Long-Life Concrete Pavement

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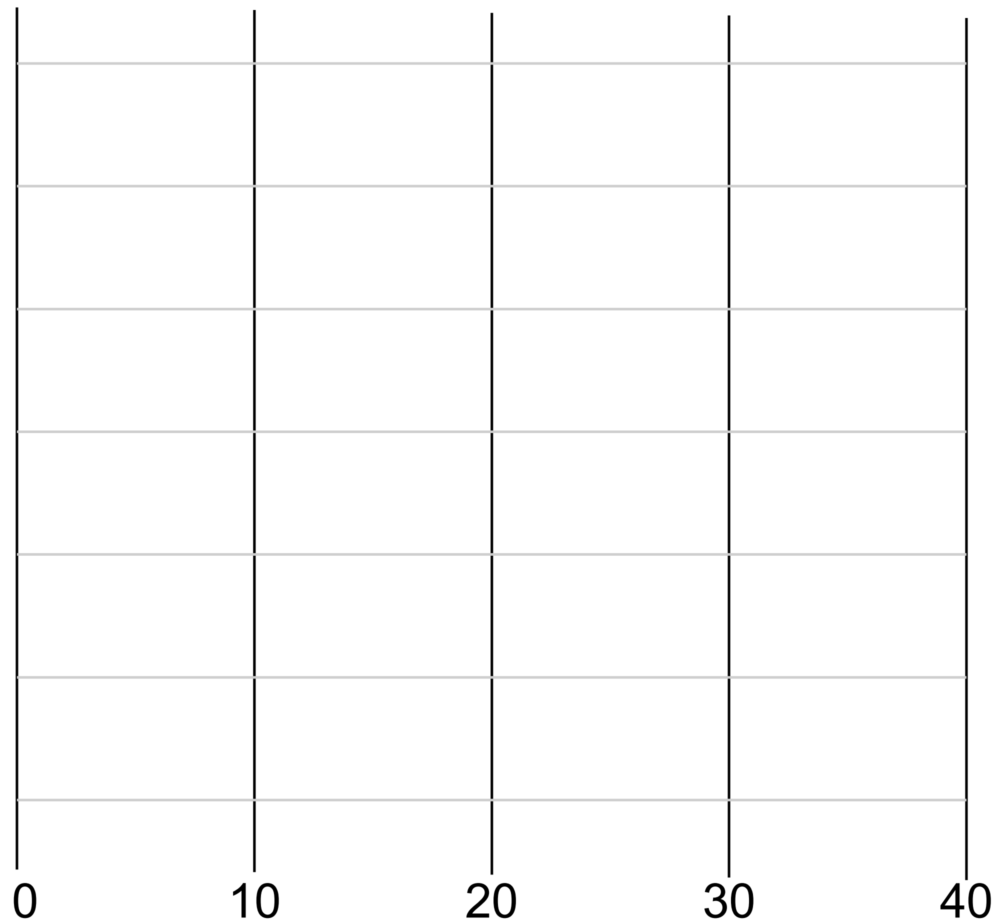
Topics Addressed in Presentation

- Long-life Pavement Perspective
- History
- High-Performance Concrete Pavement
- Improvements
  - Joint Design
  - Thickness?
  - Materials

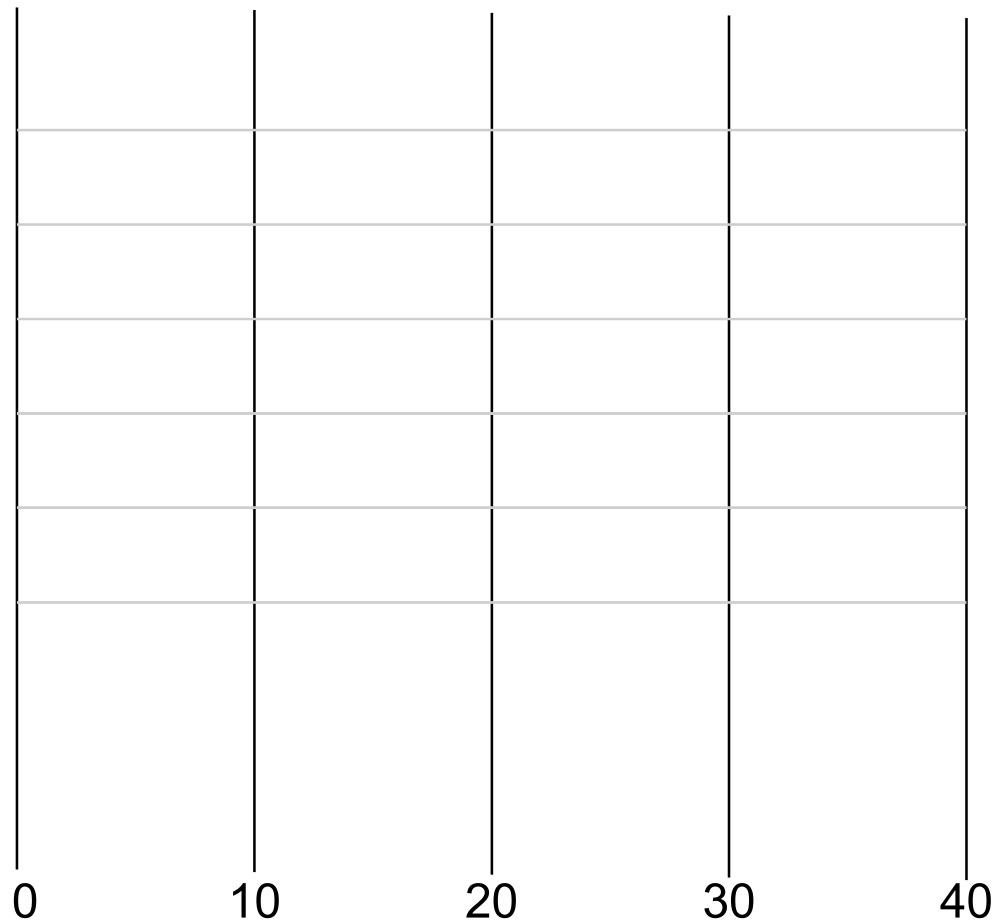
What do you consider to be long life pavement?

- 0-10 yrs.
- 11-20 yrs.
- 21-30 yrs.
- 31-40 yrs.
- 41-50 yrs.
- 51-60 yrs.
- 61+ yrs.



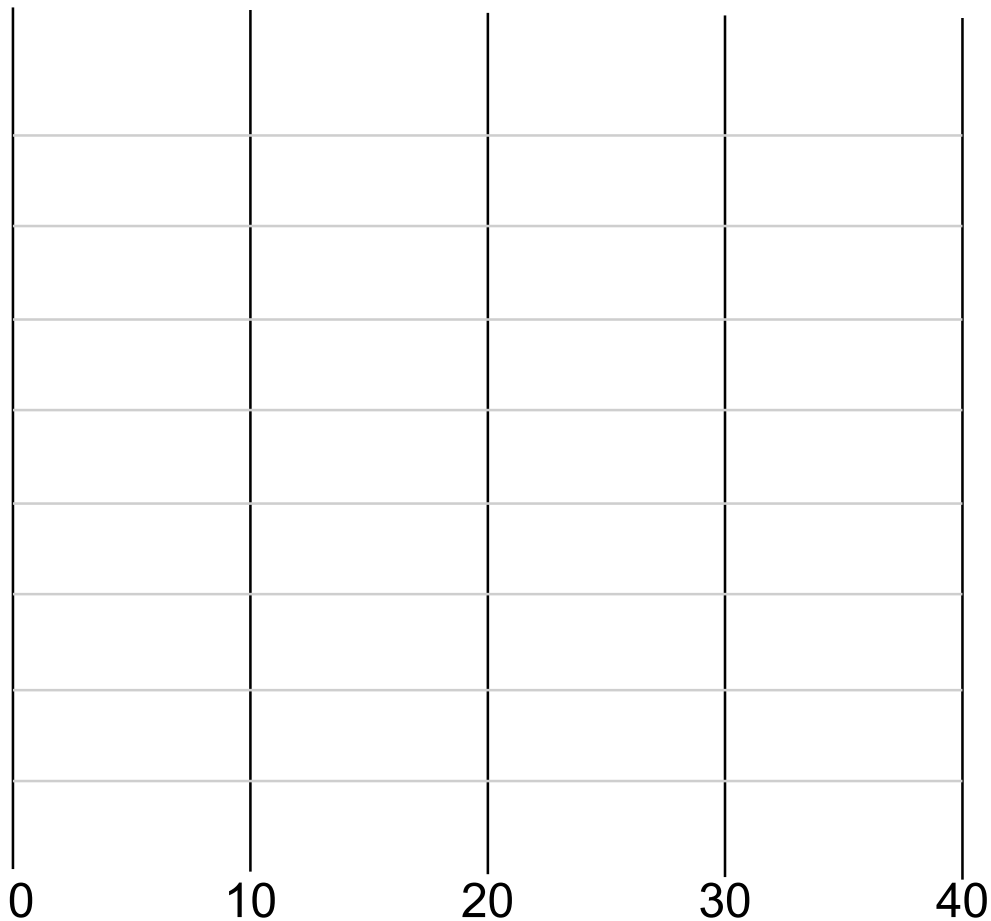
How do you measure pavement life?

