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# Impact of Subgrade Strength on HMA Section Thickness

Purdue Road School

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NATIONAL SECURITY



ENERGY & ENVIRONMENT



INFRASTRUCTURE



HEALTH SOLUTIONS

# Questions we will attempt to cover

- History of pavement design
- Pavement ME Design – What is it?
- A look at typical pavement designs and the move to perpetual design

# Pavement 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
  - Calculation of pavement responses
  - Mechanics-based pavement performance models

*Common Practice*



*State-of-the-practice*



*State-of-the-art*

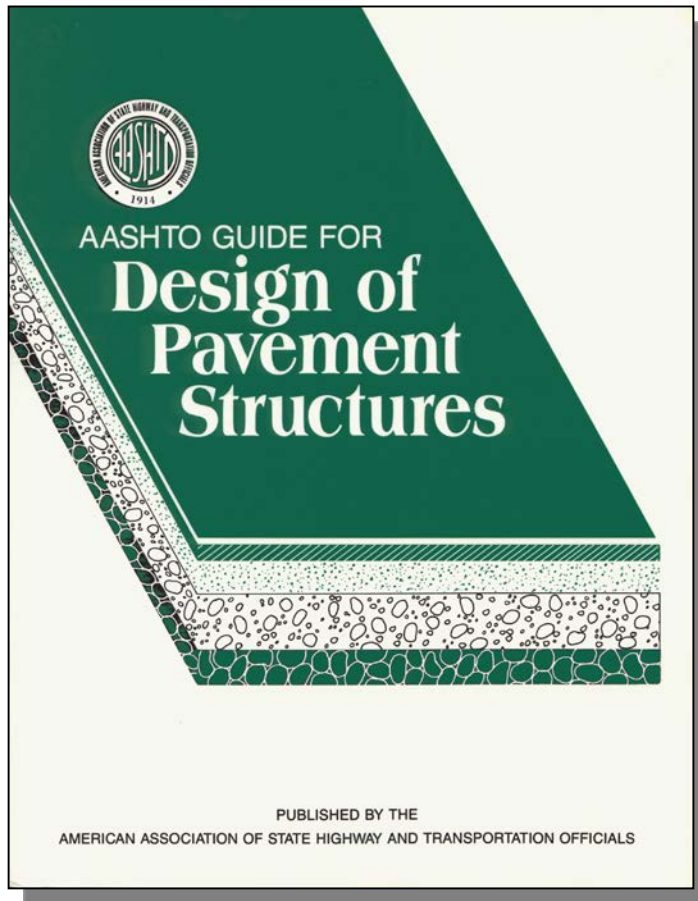


**Empirical**

**Mechanistic-  
Empirical**

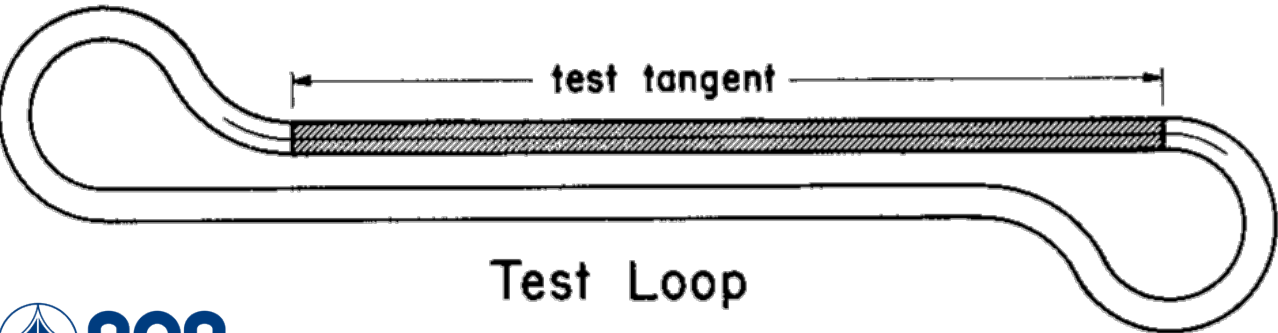
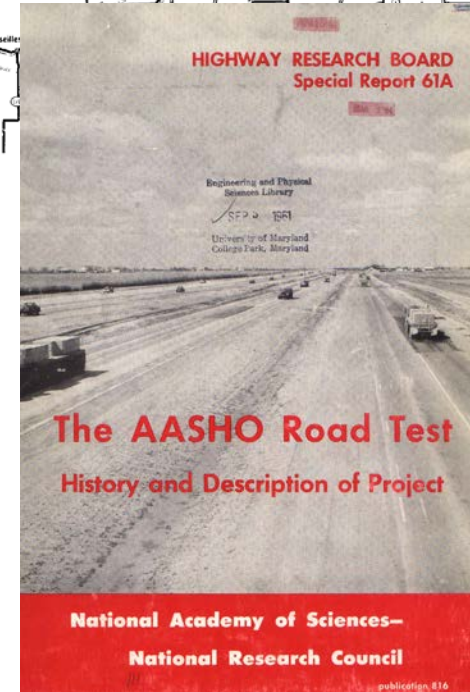
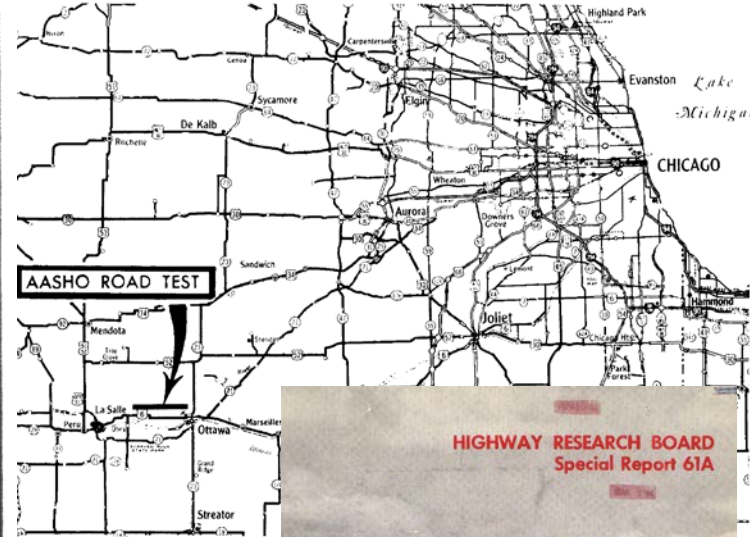
**Mechanistic**

# AASHTO Pavement Design Guide



- Empirical methodology based on AASHTO Road Test in the late 1950's
- Several versions:
  - 1961 (Interim Guide), 1972, 1986, 1993
  - 1986 Guide highlights need for mechanistic design

# AASHO Road Test (late 1950's)

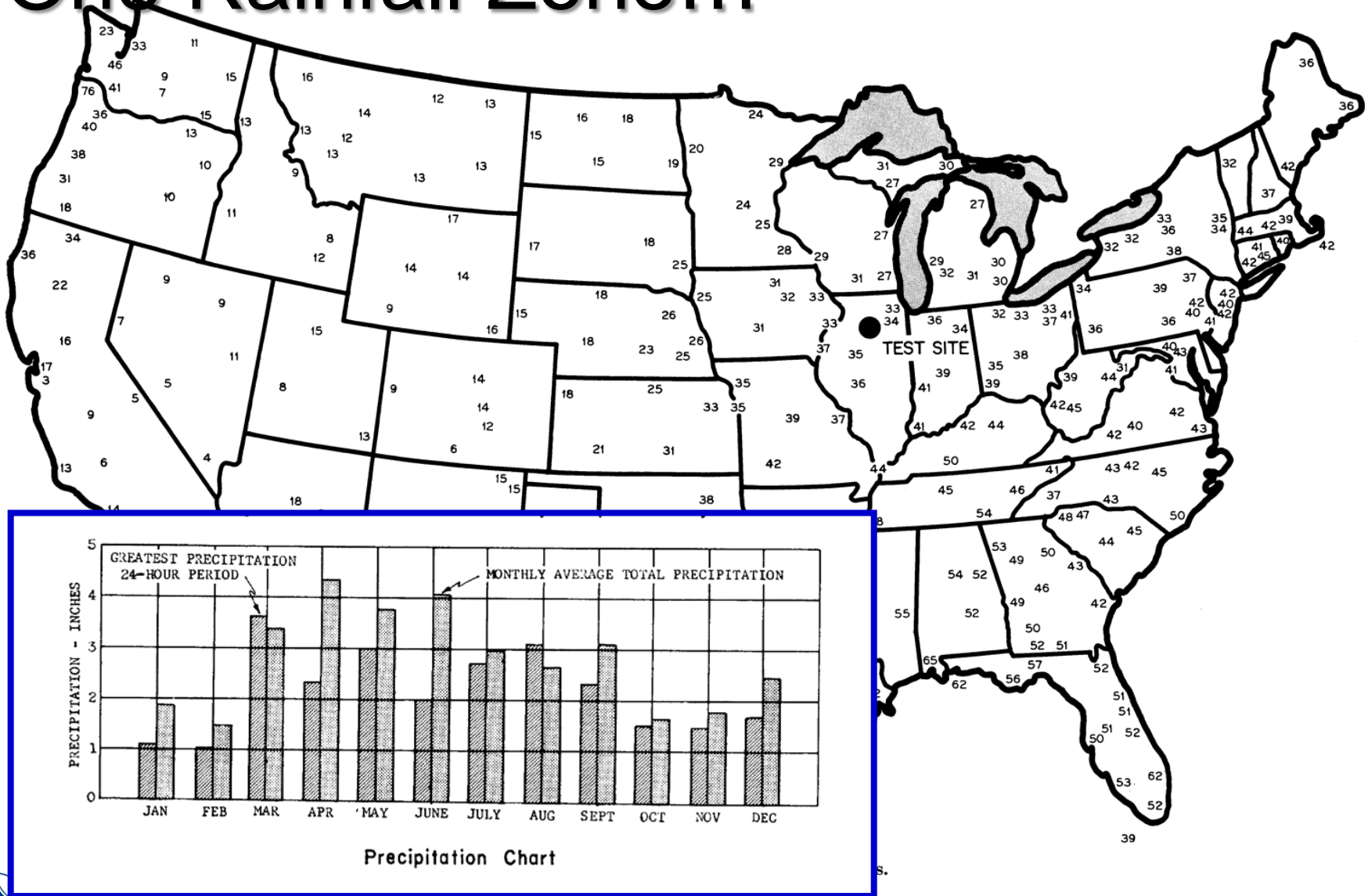


# AASHO Road Test Location



Ottawa,  
IL

# One Rainfall Zone...



# One Temperature Zone...

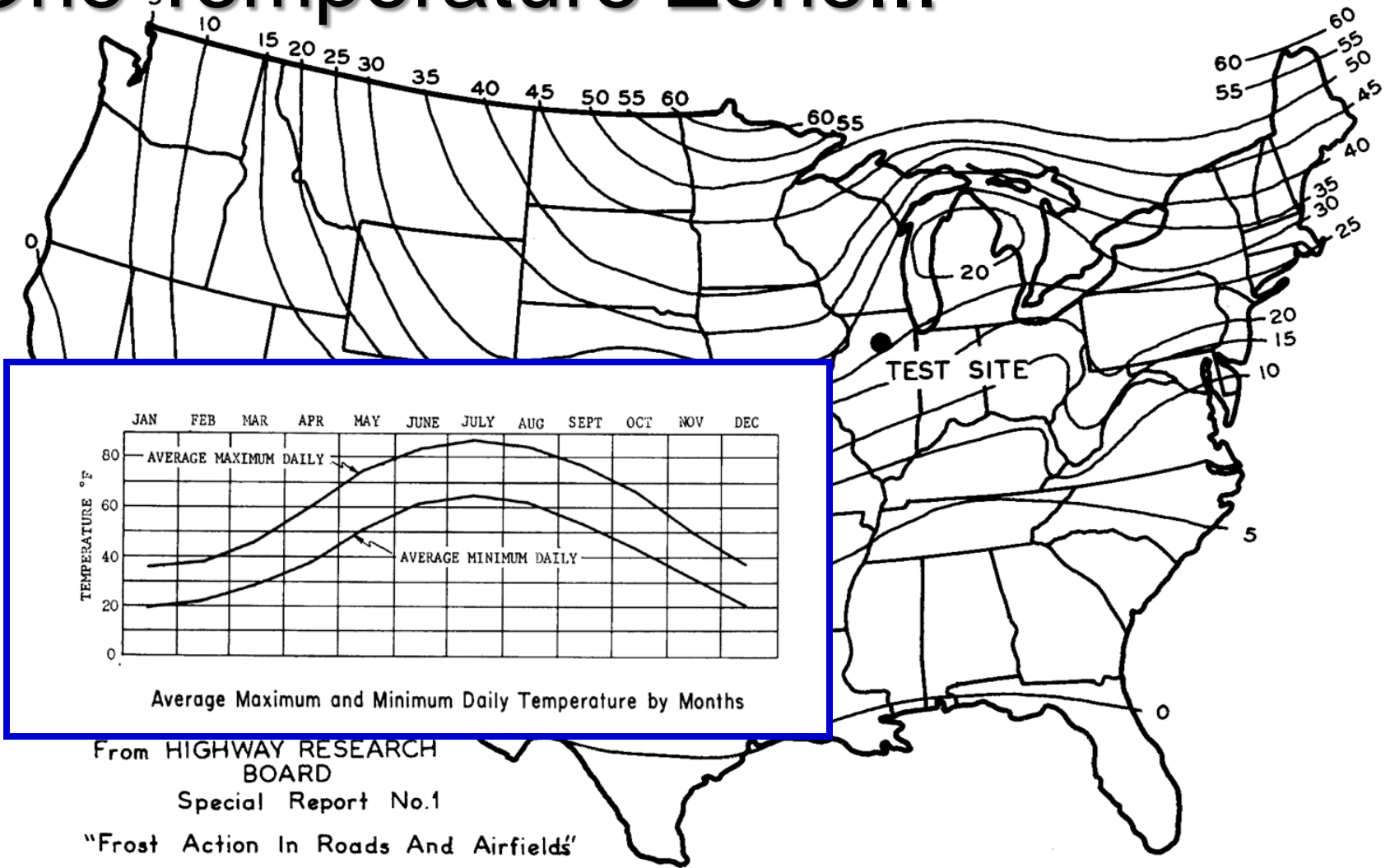


Figure 10. Average annual frost penetration, in inches.



