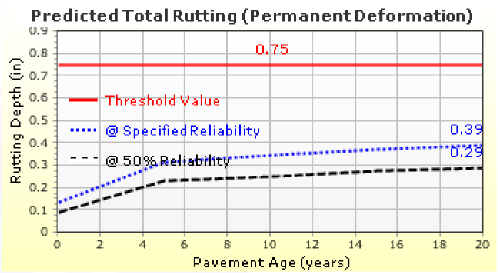

M–E PDG Design Procedure
Input Data
Traffic
Climate
Structure
Selection of Trial Design
Structural Response (σ, ε, δ)
Performance Models Predictions
Distresses
Smoothness (IRI)
Design Reliab.
Performance Verification
Failure Criteria
Design Criteria Satisfied?
No
Modify Design
Si
Final Design

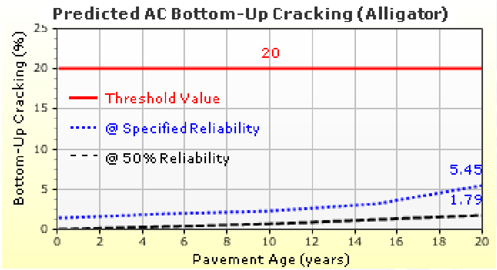


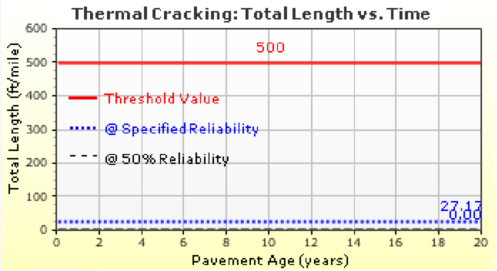
Project1:Project
SR 37, Des 1900249, Intersecti...
General Information
Design type: New Pavement
Pavement type: Flexible Pavement
Design life (years): 50
Base construction: May 2024
Pavement construction: July 2024
Traffic opening: Septen 2024
Special traffic loading for flexible pavements
Add Layer
Remove Layer
Click here to edit Layer 3 Flexible : Vincennes
Click here to edit Layer 4 Non-stabilized Base
Click here to edit Layer 5 Subgrade : Natural S
Performance Criteria | Limit | Reliability | Report Visibility
Initial IRI (in/mile) | 70
Terminal IRI (in/mile) | 190 | 90
AC top-down fatigue cracking (% lane area) | 25 | 90
AC bottom-up fatigue cracking (% lane area) | 20 | 90
AC thermal cracking (ft/mile) | 500 | 90
Permanent deformation - total pavement (in) | 0.75 | 90
Project identifiers:SR 37, Des 1900249, Intersection Improvement
Identifiers
Approver
Date approved 5/17/2022 3:08 PM
Author
Date created 5/17/2022 3:08 PM
County
Description of object
Direction of travel
Display name/identifier SR 37, Des 1900249, Intersection Improvement
District
Approver
Person who approved use of this object/material/project

■ 10 in. HMA, for Low ESAL(<3 million)