- Time to 1st Rehab.
- Time to Reconstruction
- Time to Threshold IRI
- Time to Threshold PSI
- No. of Trucks
- No. Loads to 50% cracking



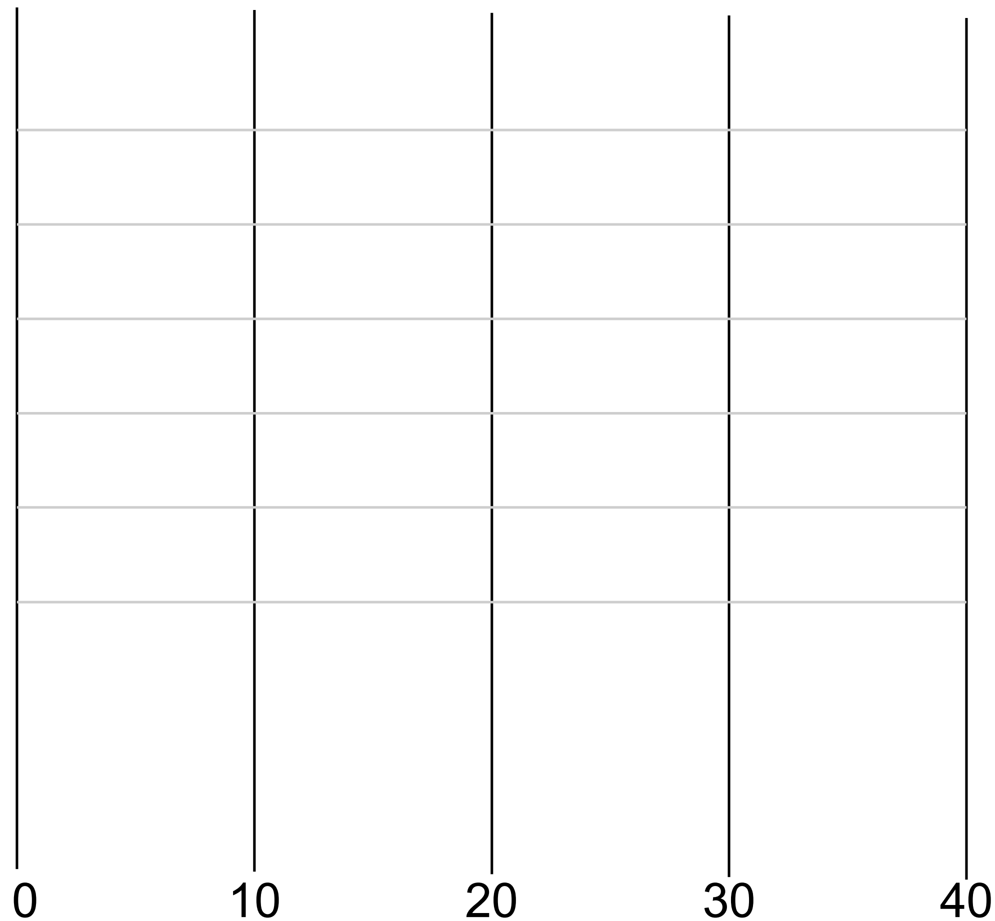
How much extra should we pay to get long pavement life?

- 0%
- 5%
- 10%
- 15%
- 20%
- 25%
- 30%
- 35% +



What is important to getting long pavement life?

- Roadbed or Grade
- Thickness Design
- Joint Design
- Concrete Materials
- Specifications
- Construction Quality



Long-Life Pavement Perspective…

What has to be done differently to meet your desires for longer pavement life, according to your requirements?

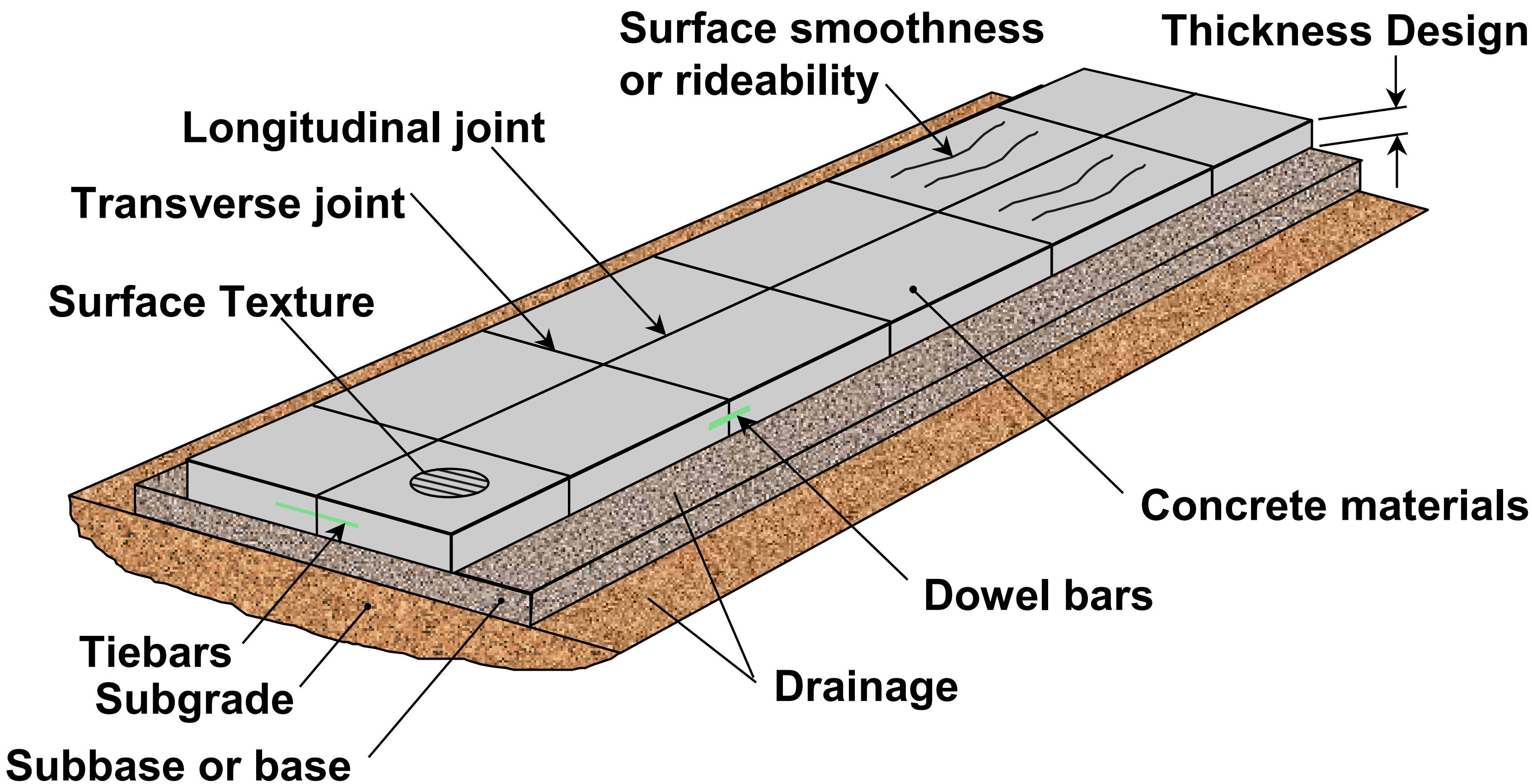
Where do you start?

- Design
- Materials
- Construction

- Performance
- Current Needs
- Future Expectations

NO SACRED COWS
Everything goes on the table…

Basic Elements of a Modern Concrete Pavement



Where to make biggest improvements?

- Concrete Durability
  - Paste
  - Aggregates
- Joints
  - Dimensions
  - Dowels
- Subgrade/Subbase
- Specifications
  - Process Control not Strength-Based

WHY NOT THICKNESS??????

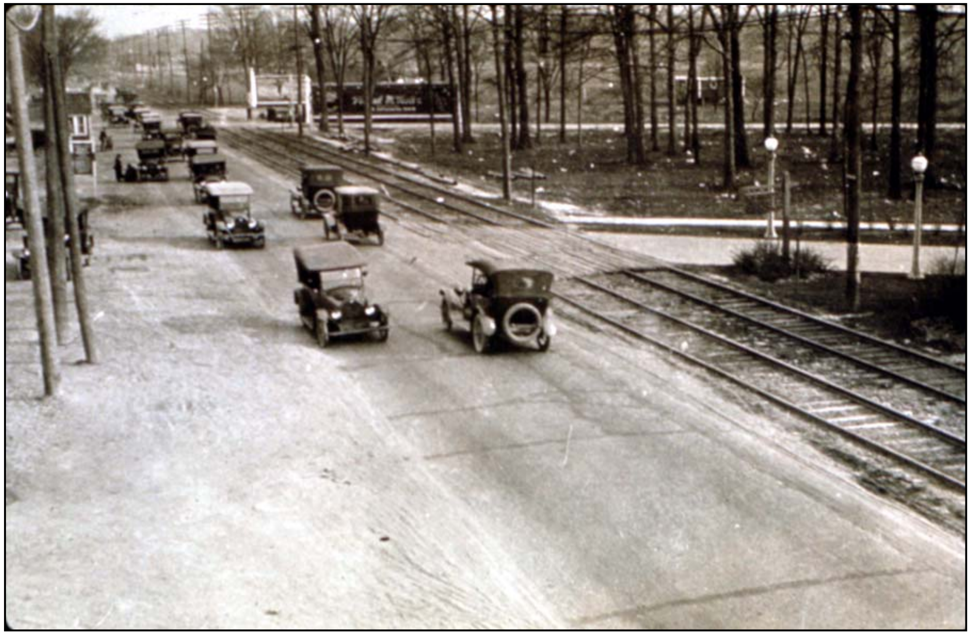
Long-Life Concrete Pavement

Aren't we really talking about High-Performance Concrete Pavement?