# One Subgrade Type...

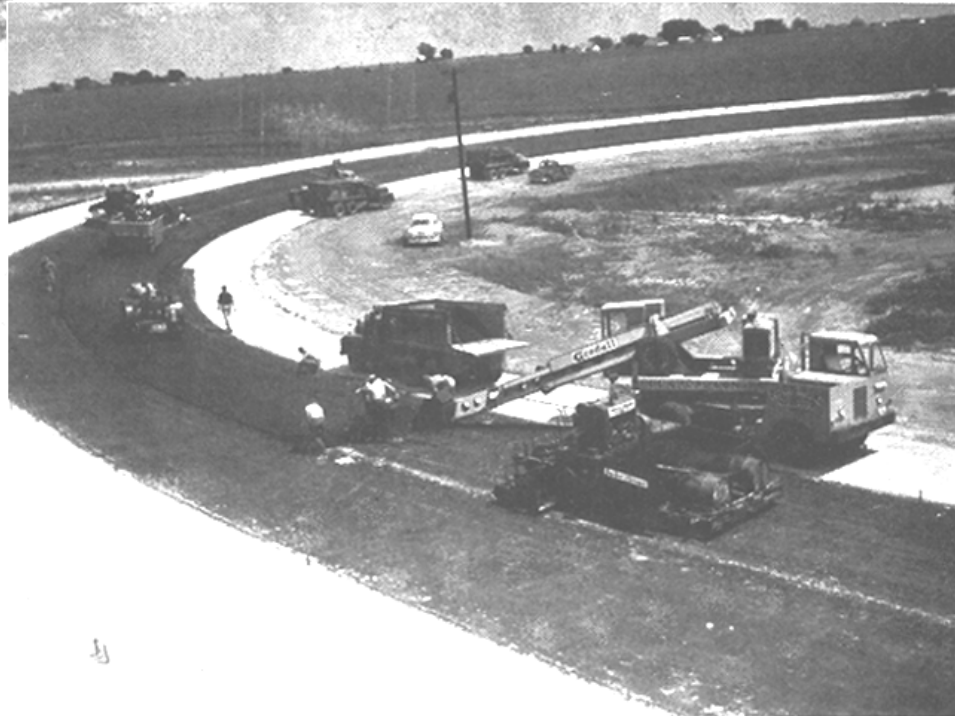


**A-6 / A-7-6 (Clay)  
Poor Drainage**

# Limited Set of Materials...

- One asphalt concrete
  - $\frac{3}{4}$ -inch surface course
  - 1-inch binder course
- Four base materials
  - Well-graded crushed limestone (main experiment)
  - Well-graded uncrushed gravel (special studies)
  - Bituminous-treated base (special studies)
  - Cement-treated base (special studies)
- One uniform sand/gravel subbase

# Controlled Construction Methods...



# 1950s' Vehicle Loads...



(And on a specific stretch of roadway!)

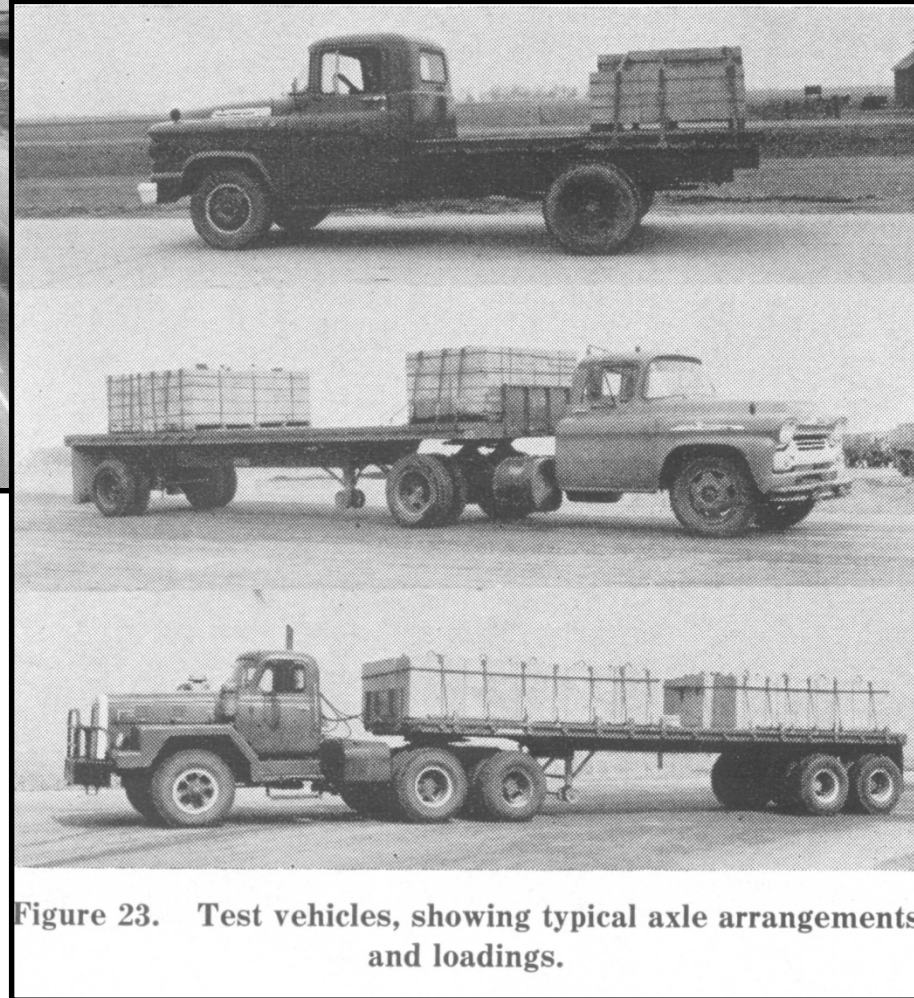
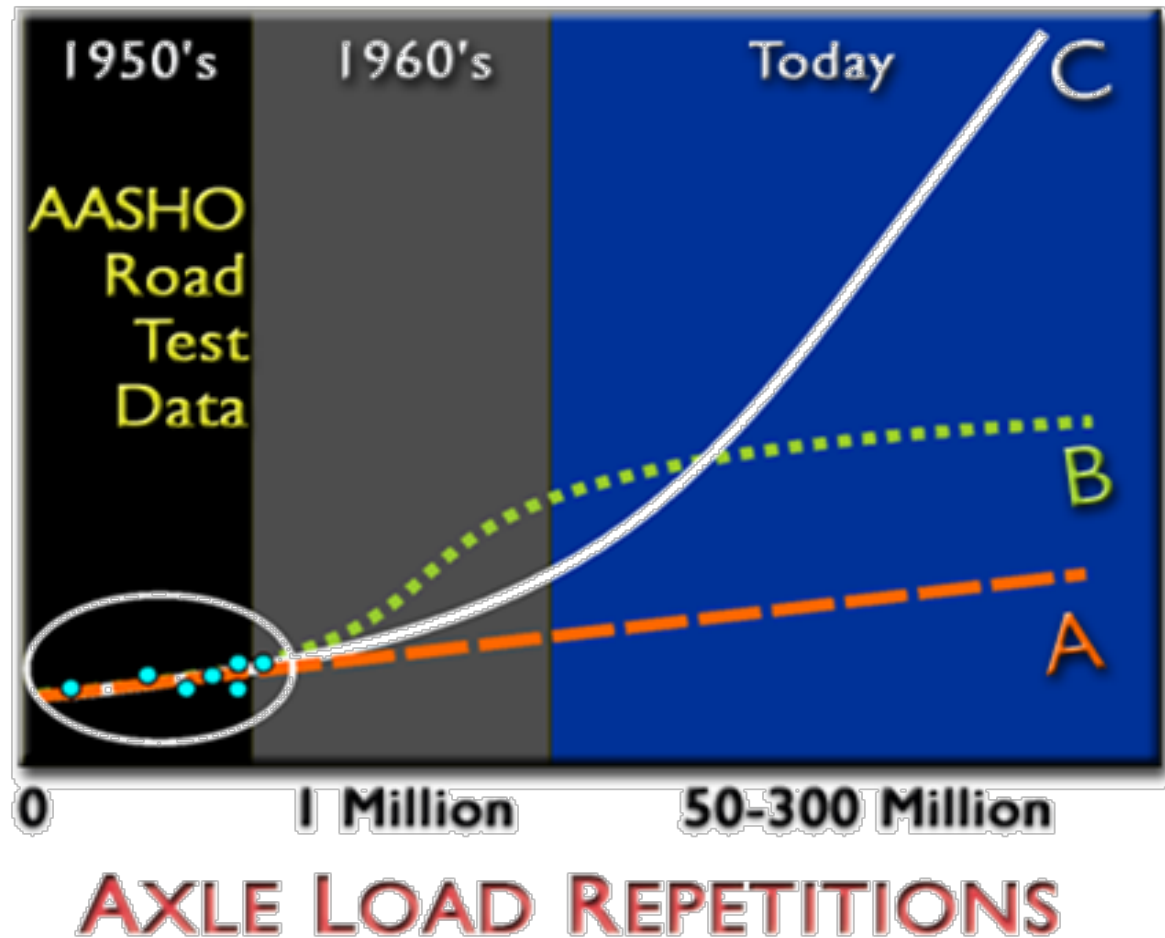


Figure 23. Test vehicles, showing typical axle arrangements and loadings.