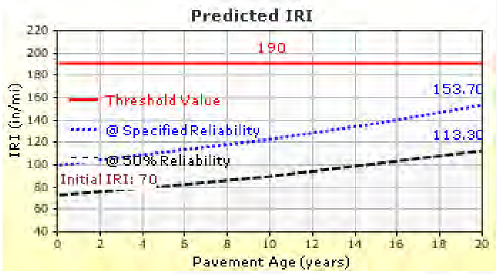


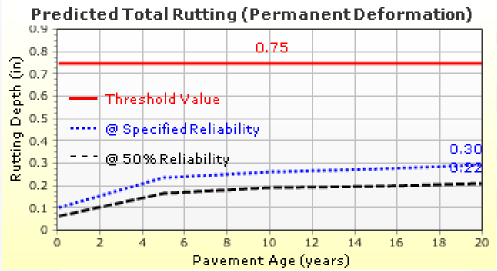


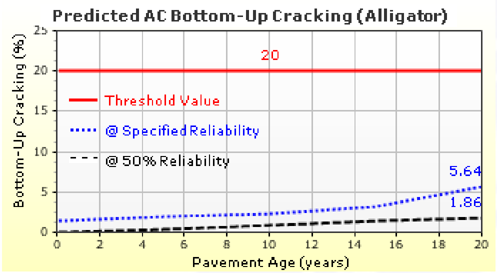


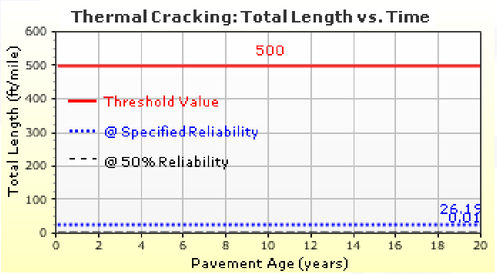


- **12 in. HMA for Medium ESAL(3 to 10M)**

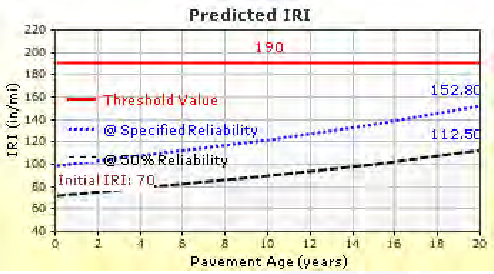


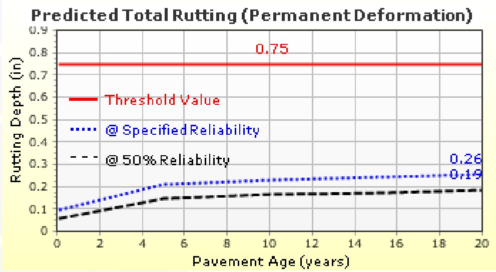


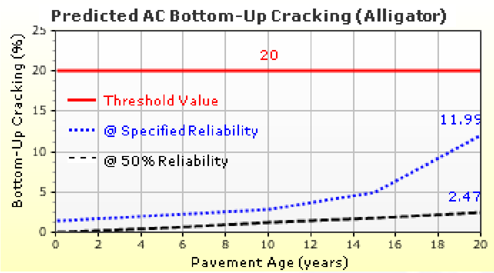


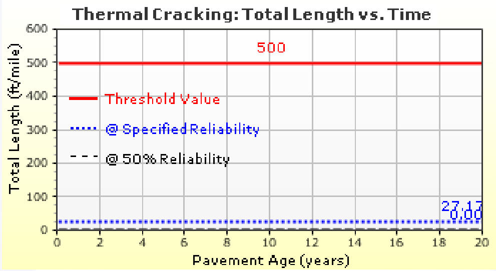


- **14 in. HMA for ESAL(10 to 30 M)**







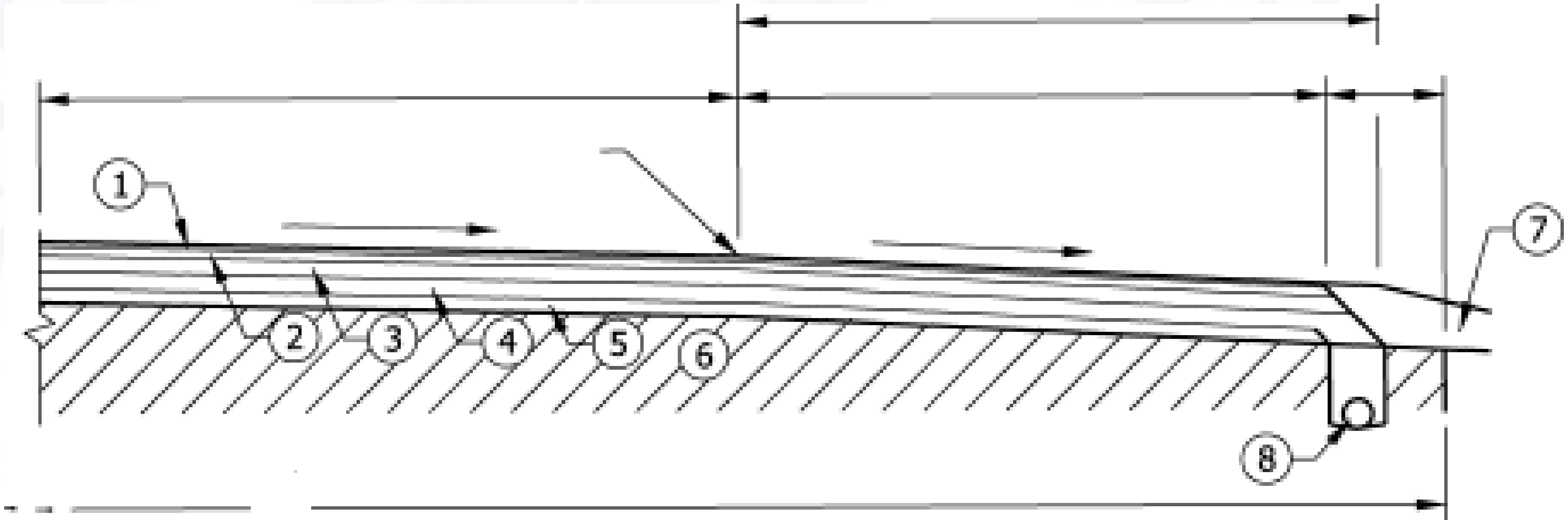


HMA Pay items

165 lbs/syd QC/QA-HMA, 3, 64, Surface, 9.5 mm

275 lbs/syd QC/QA-HMA, 3, 64, Intermediate, 19.0 mm
660 lbs/syd QC/QA-HMA, 3, 64, Base, 25.0 mm
Subgrade Treatment Type IC