Early Highway Pavements

Front Street, Chicago

Built in 1905, Lasted 60 years



Woodward Ave, Detroit

Built in 1909,

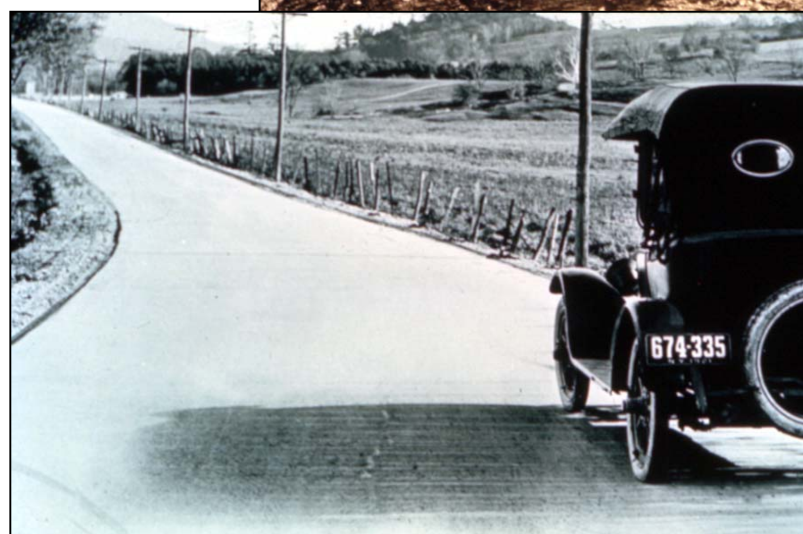
First mile of PCC

Early Highway Pavements (cont.)

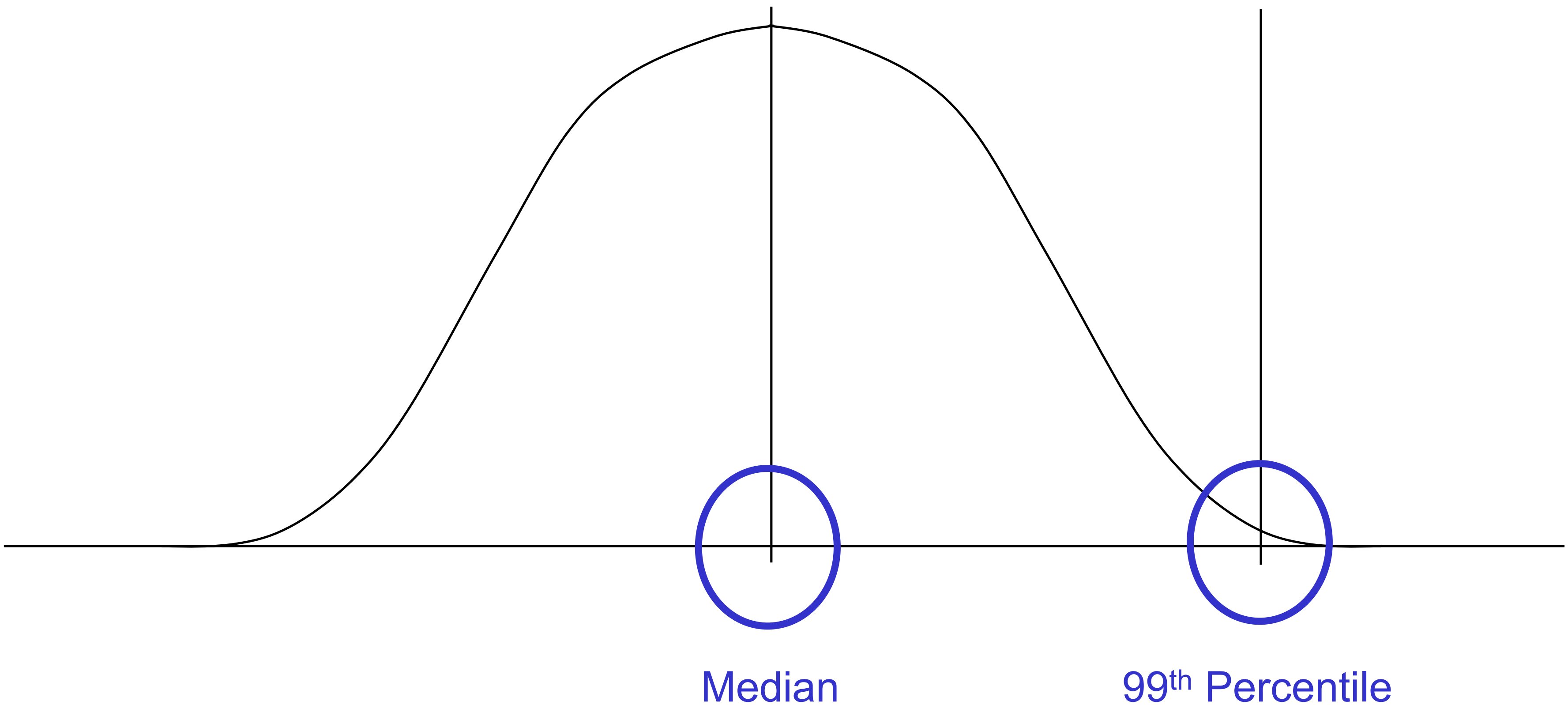
- Pine Bluff, Ark
  - Built in 1913
  - 24 miles long, 5" thick
  - Referred to as the "Dollarway"
  - Motorists would travel great distances to be able to drive up to 45 mph
  - It's preserved in a rest area along U.S. 6

The "First" Highway Bill

- In 1916 the Federal Highway Act was enacted
  - Lobbied by bicyclists organization "Wheelman of America"
- In 1916, there were 10,000 autos in the U.S.
- Some concrete roads built under the act are still in service



Average versus Outstanding



1956 Interstate Highway Act

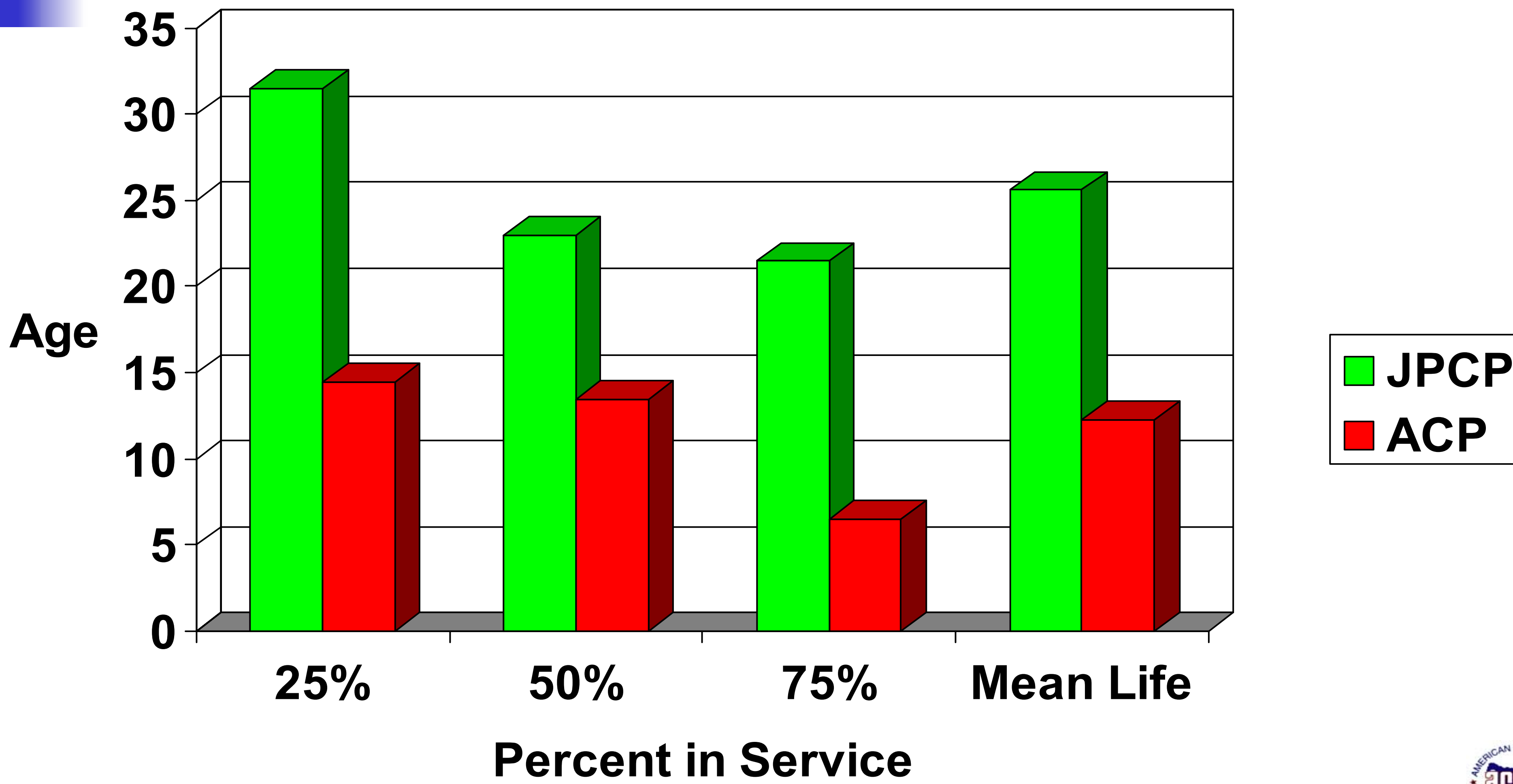
- A 41,000 mile interconnected network of limited access highways. The majority of interstate highways were constructed in the 1960's and 70's.
- Many concrete roads built under the act are still in service