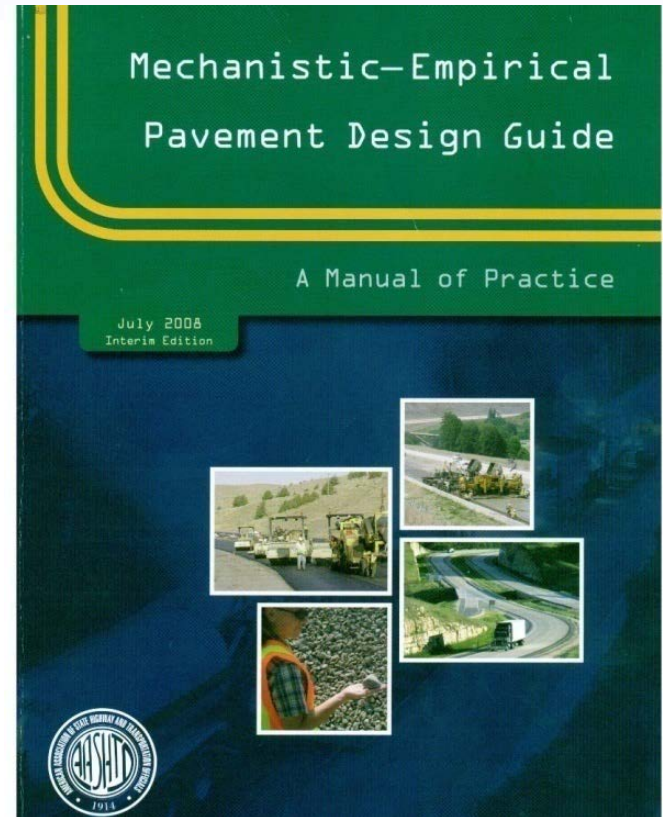
# Limitations: Huge Extrapolation

## PAVEMENT THICKNESS





Mechanistic Empirical Pavement Design



# Field Performance - The LTPP Study



# New Design Guide



**An Analysis Method**



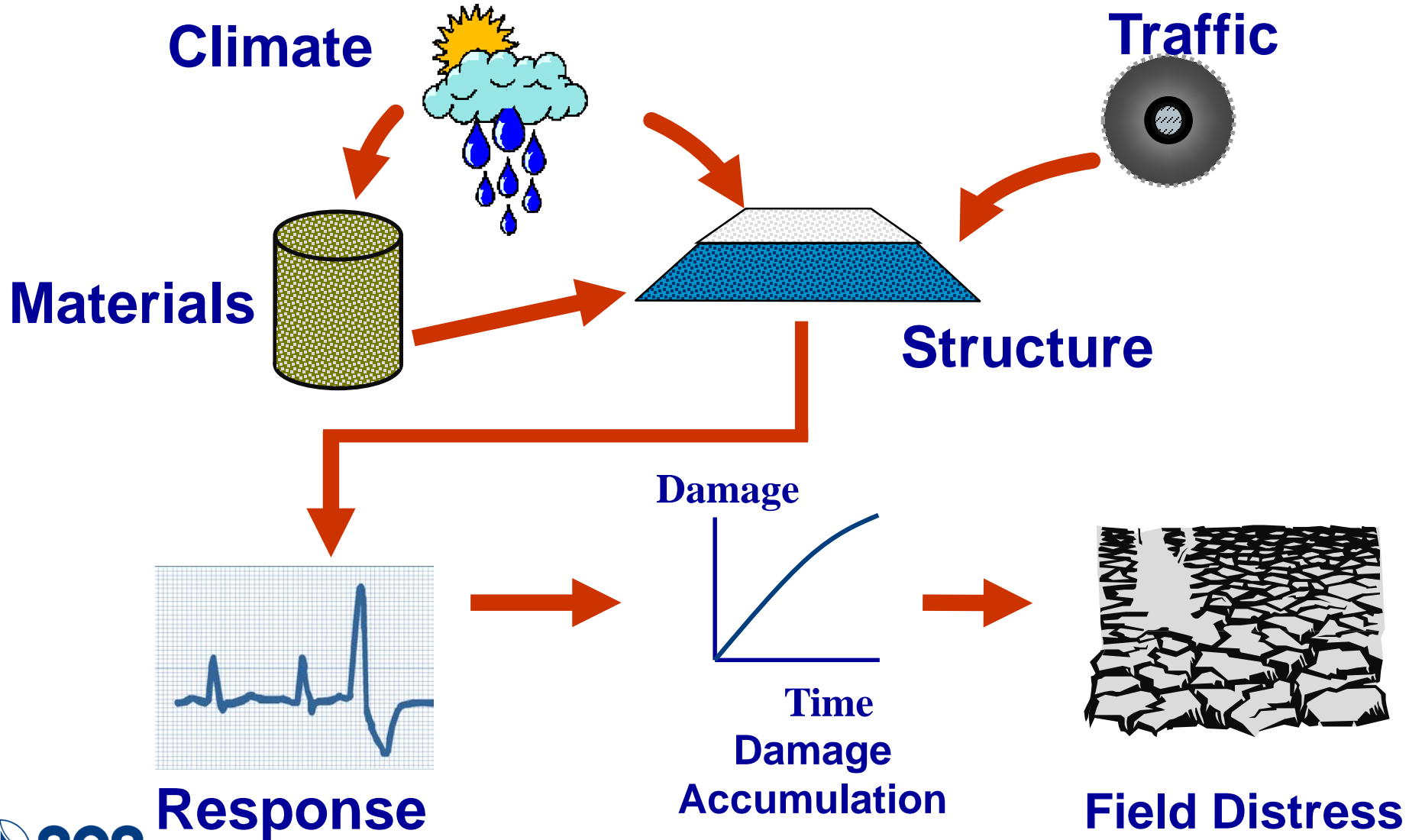
~~**Design Method**~~

The answer is

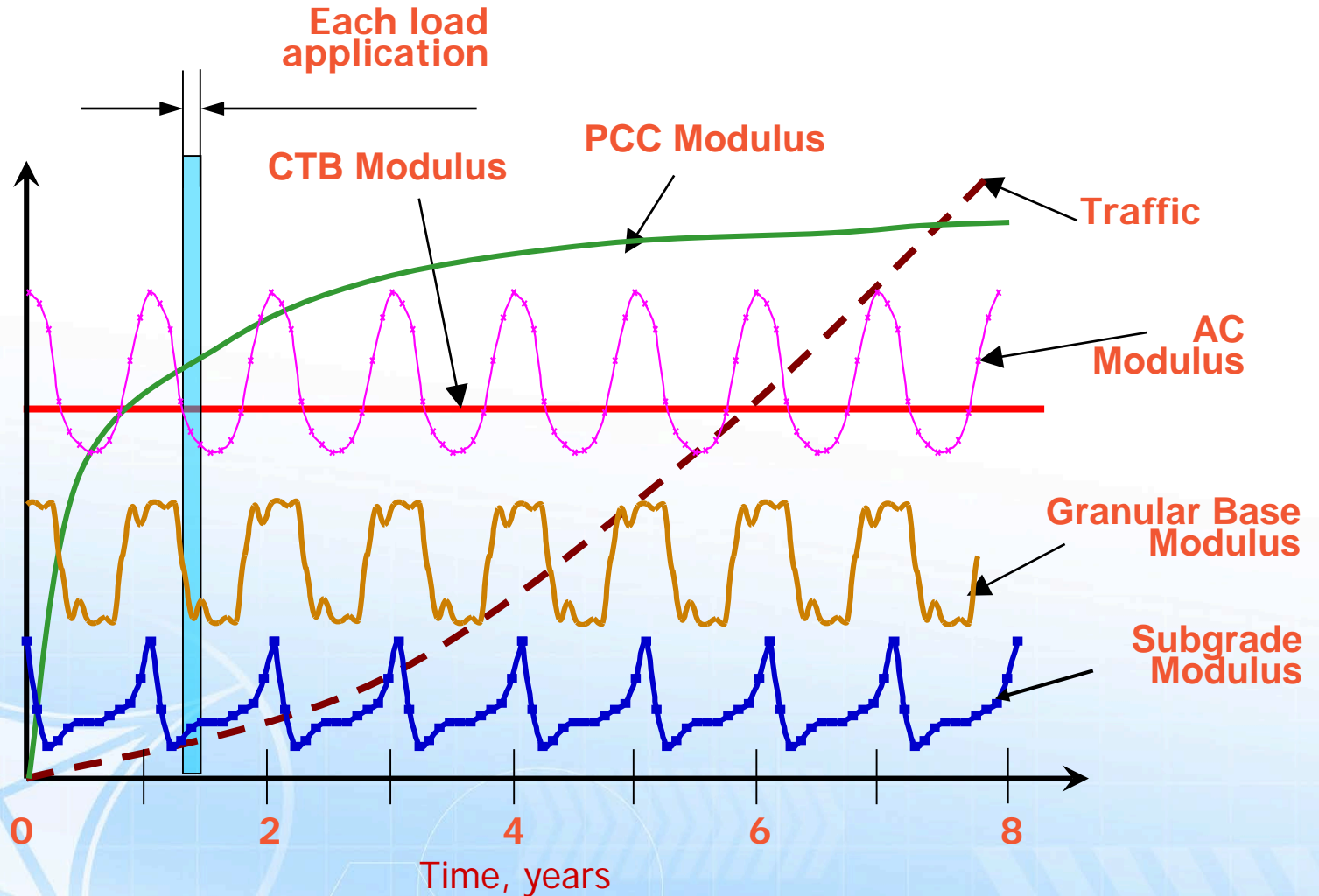
Amount of distress    Not layer thickness