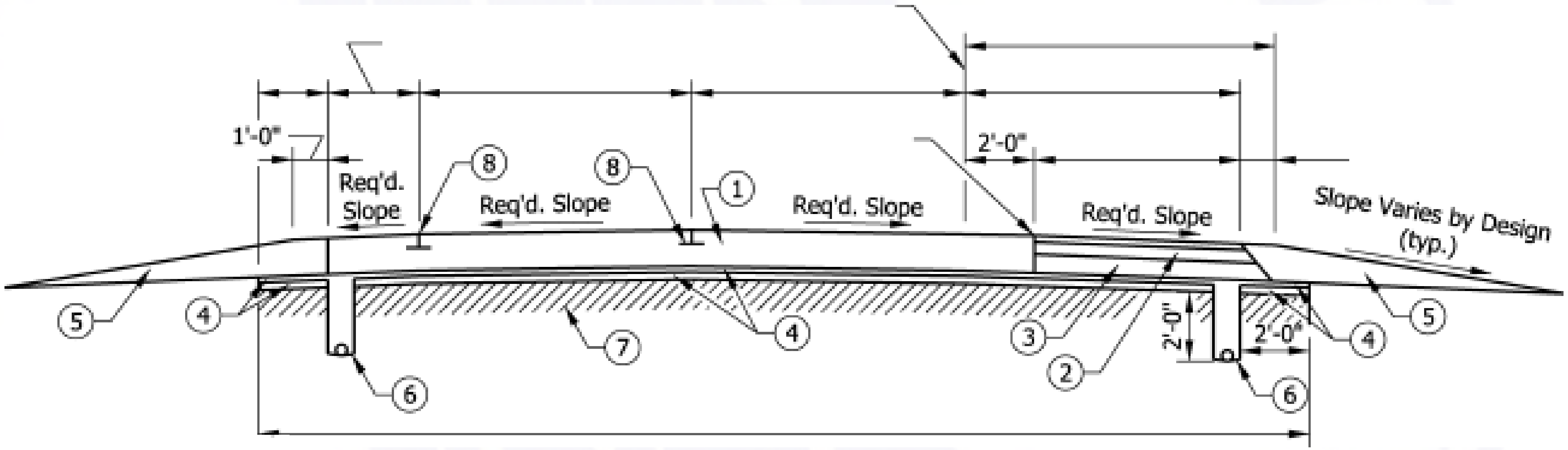
HMA Typical Section



1. _ lb/yd2 HMA Surface
2. _ lb/yd2 HMA Intermediate
3. _lb/yd2 HMA Base
4. _ Drainage Layer
5. _ Separation Layer
6. Subgrade Treatment,Type __
7. Variable-Depth Compacted Aggregate
8. Underdrain. See Figure 602-3K for detail.

NextLevel INDIANA

Concrete Typical Section(JPCP)



* (1) _ lb/yd2 HMA Surface
* (2) _ lb/yd2 HMA Intermediate
* (3) _ lb/yd2 HMA Base
(4) _ Drainage Layer
(5) _ Separation Layer
(6) Subgrade Treatment, Type __
(7) Variable-Depth Compacted Aggregate
(8) Underdrain. See Figure 602-3K for detail.

Indot Pavement Design History

Indot Pavement Design History

AASHTO 93(1990-2009)

Pavement ME(since 2010)

Pavement ME Implementation(2002-2010)

AASHTO 93 has limited inputs

AASHTO Pavement ME has 1000's inputs(traffic, material, climate)

Currently Indot uses AASHTO Pavement ME Ver 2.3

In process of calibration/verification to use Ver 2.6

Goal is to use Ver 3.0

Work Types

- New Road/Road Reconstruction
- Added Travel Lanes
  - Road RehabilitationSingle lift
  - Two lifts
  - Three lifts
  - Recycling(CIR/CCPR/FDR)
  - CPR
  - TCO/Unbonded Concrete Overlay
  - Intersection Improvement/Land slides
  - Small Structure Replacement
  - Bridge projects

Total pavement designs

FY 14=426
FY 15=560
FY 16=542
FY 17 =649
FY 18 =498
FY 19= 510
CY 20=669
CY 21=593
CY 22=550

Ave=500+
40 to 50 PD/Month

Pavement Design References

- **IDM Part 6**
- **Indot Standard Specifications**
  - Section 207 –Subgrade
  - Section 300-Aggregate Pavement and Bases
  - Section 400-Asphalt Pavement
  - Section 500- Concrete Pavement
- **Design Memo:**
  - DM 22-02 (LCPCA) Update
  - DM 22-03 PD for Small Structure and Bridge
  - DM 22-12 Subgrade Treatment for FDPatching

Pavement Design References

- **INDOT Standard Drawings**
- **Indot Pavement Design Request Form**
- **Indot Pavement Design Process**
  - In house
  - Consultant
  - 500+ Pavement designs/year

Pavement Design Team

- Kumar Dave
  1. Nick Cosenza
  2. Pankaj Patel
  3. Matt Thomas
  4. Allen Davidson
  5. Tony Jones

Thank You!