Comparative Performance Studies Overview

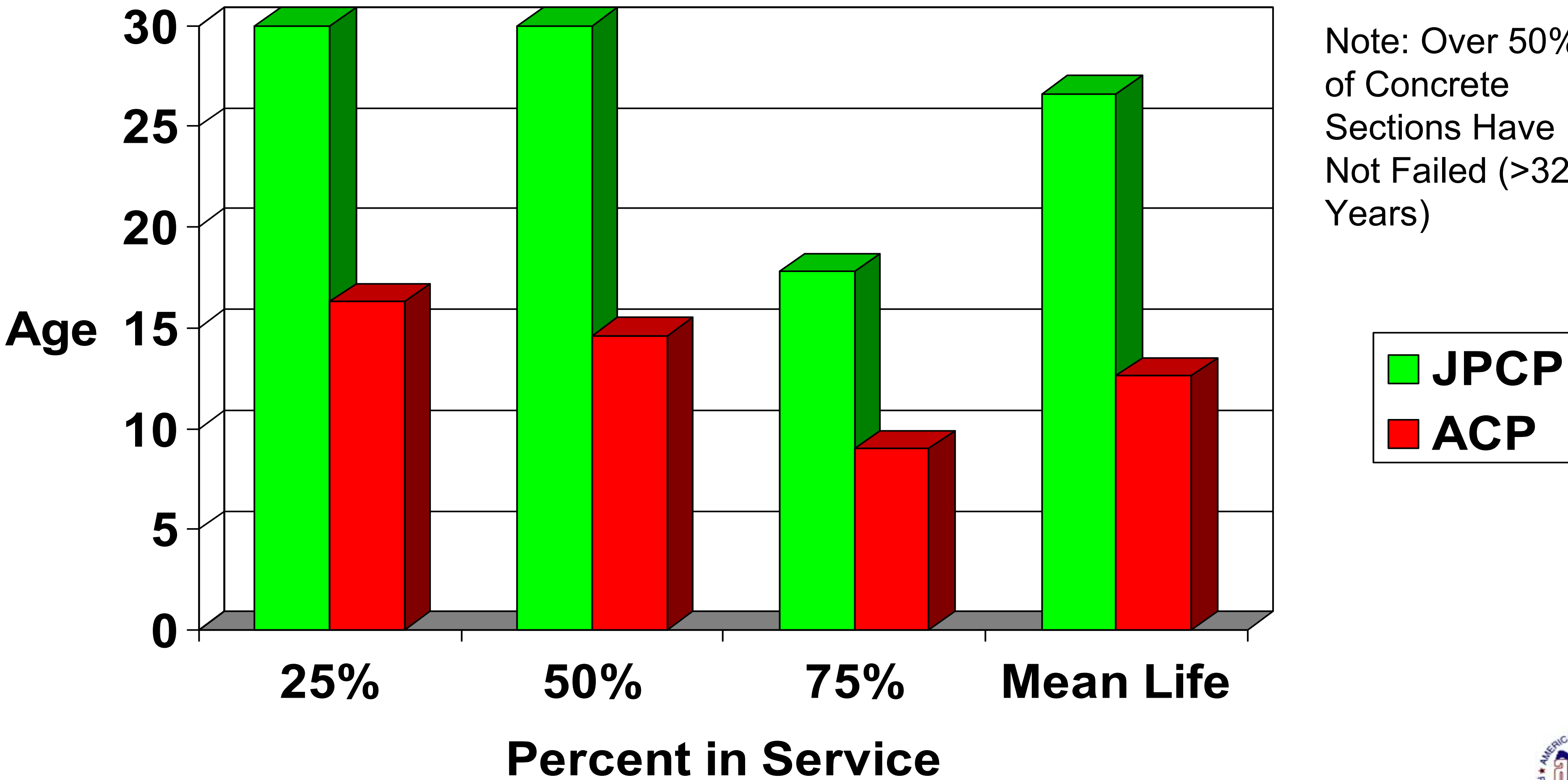
Selected highway corridors (interstate era):

- I-40 in Western Tennessee
- I-15 in Utah, South of Salt Lake City
- I-40 in Eastern Oklahoma

Survival Analysis Results - I-40 in TN

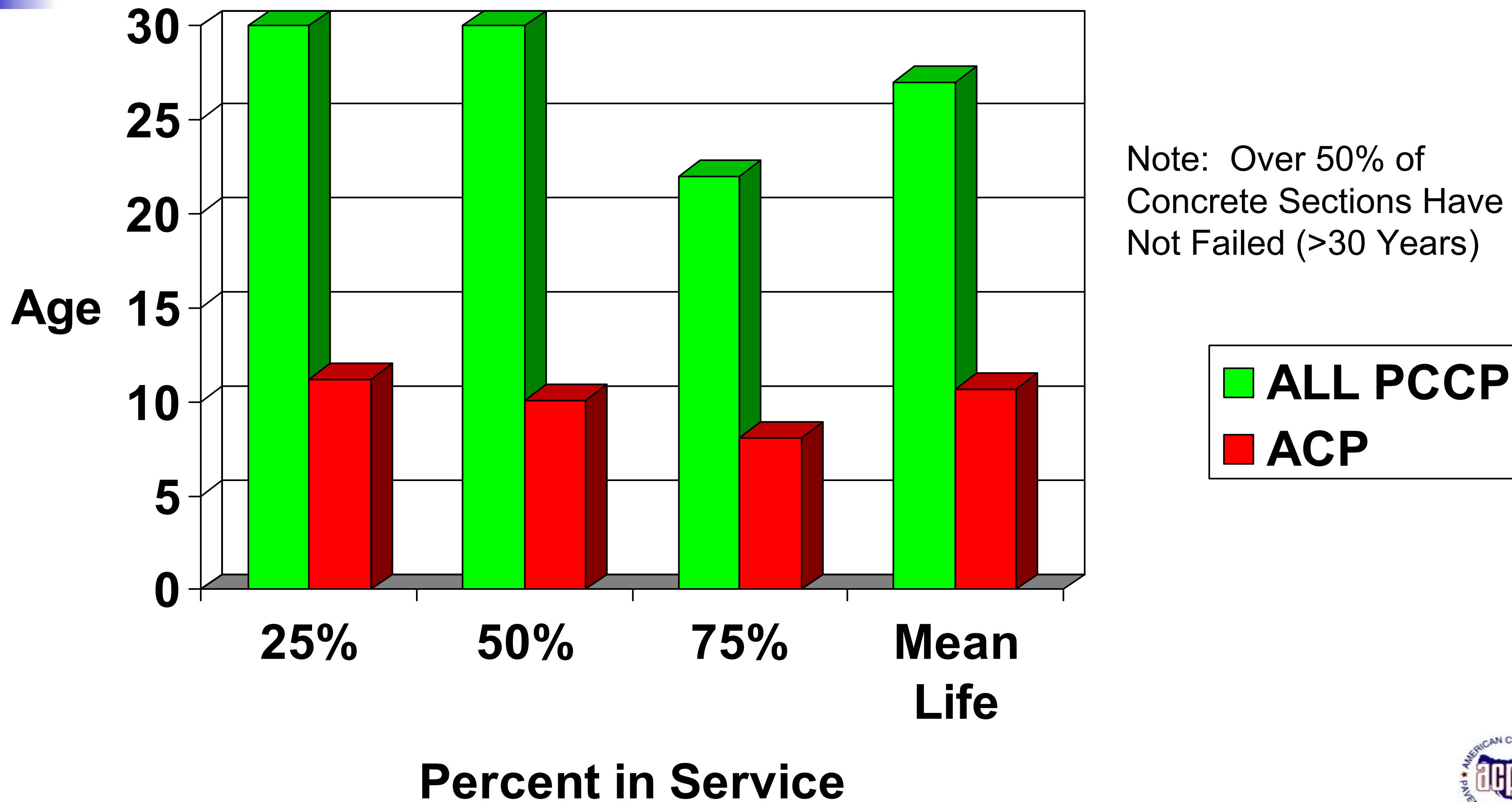


Survival Analysis Results - I-15 in UT



Note: Over 50% of Concrete Sections Have Not Failed (>32 Years)

Survival Analysis Results - I-40 in OK



Note: Over 50% of Concrete Sections Have Not Failed (>30 Years)

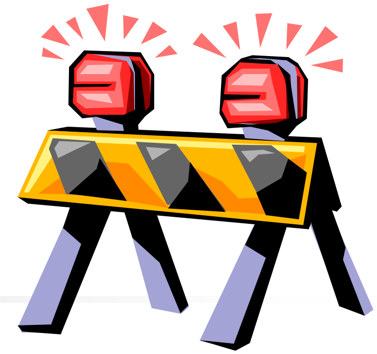
Long-Life Concrete Pavements

- Do not necessarily require elements of high-performance concrete pavement (HPCP)
- Would benefit from from HPCP techniques
  - Narrow the variability of performance
  - Address key elements
- May include improvements HPCP cases have not considered