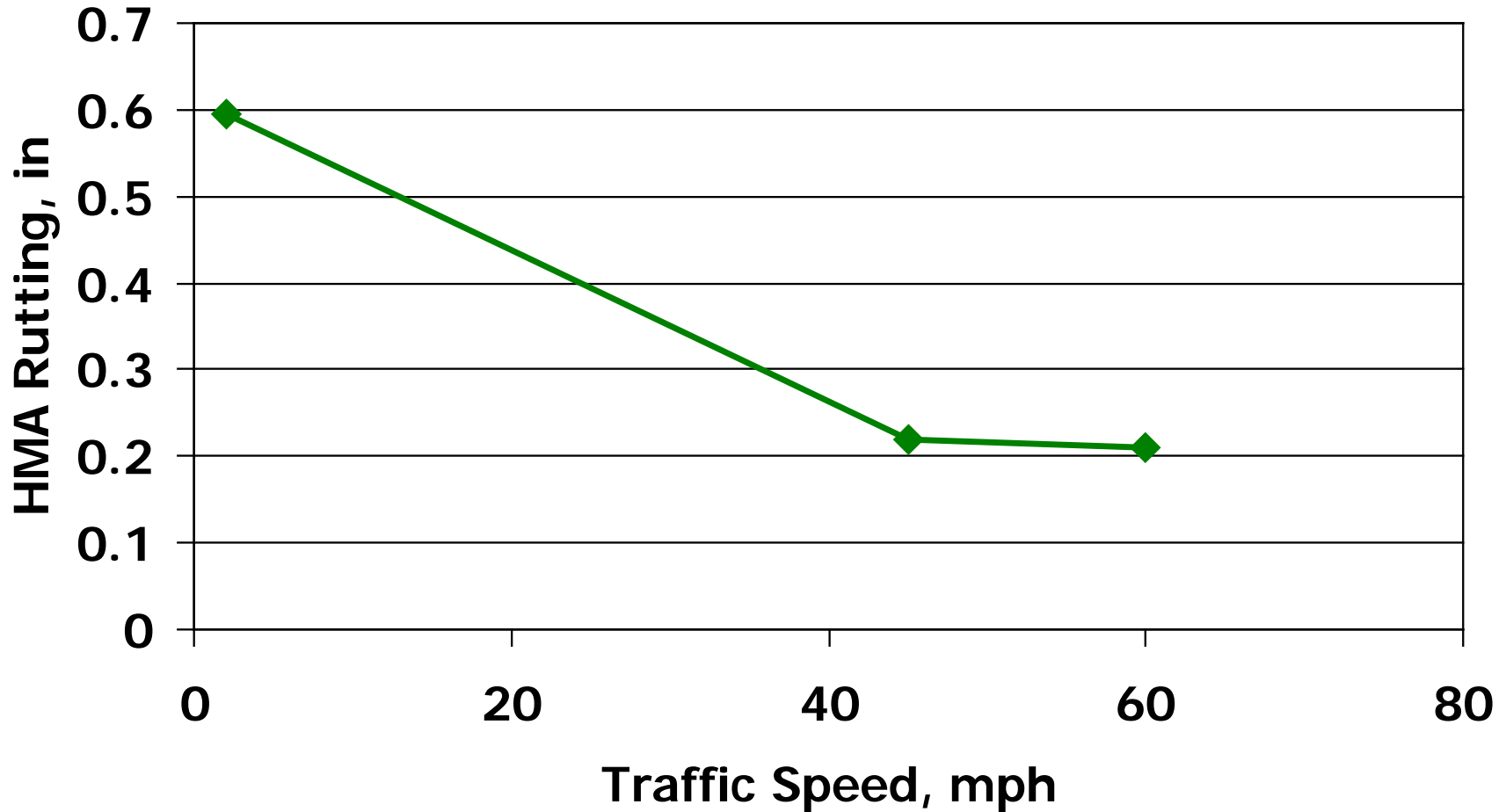
# Mechanistic-Empirical Design



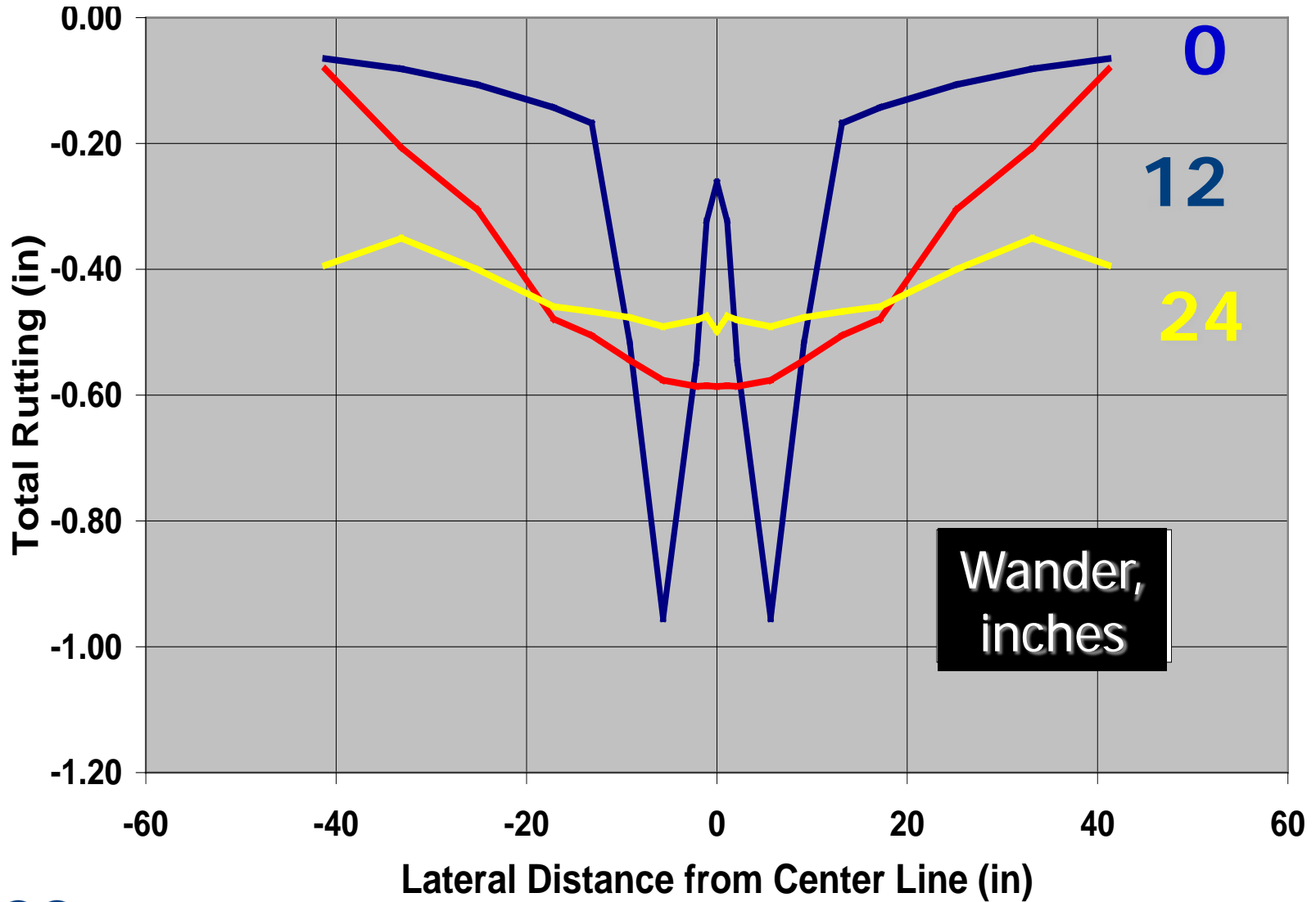
# Design Parameters Over Pavement Life



# Speed Impact



# Effect of Traffic Wander



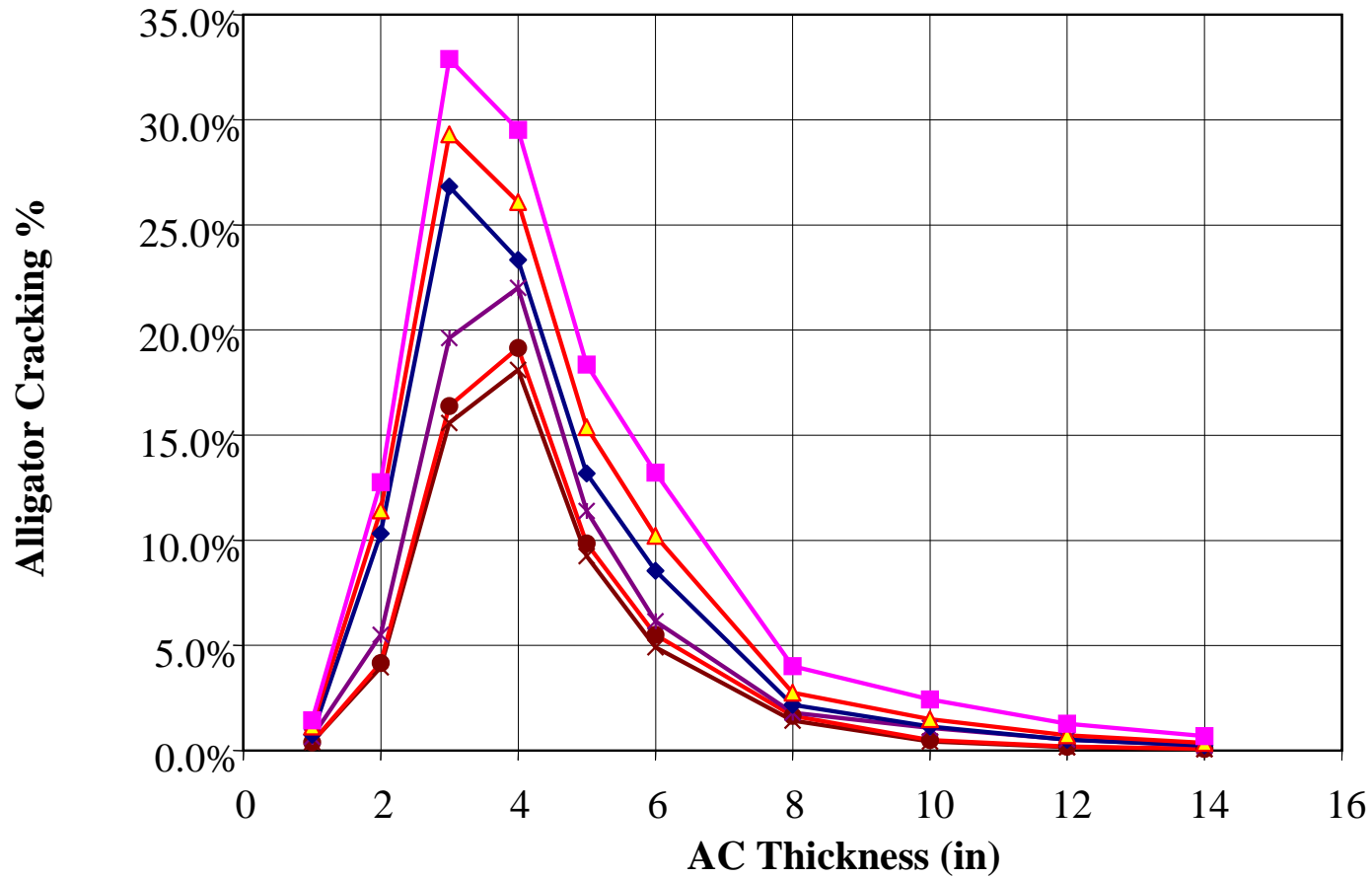
Wander,  
inches

0

12

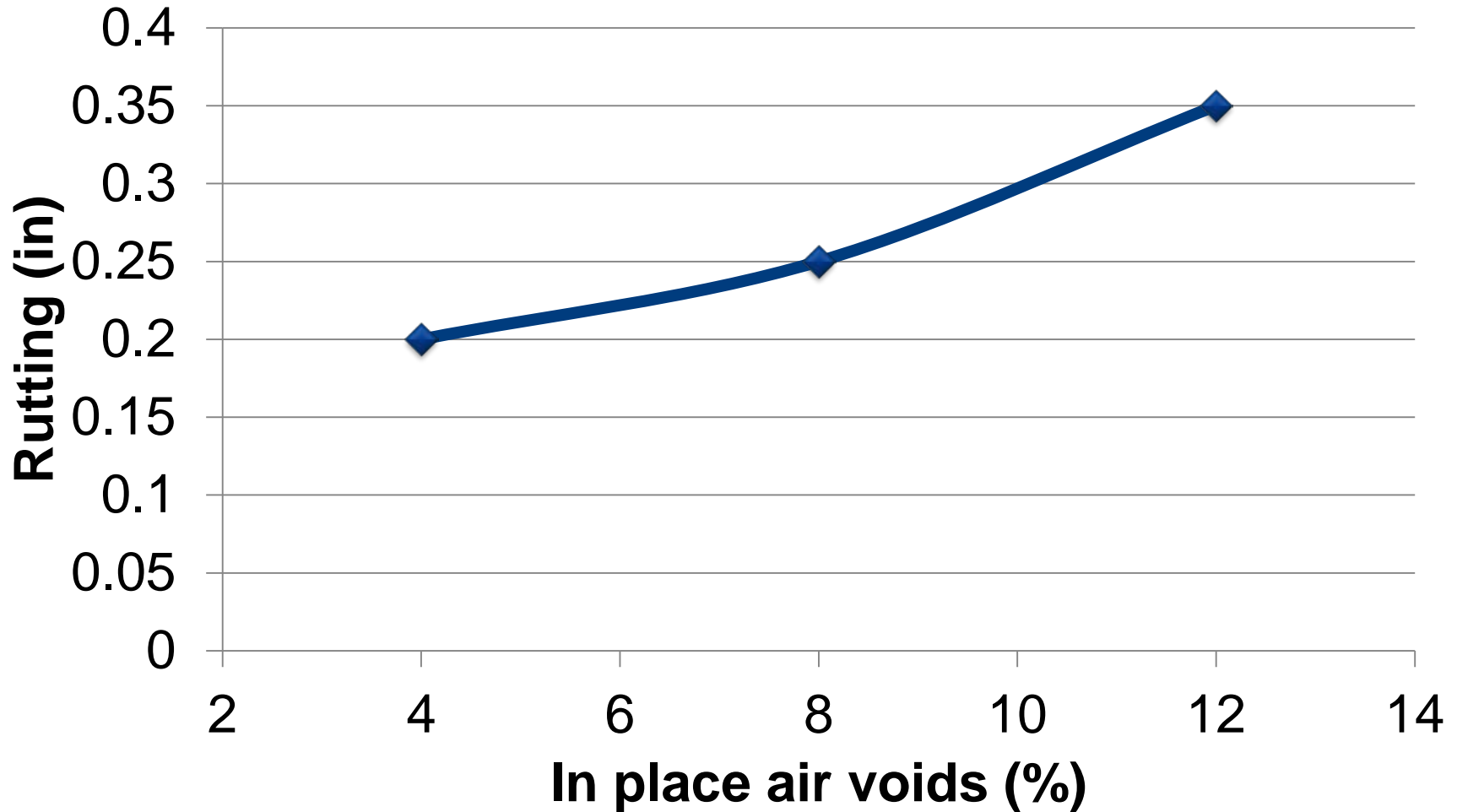
24

# Thickness Impact



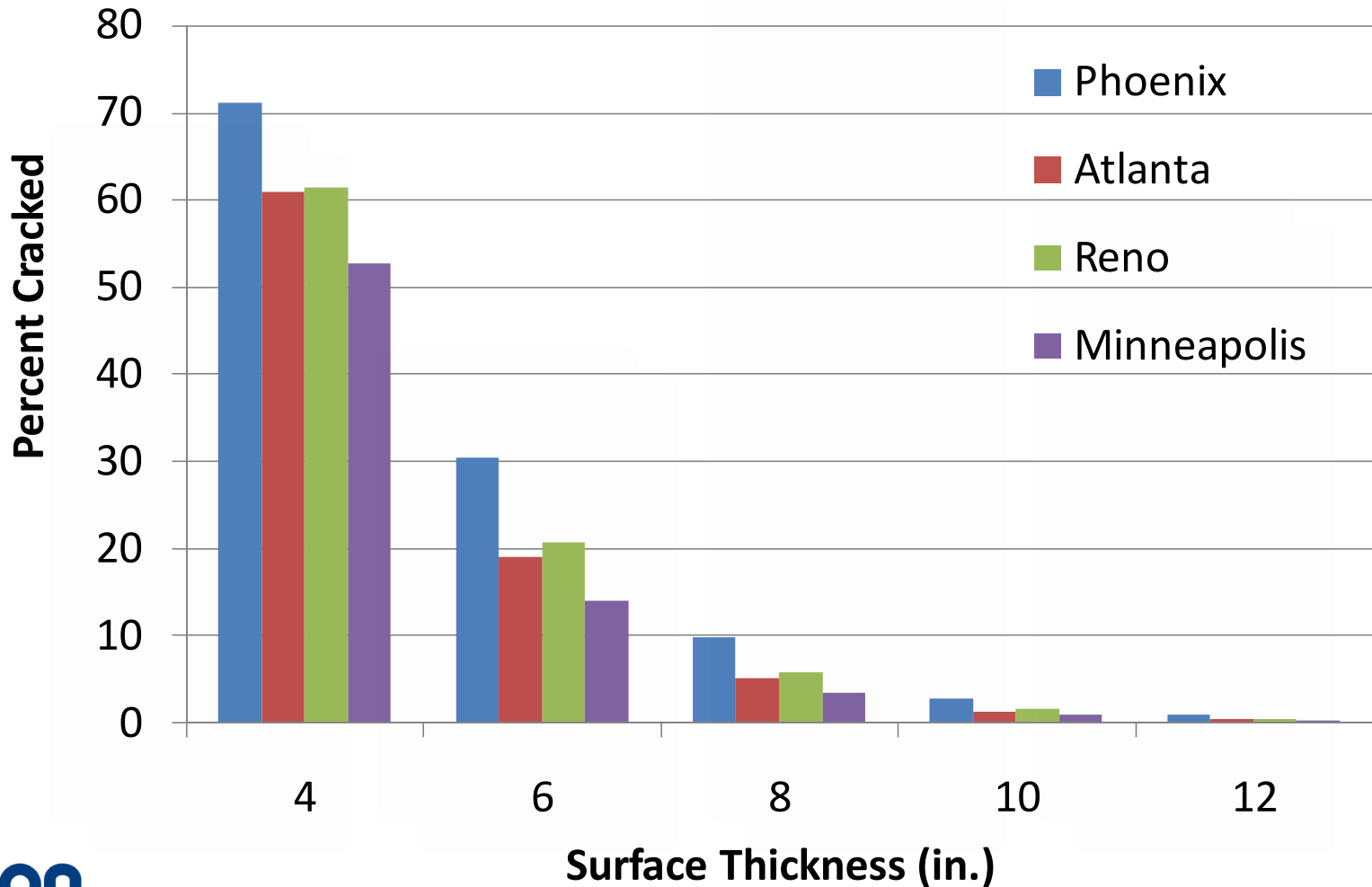
- ✕ SG Mr = 30 ksi
- SG Mr = 25 ksi
- ✱ SG Mr = 20 ksi
- ◆ SG Mr = 15 ksi
- ▲ SG Mr = 8,000
- SG Mr = 3,000

# Asphalt Density Impact



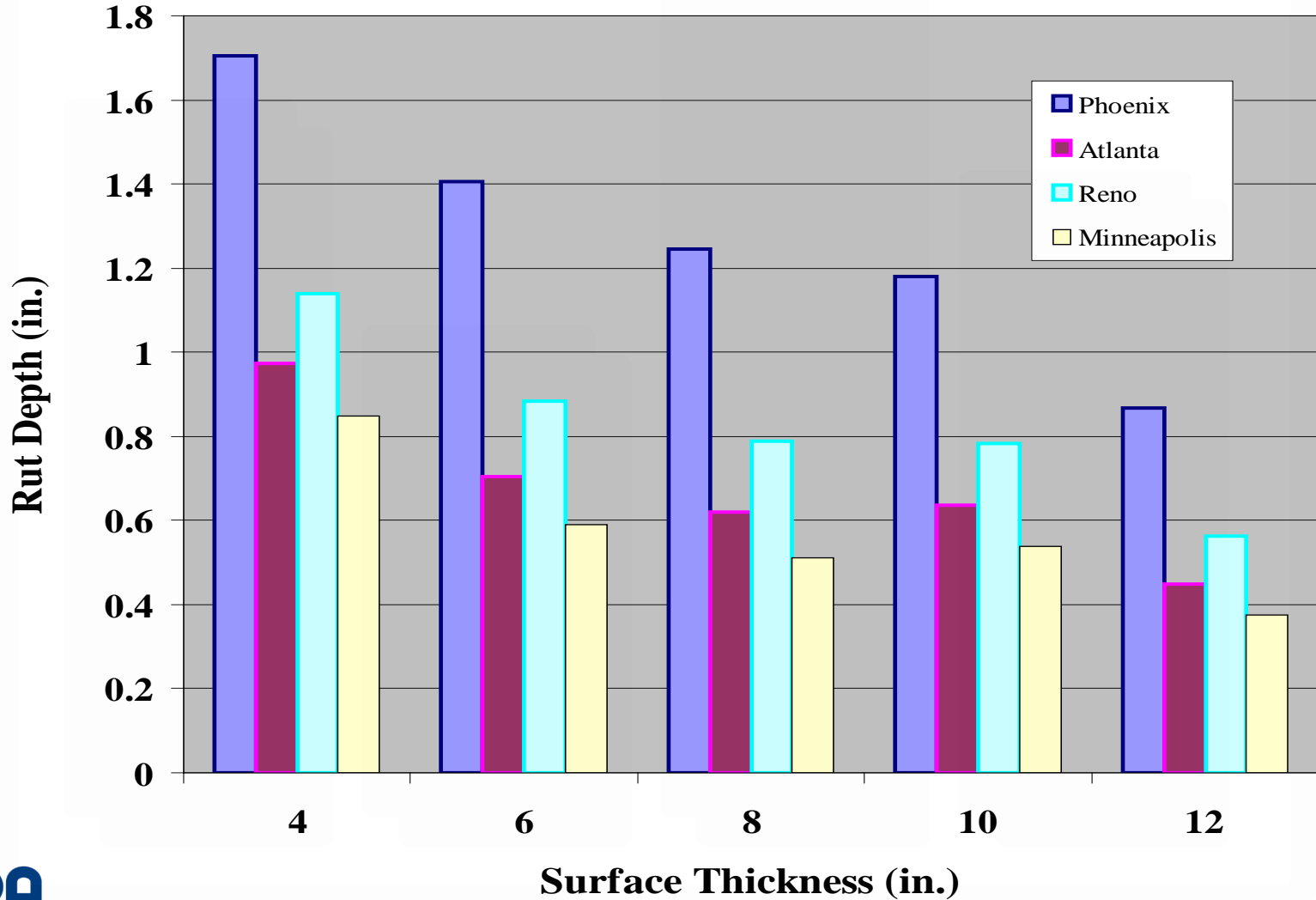
# Bottom-up Cracking

Percent Alligator Cracked at 20 Years



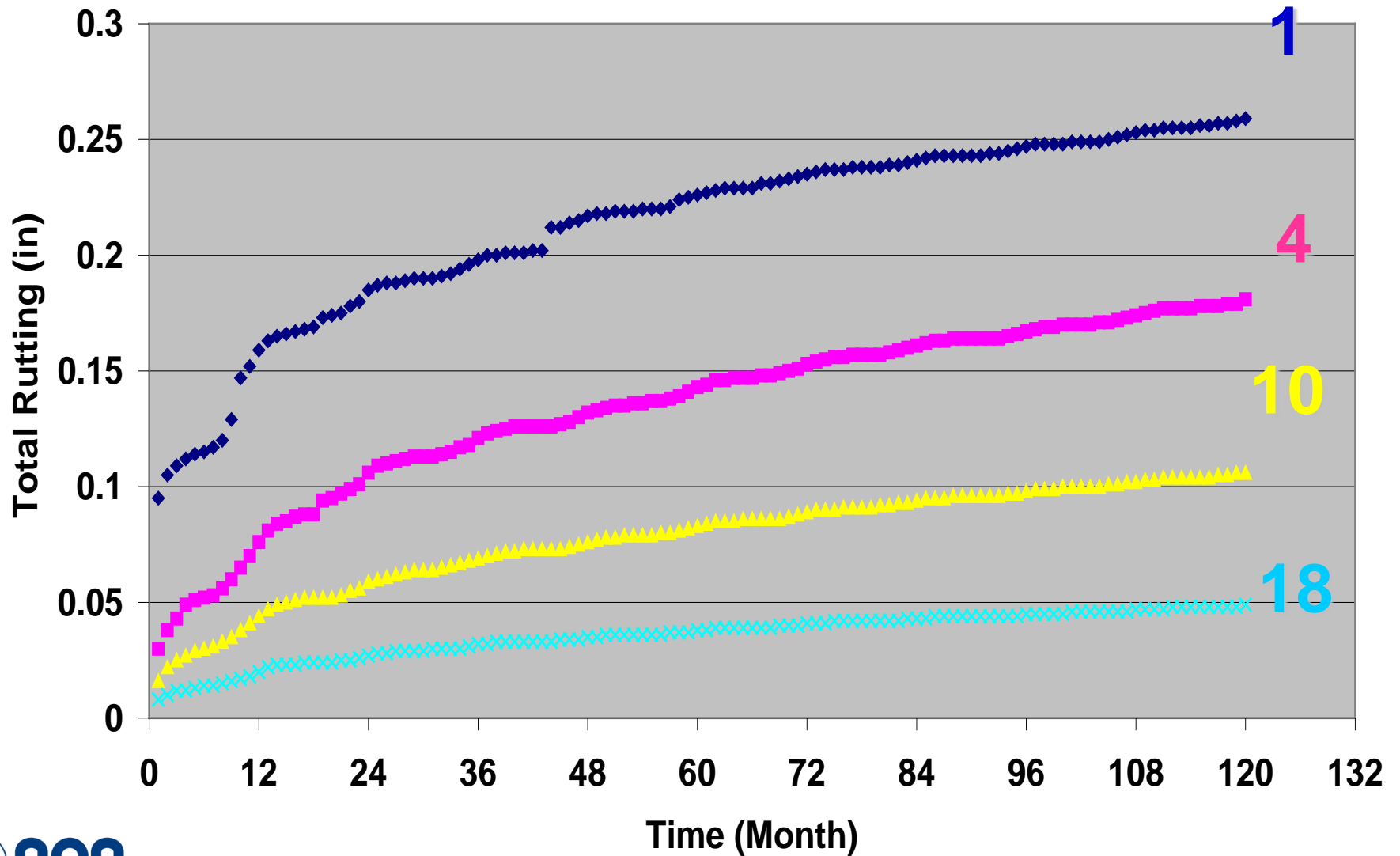
# Rutting

## Total Rutting at 20 Years

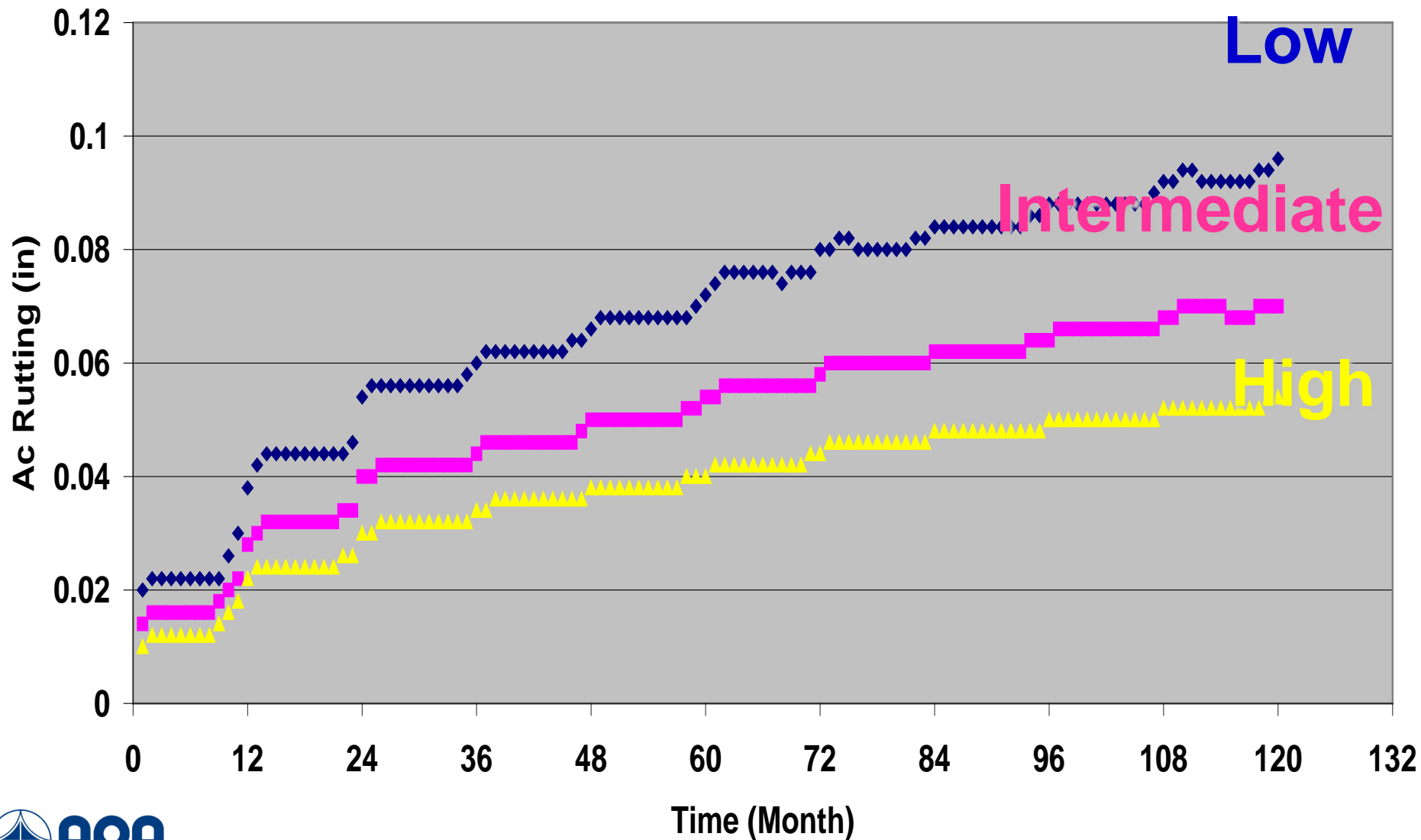




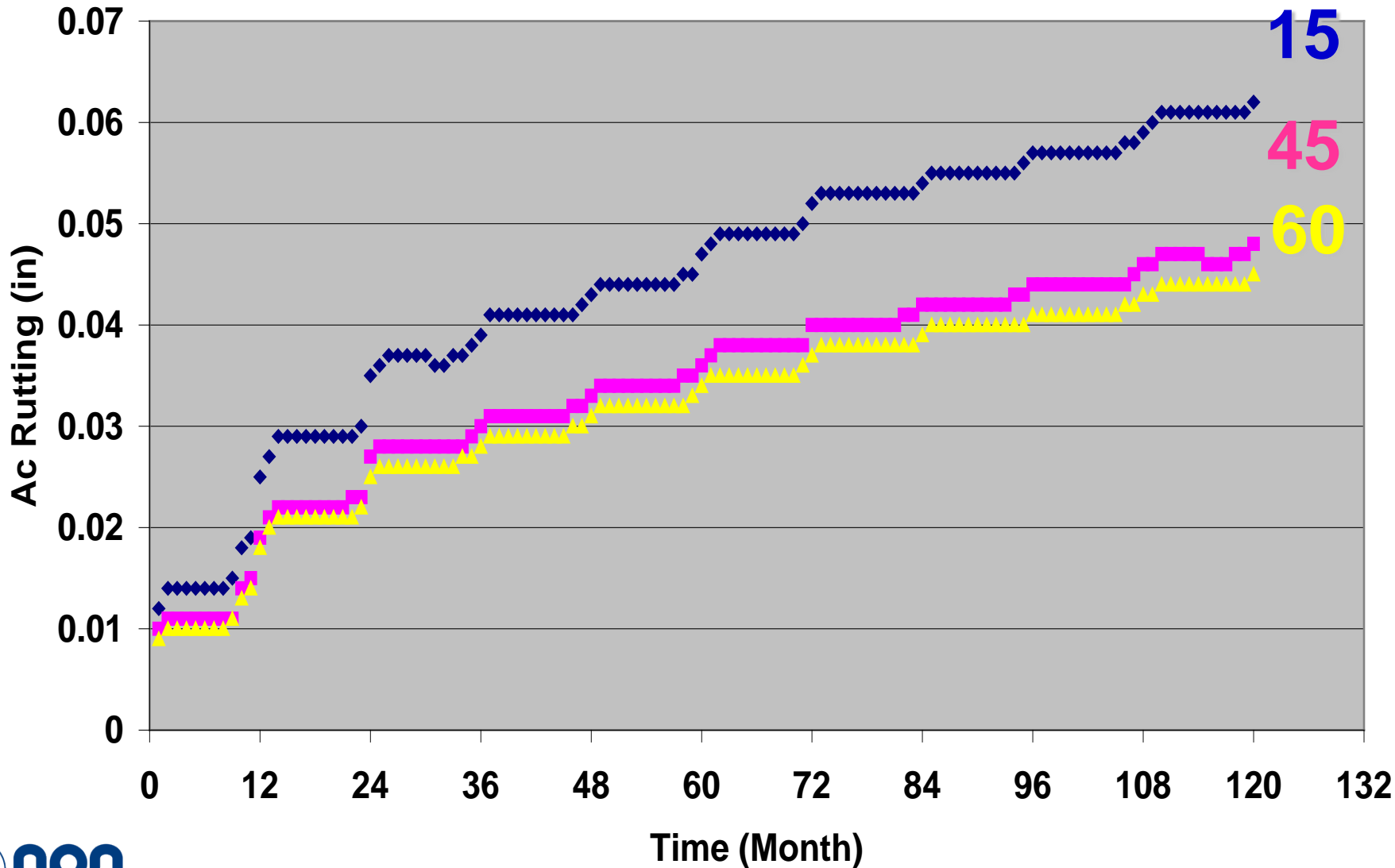
# Effect of HMA Thickness



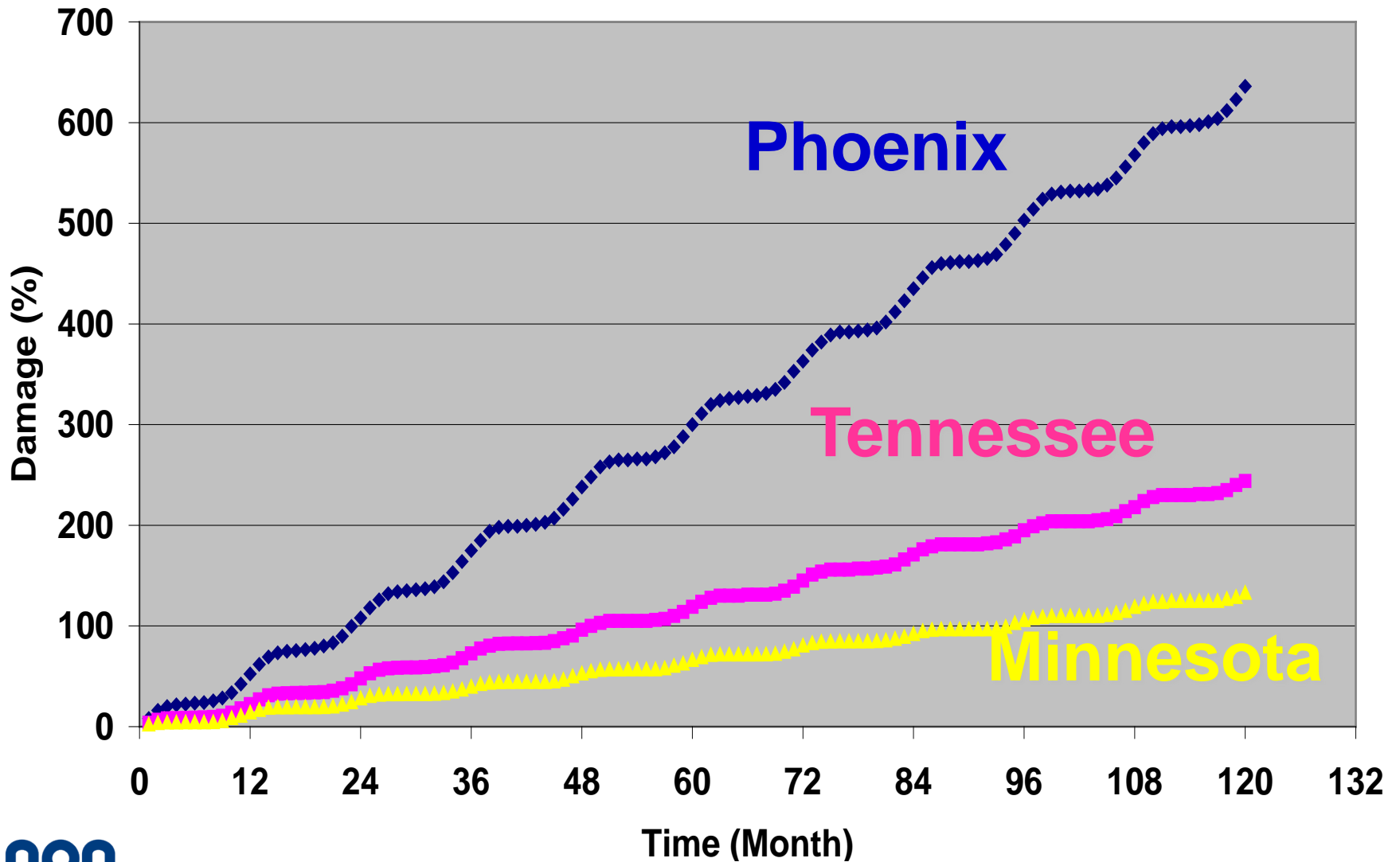