High-Performance Concrete Pavement

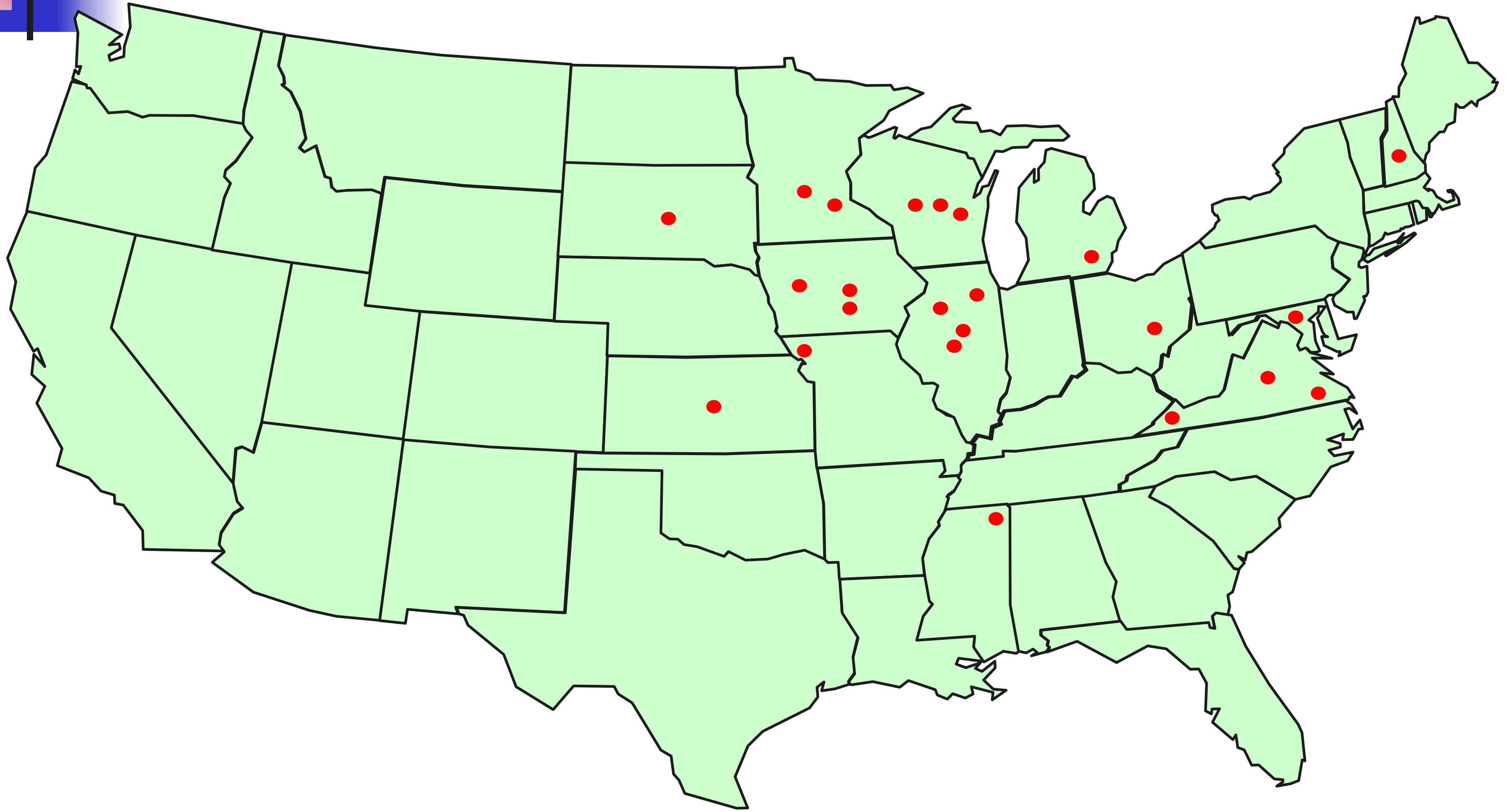
- Goal of HPCP Program per FHWA
  - Explore applicability of design and construction innovations to provide long-lasting, economical PCC pavements
- HPCP program is not "high strength" concrete
- HPCP is the combination of: materials, mix design, structural design, and construction activities…
  - to ensure long-term pavement performance in a specific application

HPCP Projects



- Twenty three (23) projects in 13 States
- Range of design features and construction innovations
  - Alternate Dowel Bars
  - Durable Concrete Mixes
  - Improved Materials (including fiber-reinforced PCC)
  - Optimized Surface Textures
  - Joint Sealing Variations