# Effect of HMA Mixtures



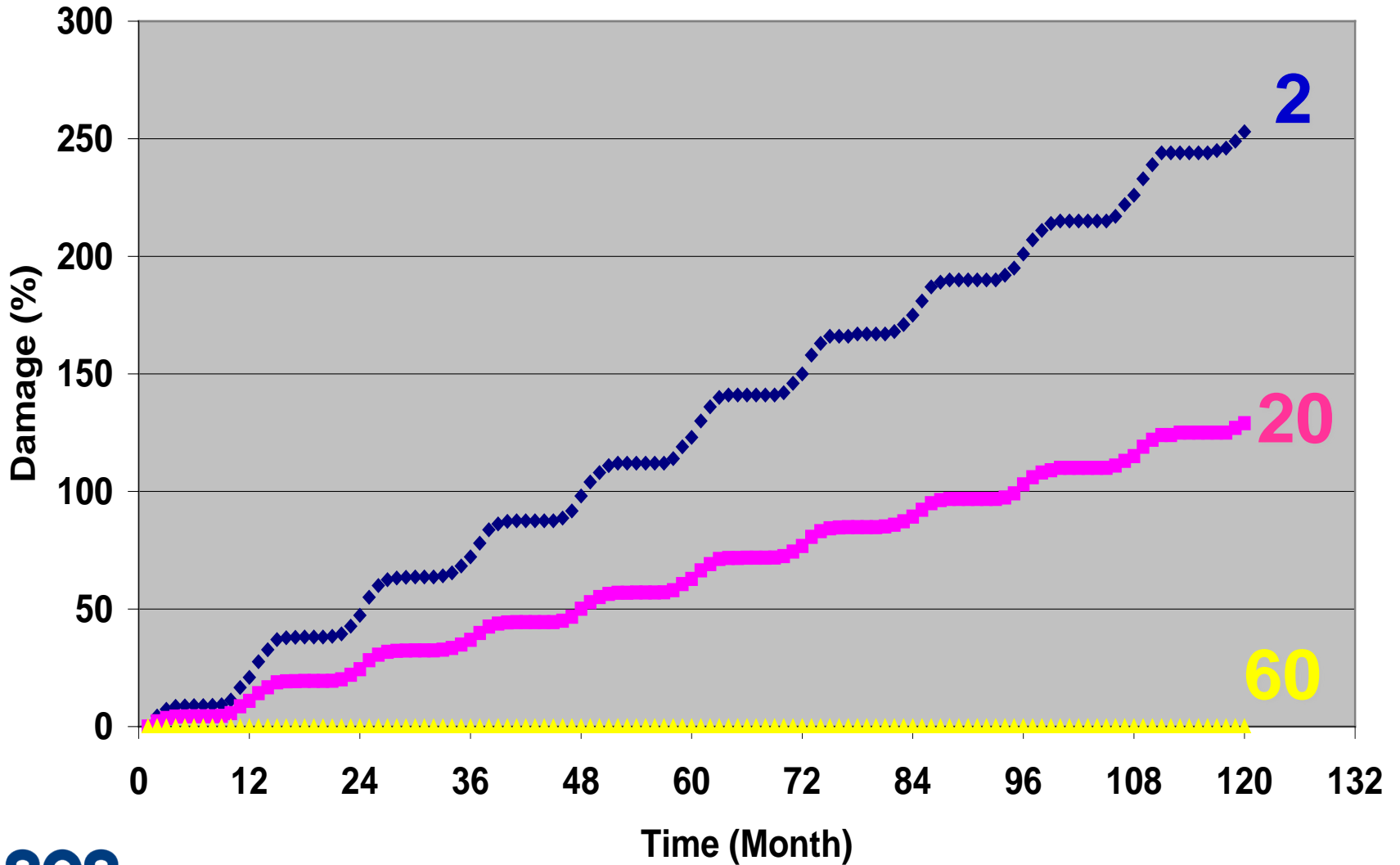
# Effect of Truck Operating Speed



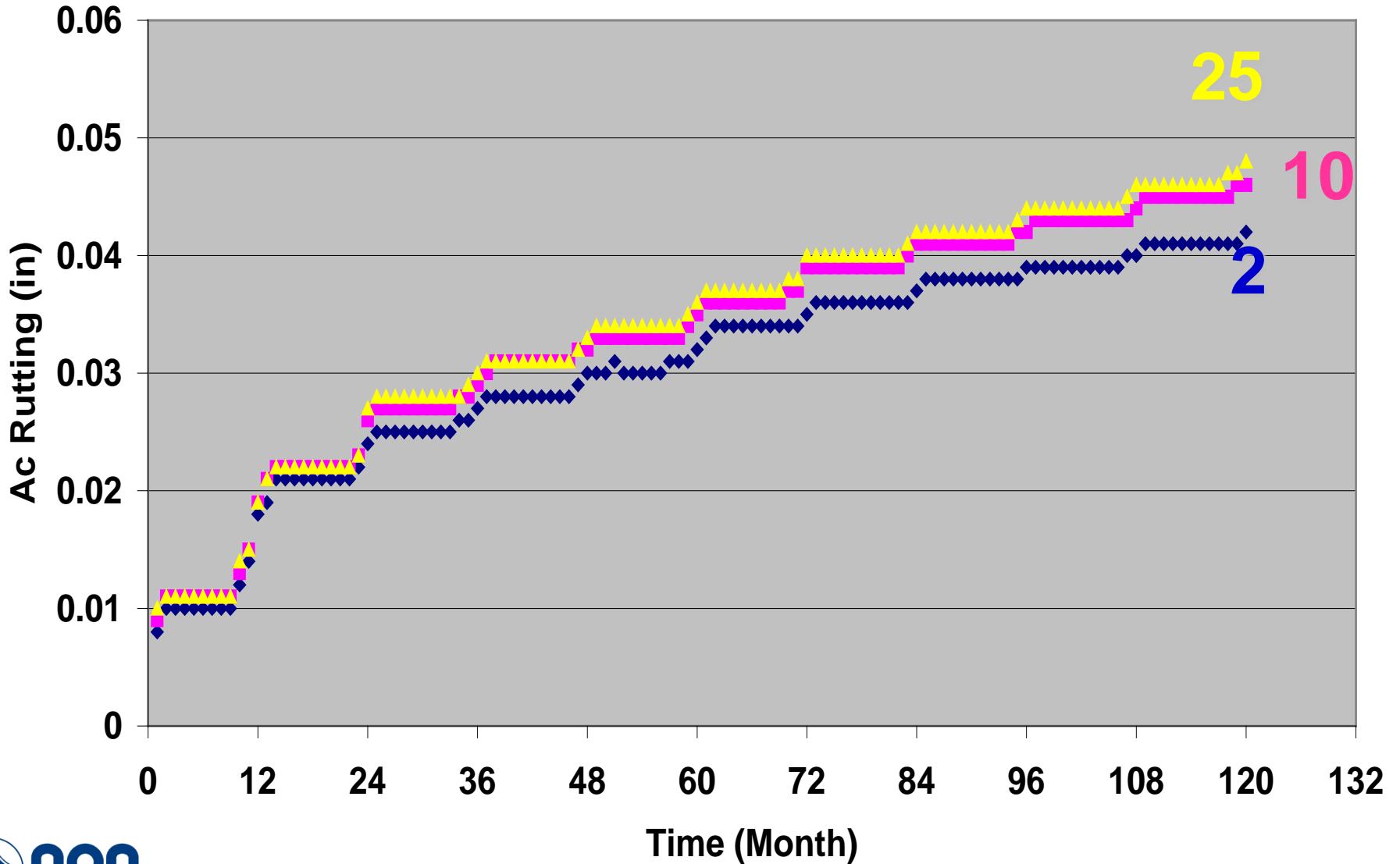
# Effect of Climate on Cracking



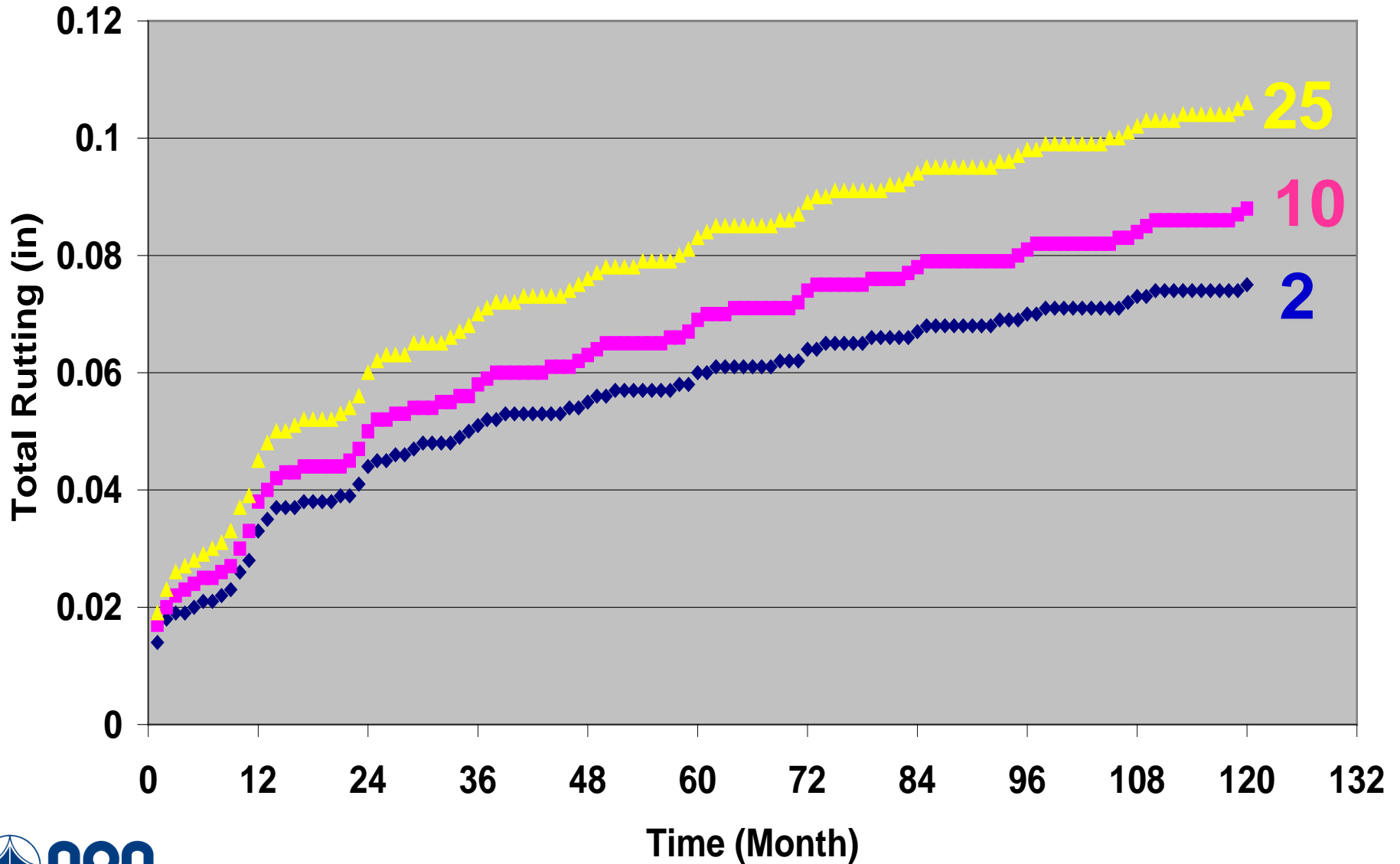
# Effect of Ground Water Table



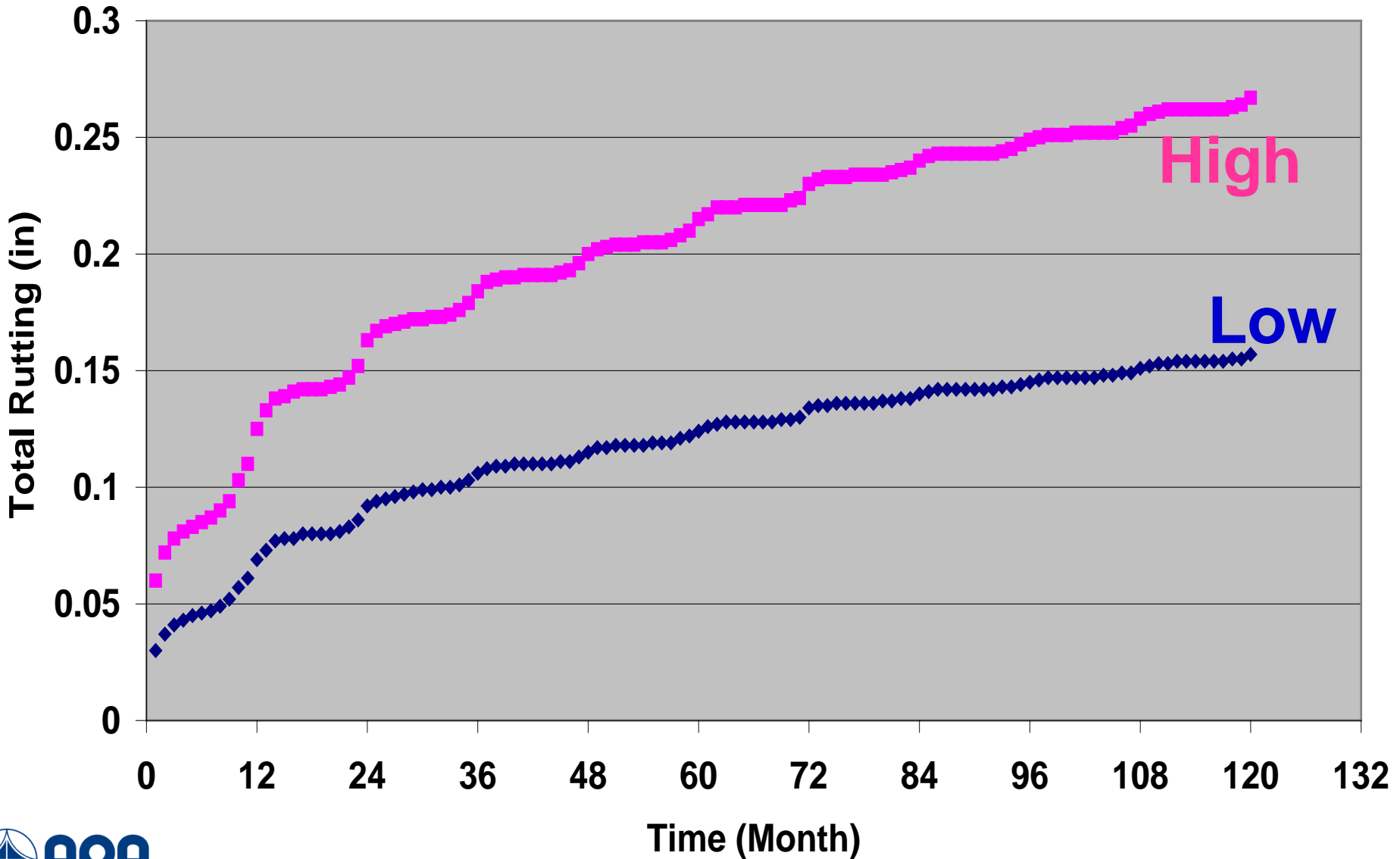
# Effect of Bedrock Elevation



# Effect of Bedrock Elevation



# Effect of Traffic

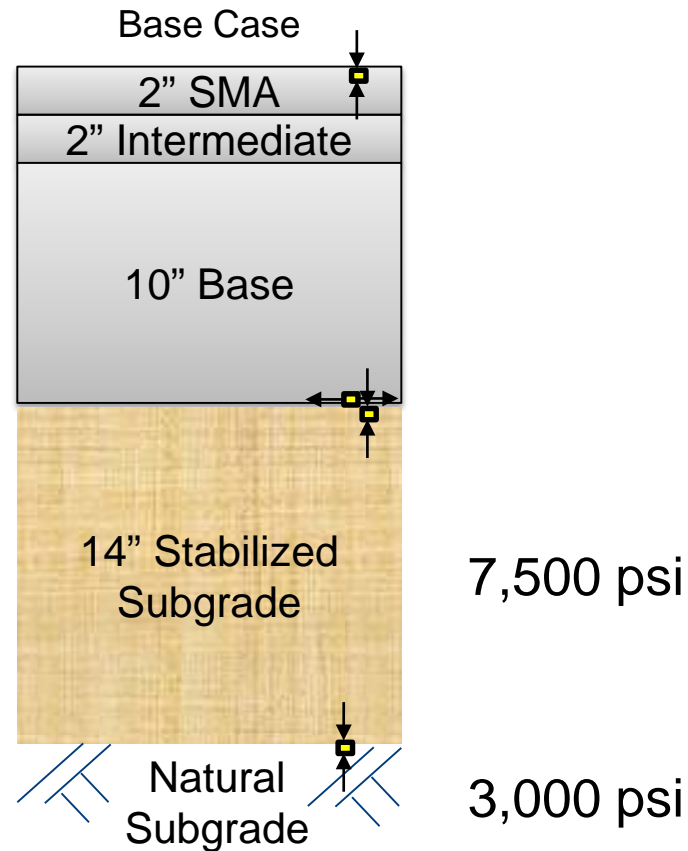




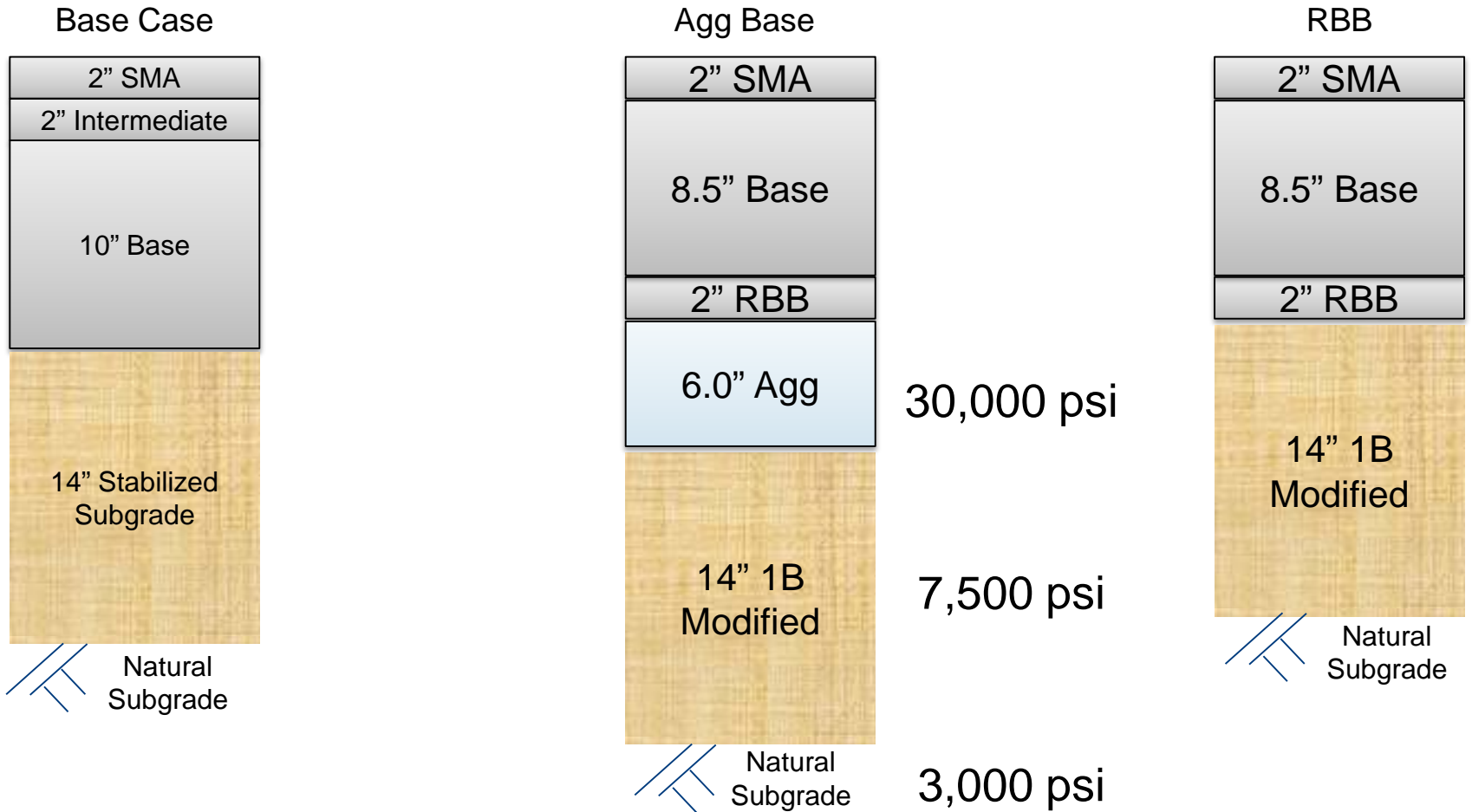
Let's look at a  
typical design...



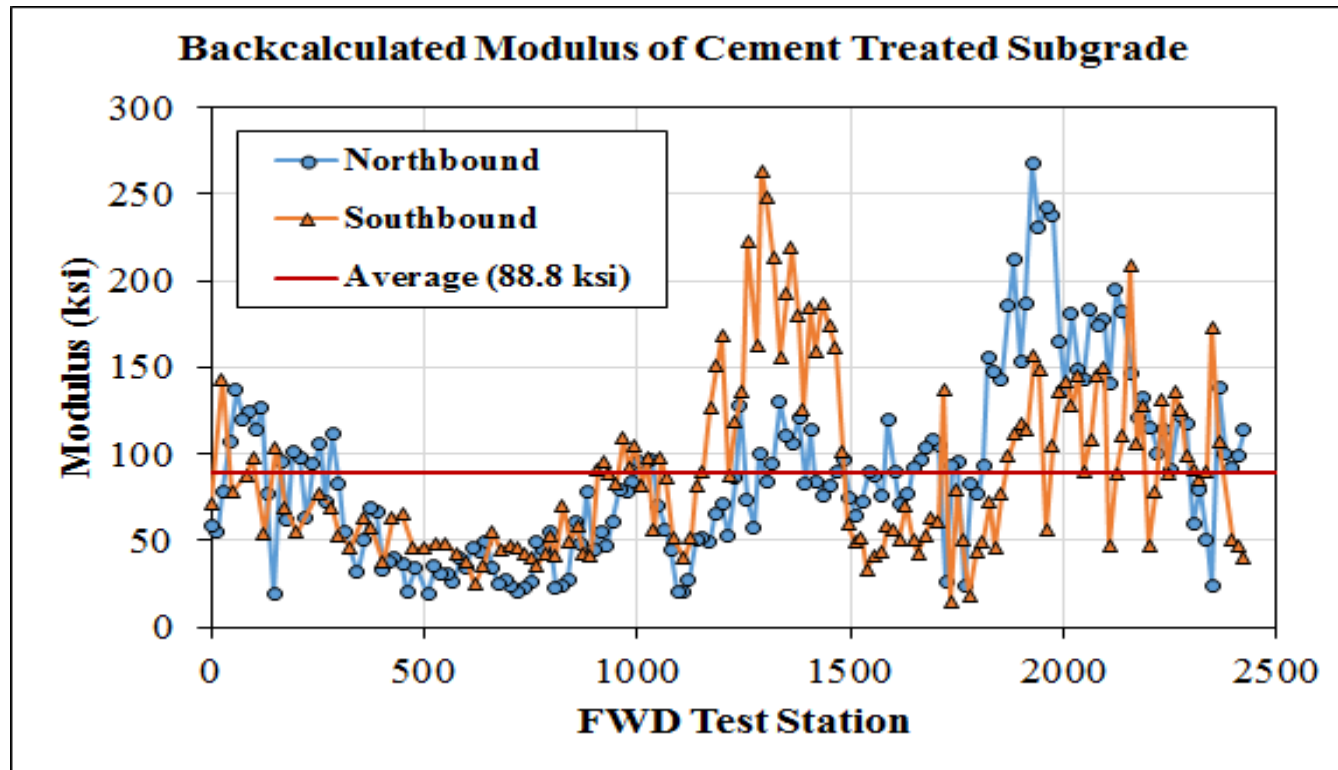
# A typical InDOT medium volume interstate design



# Variations on the theme



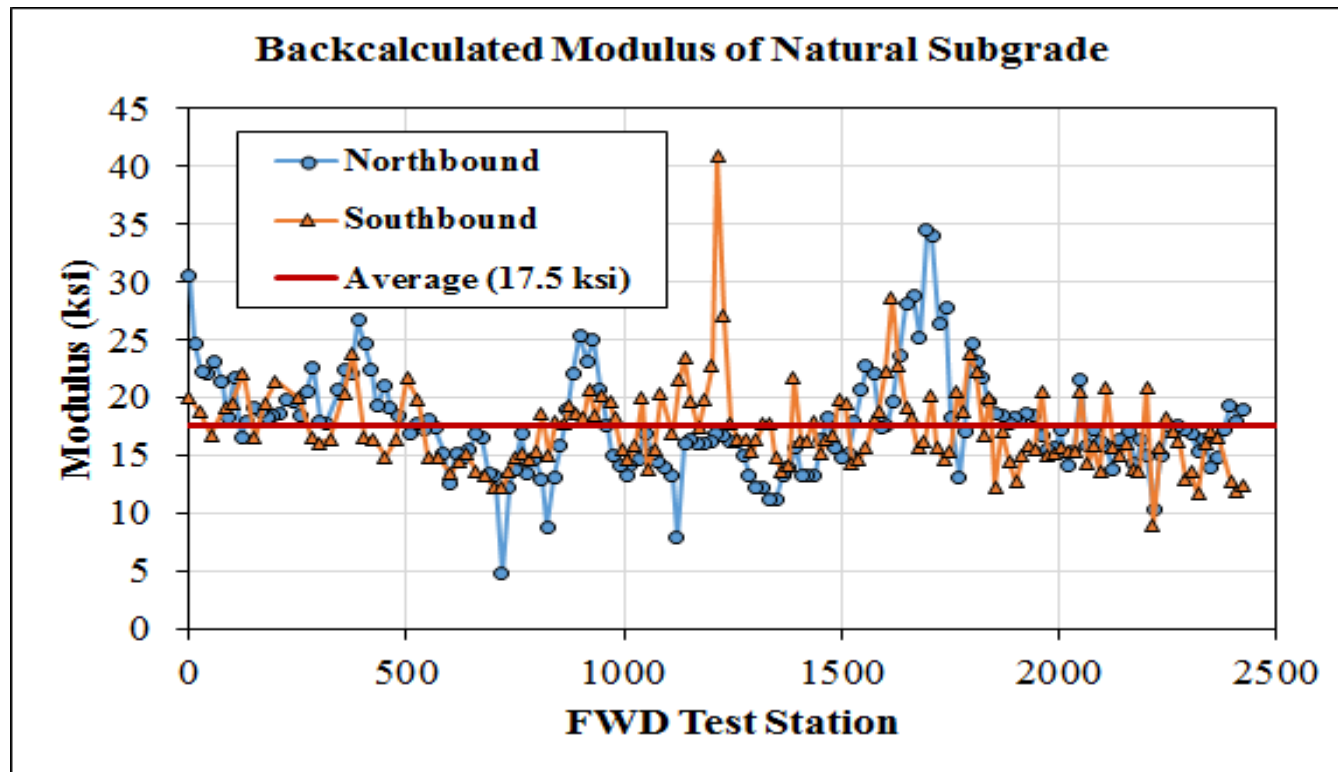
# Measuring field properties 1B Modified