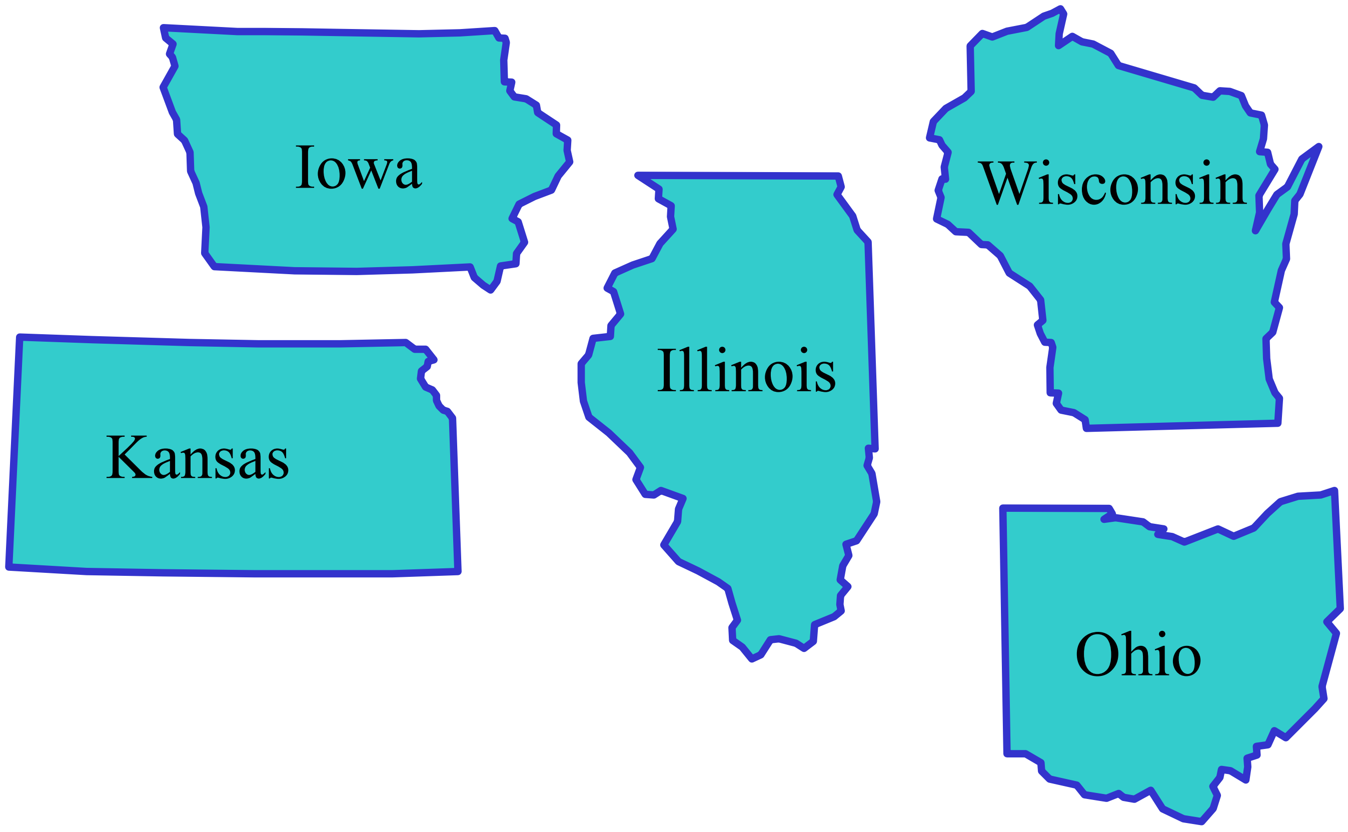
HPCP Project Locations



Long-Life Pavements

Joint Design Improvements

Alternate Dowel Bars

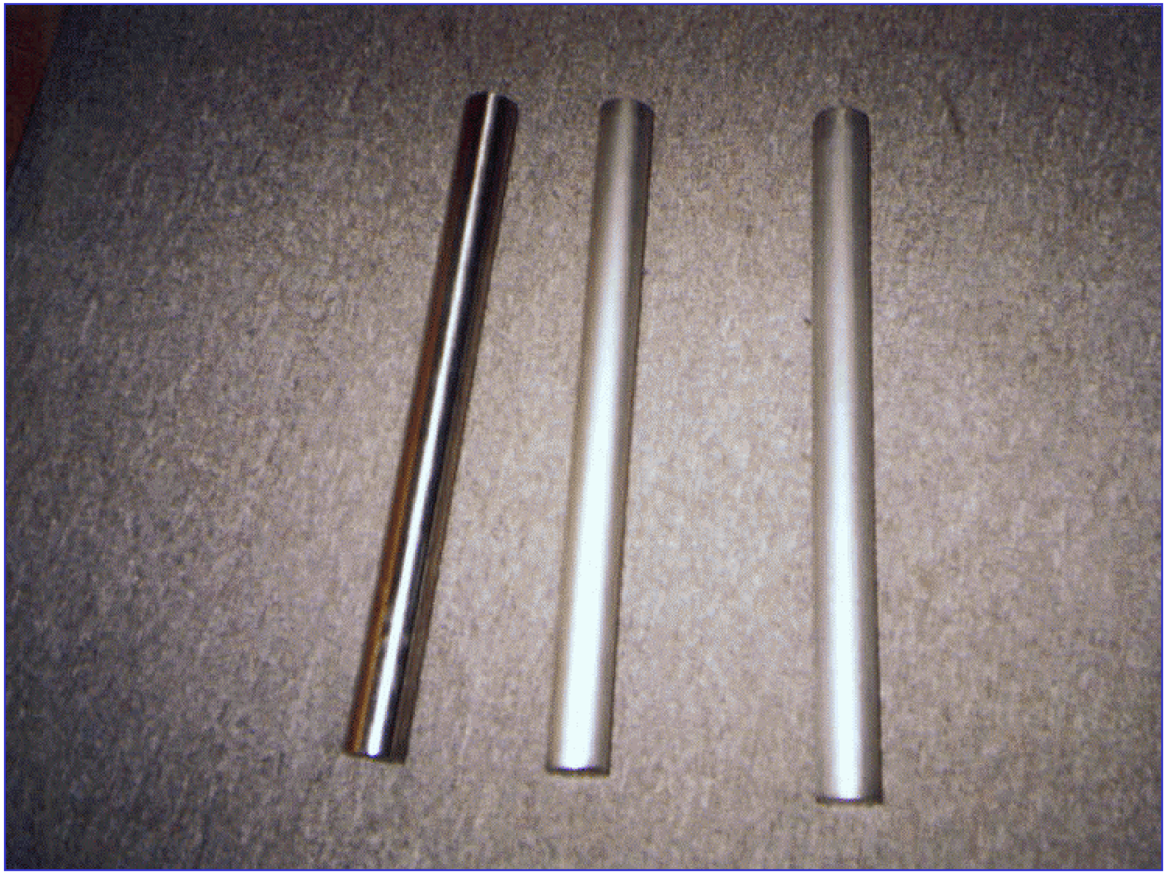


Dowel Bar Corrosion

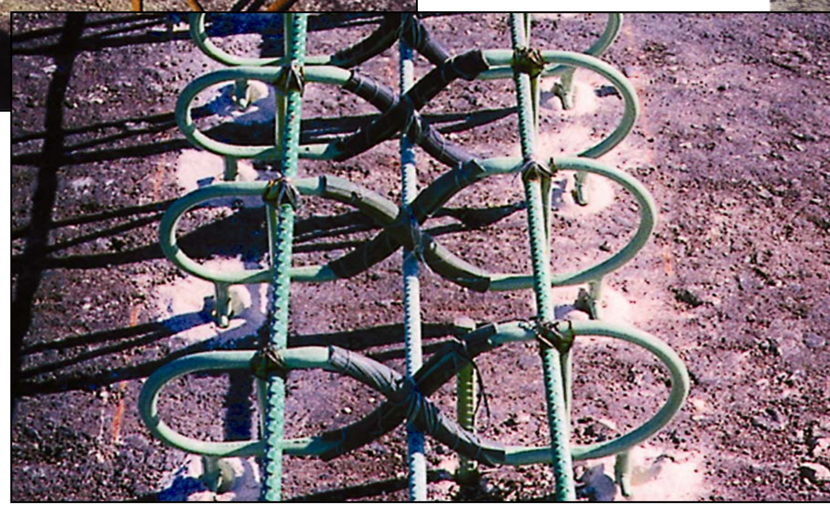
Alternate Dowel Bars

- Materials
  - Fiber-Reinforced Composite (FRC)
  - Grout-filled FRC
  - Stainless Steel
  - Stainless Steel Clad
  - Grout-filled Stainless Steel tubes
  - MMFX Steel
- Elliptical Shapes

Alternate Dowel Bars



Alternate Dowel Bars



Long-Life Pavements

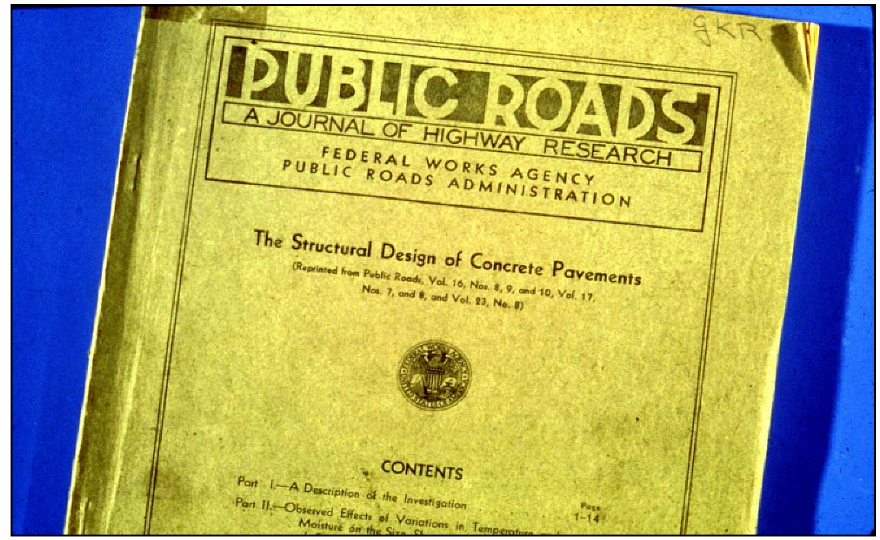
Thickness Design?

Empirical Design

- Early pavement design methods were empirical and based on the results of various road tests
  - Bates Road Test
  - Maryland Road Test
  - AASHO Road Test
  - Others

First Design Equations

- In 1926, Prof. Westergaard, University of Illinois published equations for stresses and deflections of concrete pavement
- To test Westergaard's equation, the Bureau of Public Roads (forerunner of FHWA) conducted four years of testing and published a very complete report on the "Structural Design of Concrete Pavements".



$$d = \sqrt{\frac{cp}{s}}$$

d = thickness
c = stress coefficient
p = wheel load
s = allowable tensile stress

AASHO Road Test - Extended Design Equation

- Developed mechanistic-empirical relationship between Log W and stress ratio.

$$\text{Log}(W) = A + B \,\text{Log}\, \frac{S'c}{\sigma}$$

W = Number of axle loads to terminal serviceability
(from main loop equation)
A = Regression constant
B = Slope of Log W vs. Log S'c/σ curve
S'c = 28-day flexural strength, 3rd point loading
σ = Spangler's corner stress

1986-93 Rigid Pavement Design Equation

$$\log(ESALs) = Z_R * s_o + 7.35 * \log(D+1) - 0.06 + \left[\frac{\log\left[\frac{\Delta PSI}{4.5 - 1.5}\right]}{1 + \frac{1.624 * 10^{7}}{(D+1)^{8.46}}} \right] + (4.22 - 0.32 p_t) * \log \left[\frac{S'_c * C_d * \left[D^{0.75} - 1.132\right]}{215.63 * J * \left[D^{0.75} - \frac{18.42}{(E_c / k)^{0.25}}\right]} \right]$$

Standard Normal Deviate

Overall Standard Deviation

Depth

Change in Serviceability

Terminal Serviceability

Modulus of Rupture

Drainage Coefficient

Load Transfer

Modulus of Elasticity

Modulus of Subgrade Reaction

Current AASHTO vs. 2002 Design

Thickness Design Impact?

- Mechanistic-empirical design
  - Offers a more scientific and potentially "reasonable" approach
- To implement AASHTO 2002 successfully
  - Must calibrate
  - Must develop realistic inputs
  - Must have working knowledge of mechanistic-empirical design fundamentals
- But… do not expect large changes in required thicknesses
  - Could even go down for long-life timeframes

Long-Life Pavements

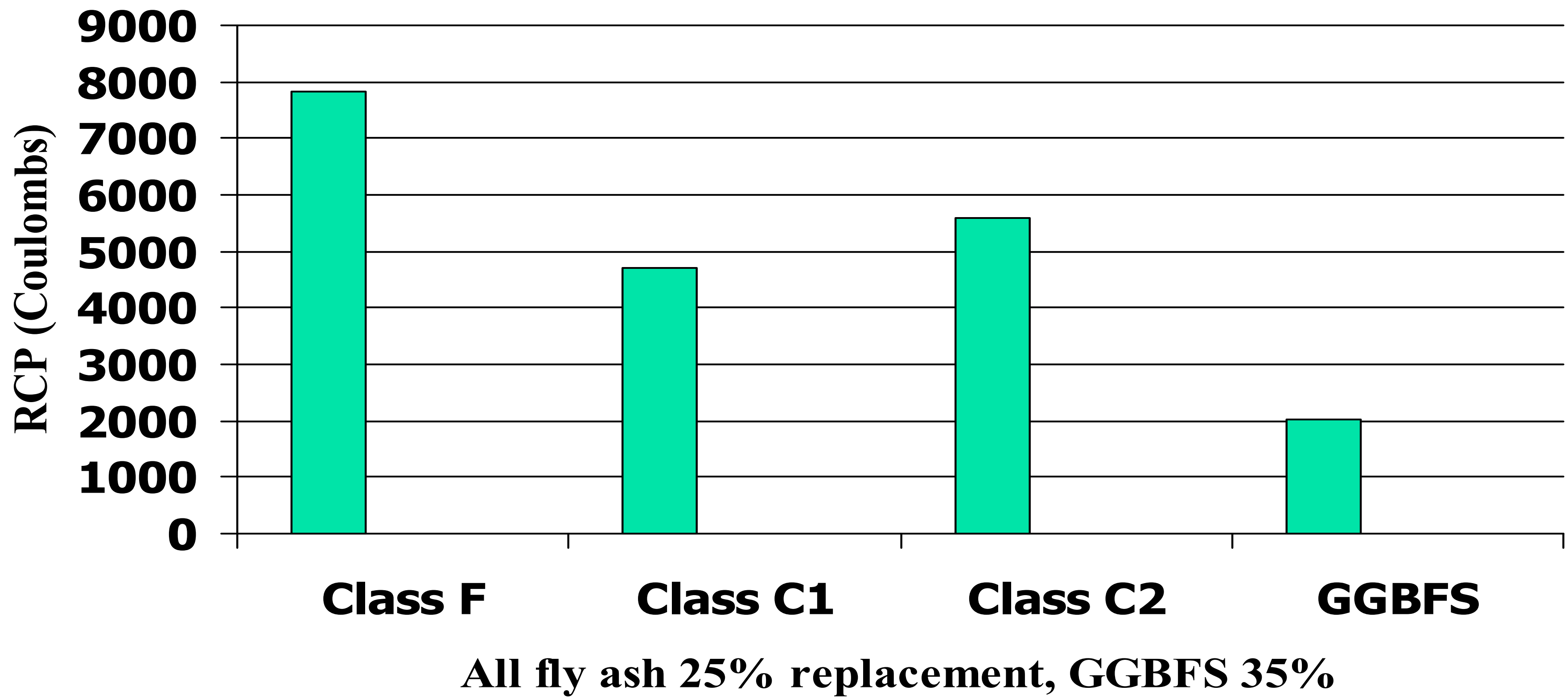
Concrete Materials

Paste Durability – Minnesota Case

- Required Maximum 28 day Rapid Chloride Permeability to be 2500 coulombs
- Increased Target Plastic Air Content from 6.5% to 8.5% ($\pm$ 1.5%)
- Require max W/C = 0.40 (same as current)
- Use Poly-alpha-methylstyrene curing compound