Mean Modulus = 89 ksi  
Minimum Value = 15 ksi

Standard Deviation = 50.6 ksi  
Low Quartile = 50 ksi

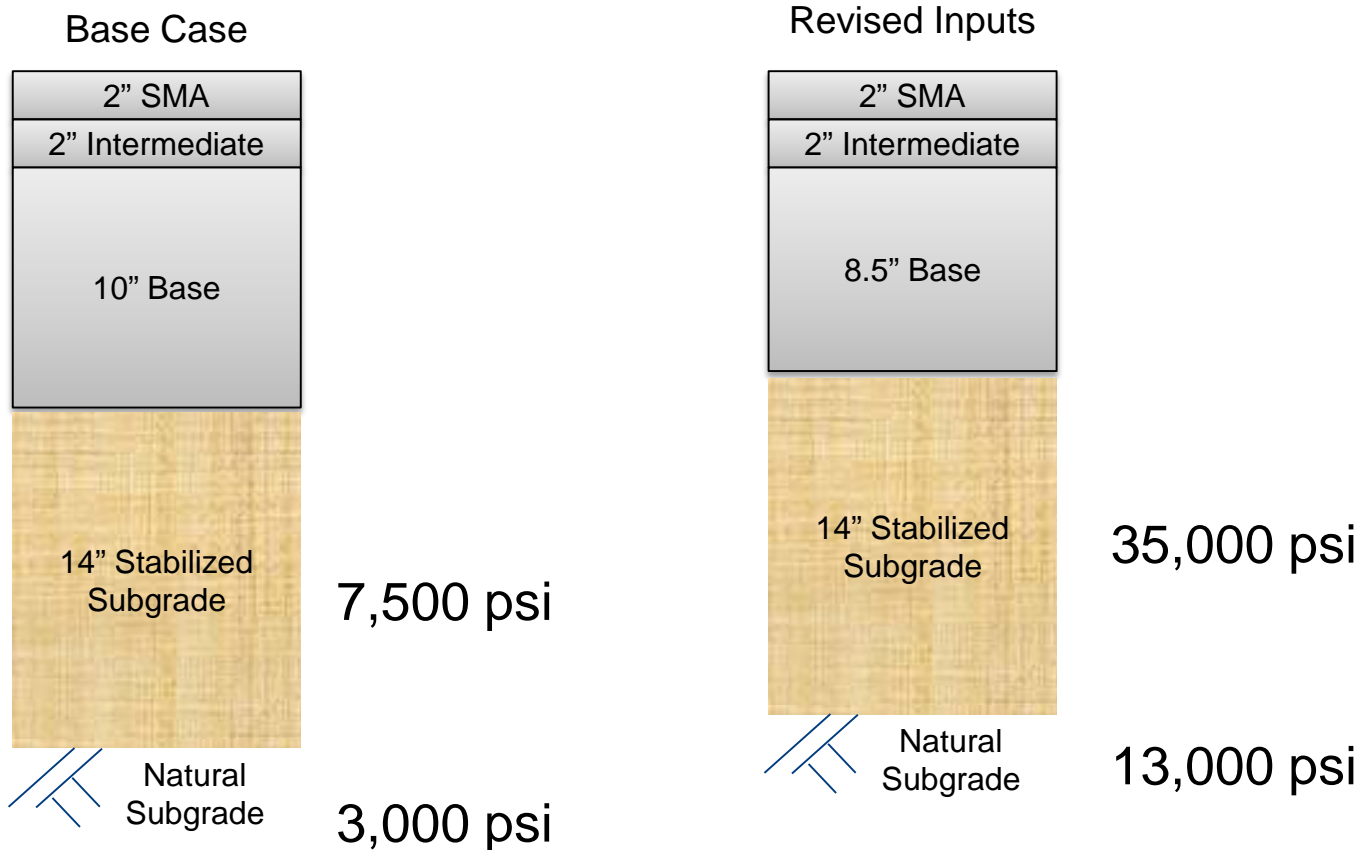
# Measuring field properties - Subgrade



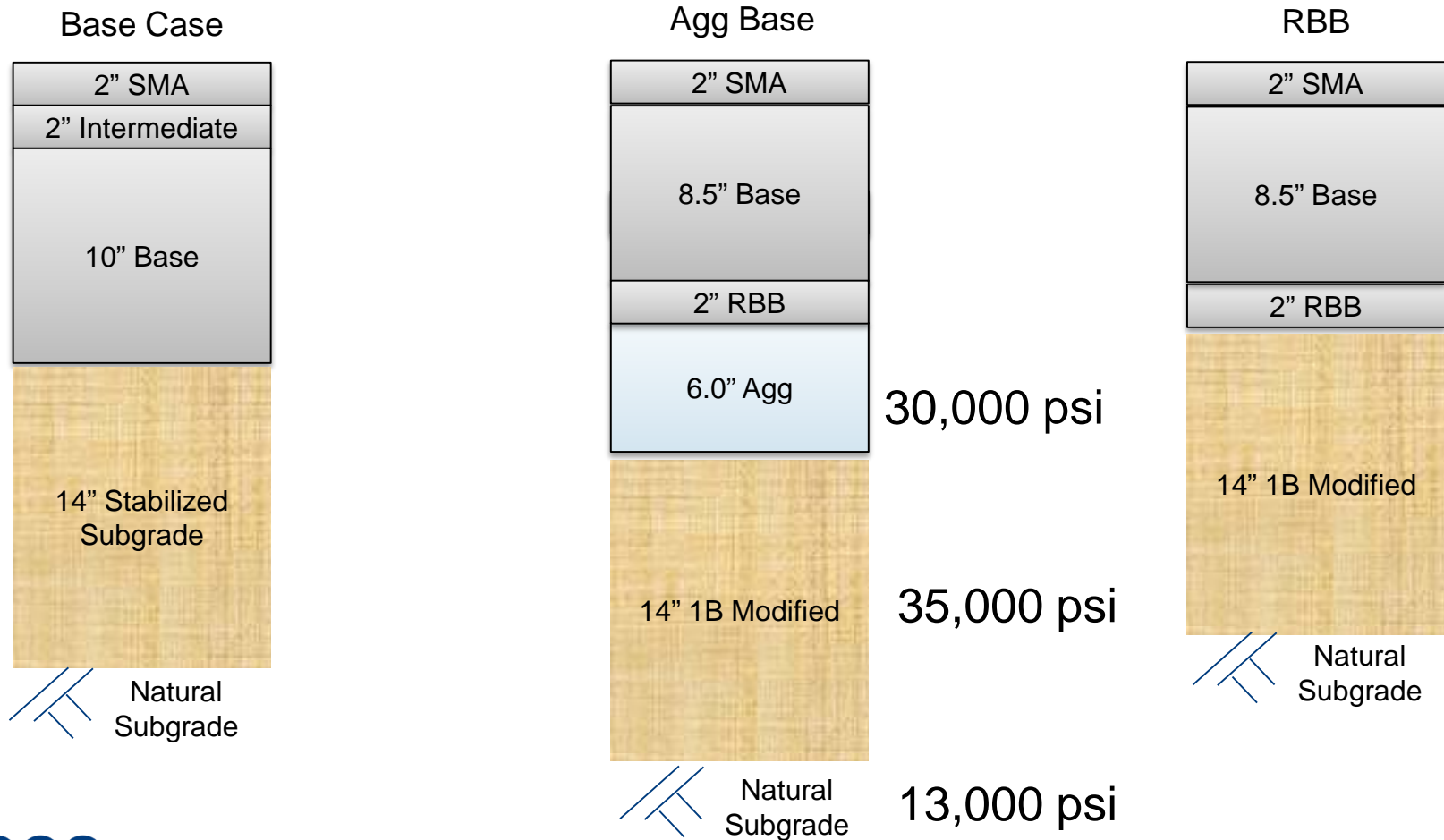
Mean Modulus = 18 ksi  
Minimum Value = 5 ksi

Standard Deviation = 4.1 ksi  
Low Quartile = 15 ksi

# What if we use values below the lower quartile in the design



# The variations also reduce in thickness

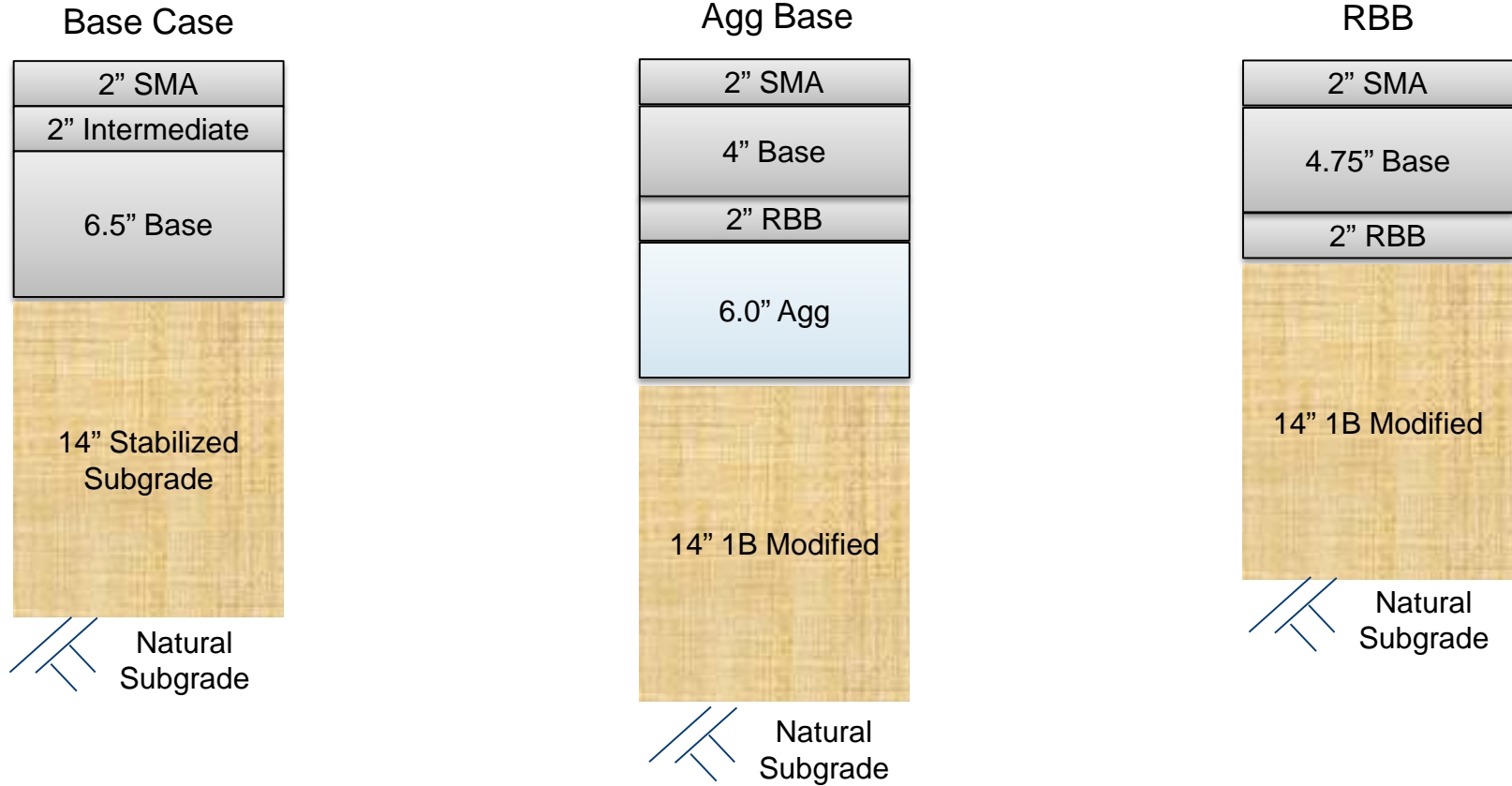


# What if we use the average in-place values and ensure perpetual design?

- **Protect against bottom up fatigue**
  - 50-year analysis at 90% reliability under 10% cracking
  - Will allow for mill & fill cycles with occasional added thickness and perpetual life
  
- **Initial Construction Tied to Typical Values**
  - Use SMA for rut prevention
  - Initial IRI = 50
  - Evaluate roughness & AC rutting at 20 yrs, 90% reliability

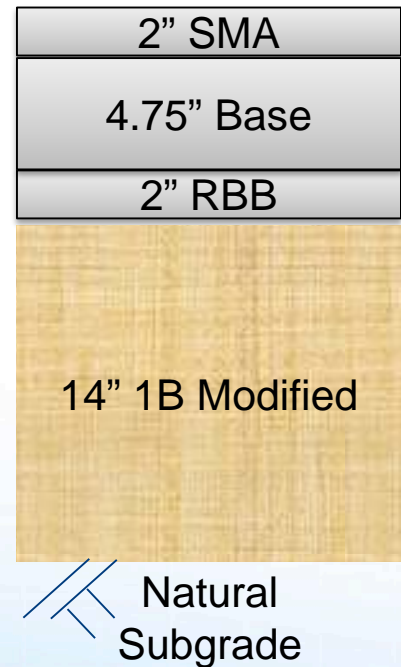


# Perpetual design with as-built inputs



# Find the pavement that gives you the best value and uses the best design strategy

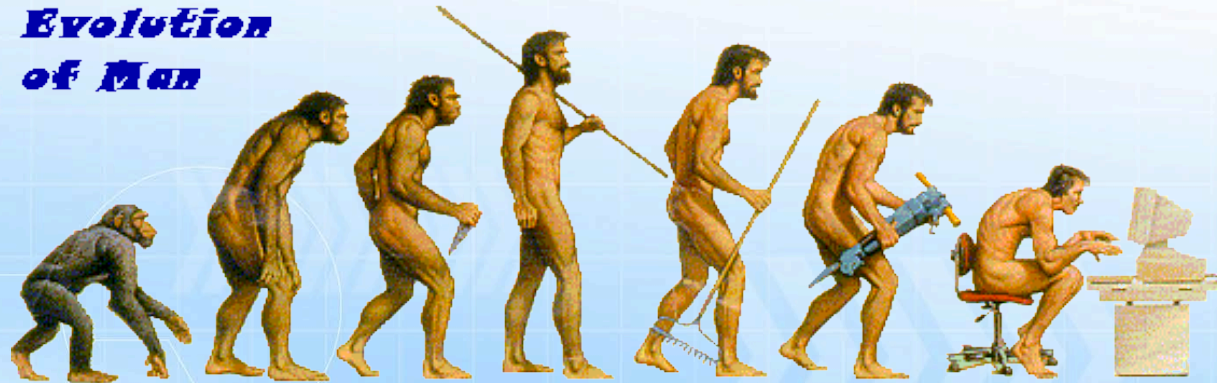
- Each Layer Designed for its purpose
  - SMA Surface – long life
  - Base Mix to provide stability
  - Rich bottom binder protect for fatigue
  - 1B Modified for stability
    - Consider adding durability test for longer life
  - MOP consideration of subgrade soils
- Design Considerations different by distress
  - IRI – 20 yr – Initial 50 in/mi
  - Rutting – 20 yr
  - Thermal Cracking – 20 yr
  - Asphalt fatigue – 50 yr – 10% or less



# MEPDG is not perfect, but...

- Great pavement design tool
  - Design, rehabilitation
  - Analysis of effects of many variables (e.g., construction deficiencies)
  - Prediction of performance: use for LCCA.
  - Pavement management needs & uses.
  - Truck cost allocation of axle weights.
  - Excellent University training tool.

## *Evolution of Man*



# Questions



# Thank You!

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