Rapid Chloride Permeability Results of HPC Mixes

(w/c = 0.365, sample @ 28 days)



Aggregate Durability – Minnesota Case

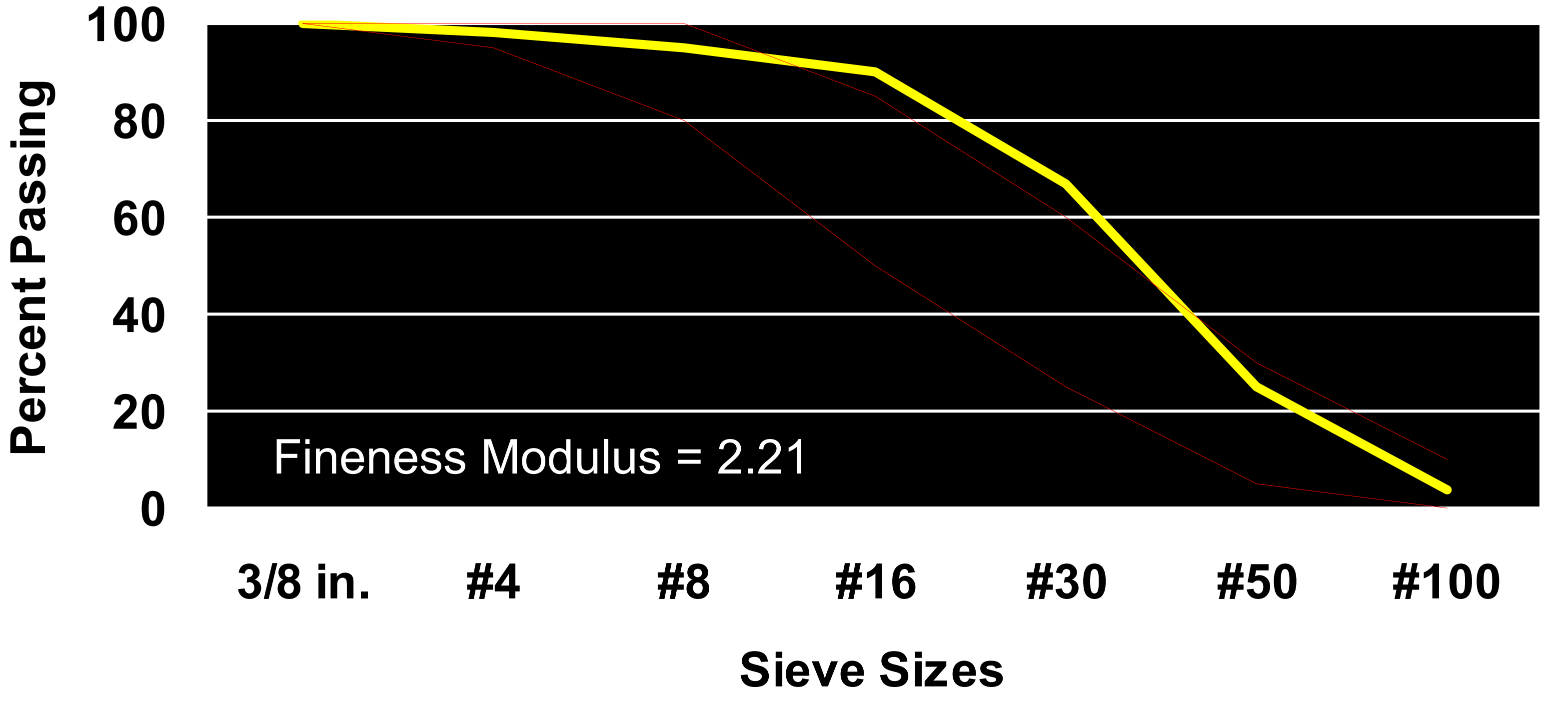
- Maximum of 20% limestone in gravel, with incentives to reduce to 10%
- Incentives to use Class A aggregate (quarried igneous, metamorphic)
- Well graded aggregate required
  - reduce paste, improve workability
  - 8 to 18 specification.

Aggregate Selection

- Watch for Water Demand
  - Fine aggregate gradation
  - Combined aggregate gradation
  - Cement content (+400 lb)
  - Supplementary Materials

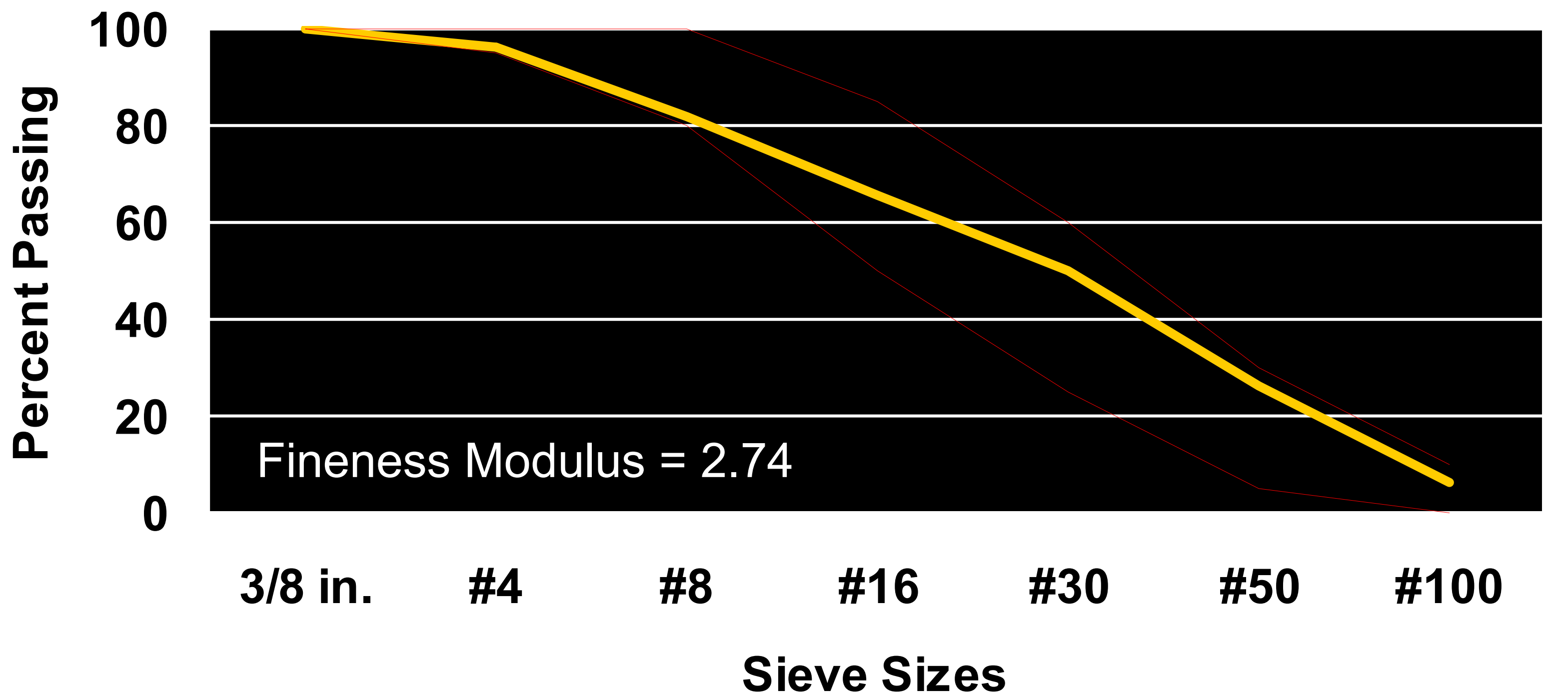
ASTM C33 requirements are not always favorable

ASTM C33 ?



Grading distribution of sand allowed by some states, but does not meet ASTM C-33 limits --- Results in a mixture prone to early problems

ASTM C33 ?

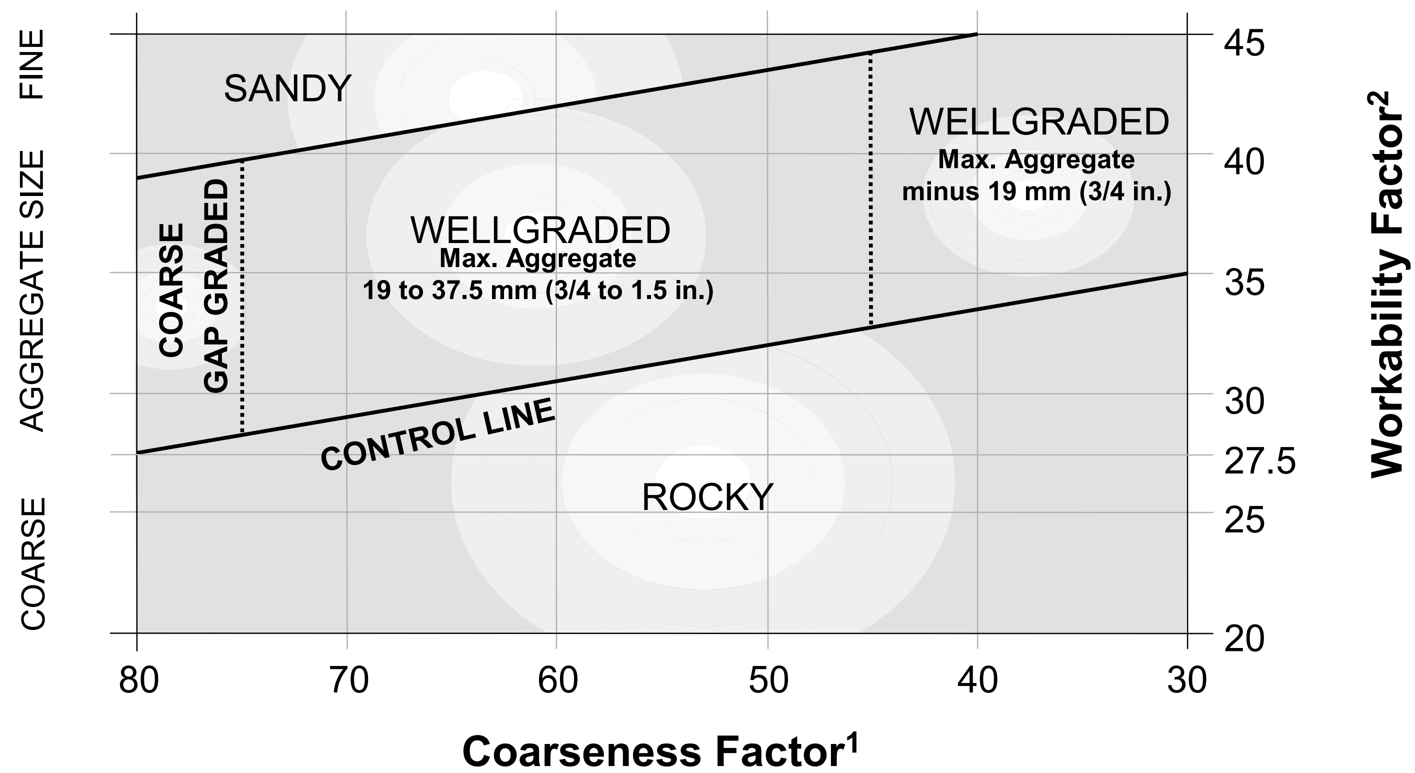


Grading distribution of sand with high bulking volume that meets ASTM C-33 --- Results in a mixture prone to early problems

ASTM C33 ?

Grading distribution of well-graded sand that meets ASTM C-33 --- Results in mixture with little potential to contribute problems

Combined Gradation



1. Coarseness Factor = $\frac{\text{\% RETAINED ABOVE 3/8 in. (9.5 mm) SIEVE}}{\text{\% RETAINED ABOVE \#8 (2.36 mm) SIEVE}}$ X 100

2. Workability Factor = % PASSING #8 (2.36 mm) SIEVE

Long-Life Pavements

Kansas Demo Project

HPCP – Kansas Demo Project

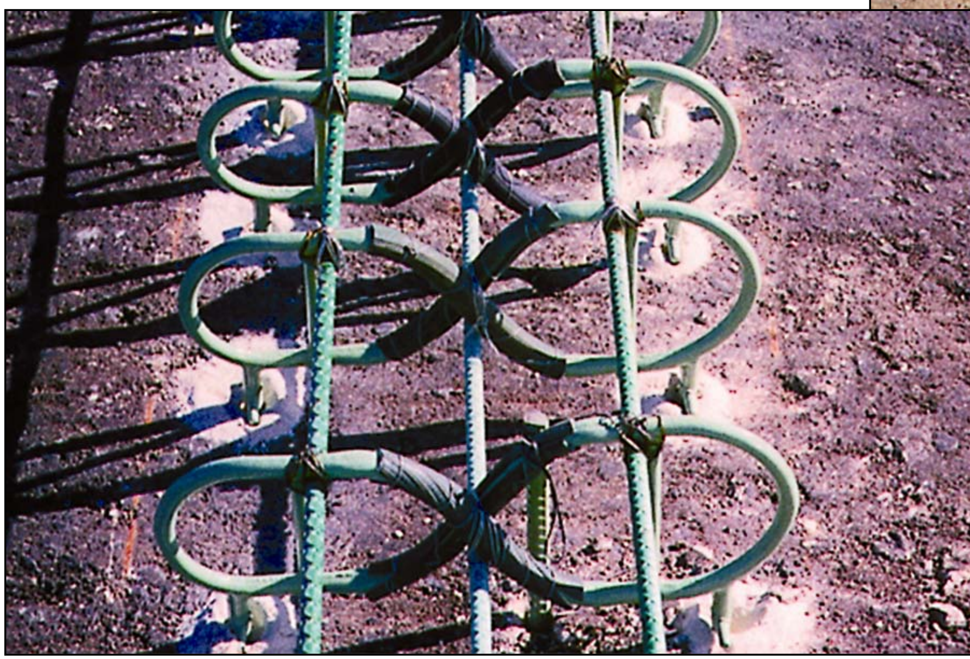
- Alternative Dowel Materials and spacing,
  - Fiber reinforced and stainless steel dowel bars, Cross Flex
- New mix designs
  - Ground Granulated Blast Furnace Slag (GGBSF)
  - Recycled asphalt
- Joint sawing and sealing options
- Longitudinal Tining
- Curing
- Two lift construction

Kansas HPCP Demonstration

Fiber Reinforced Polymer Dowels

Kansas HPCP Demonstration

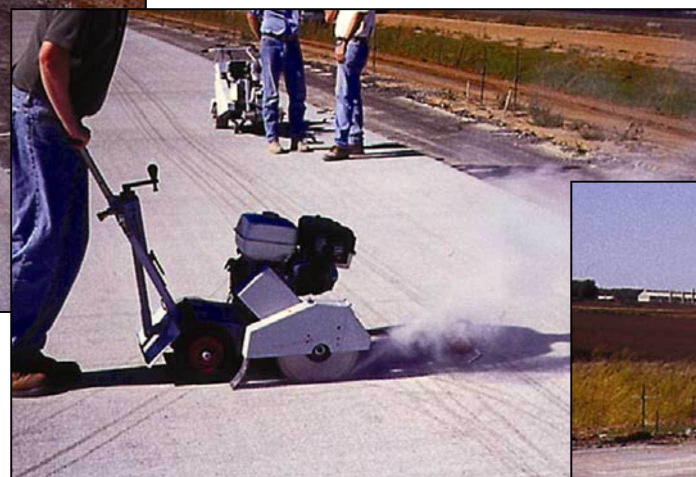
Cross-Flex



Not a Good Idea

Kansas HPCP Demonstration

Soft-cut

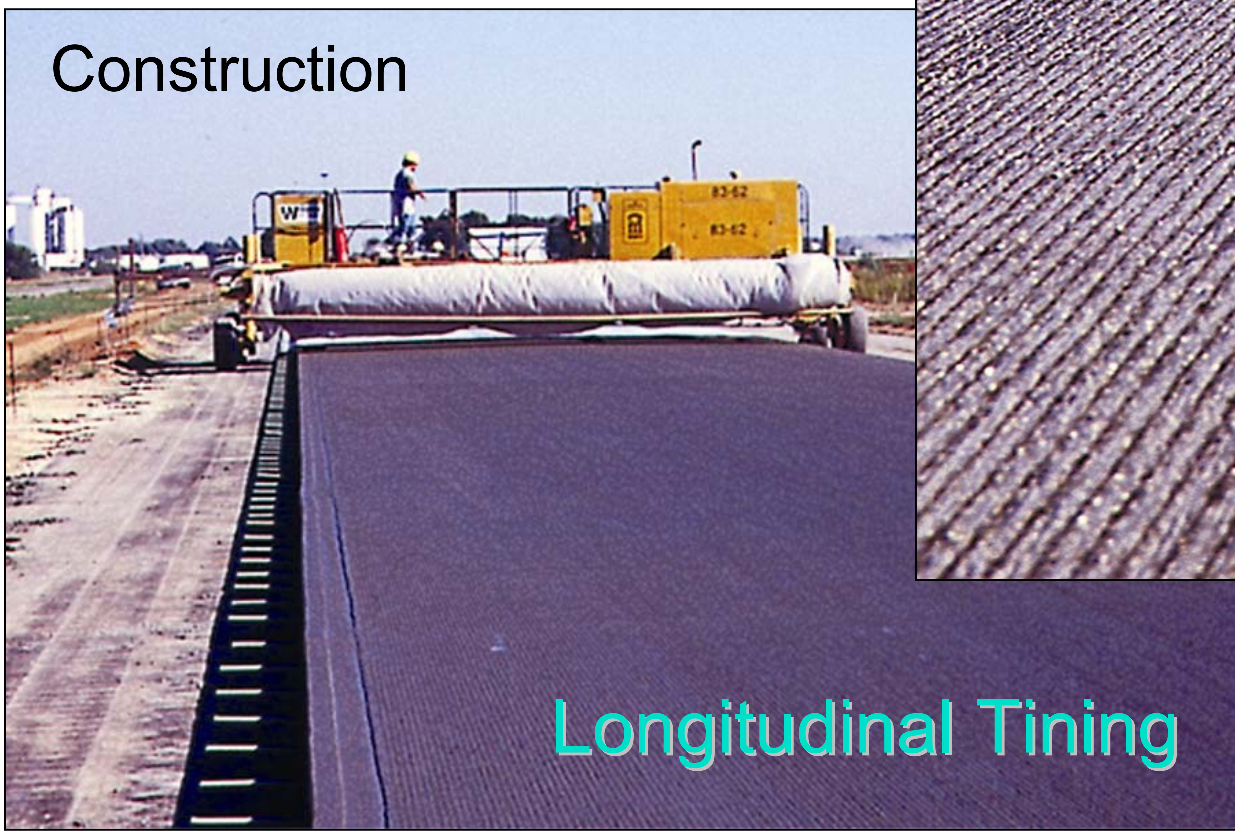


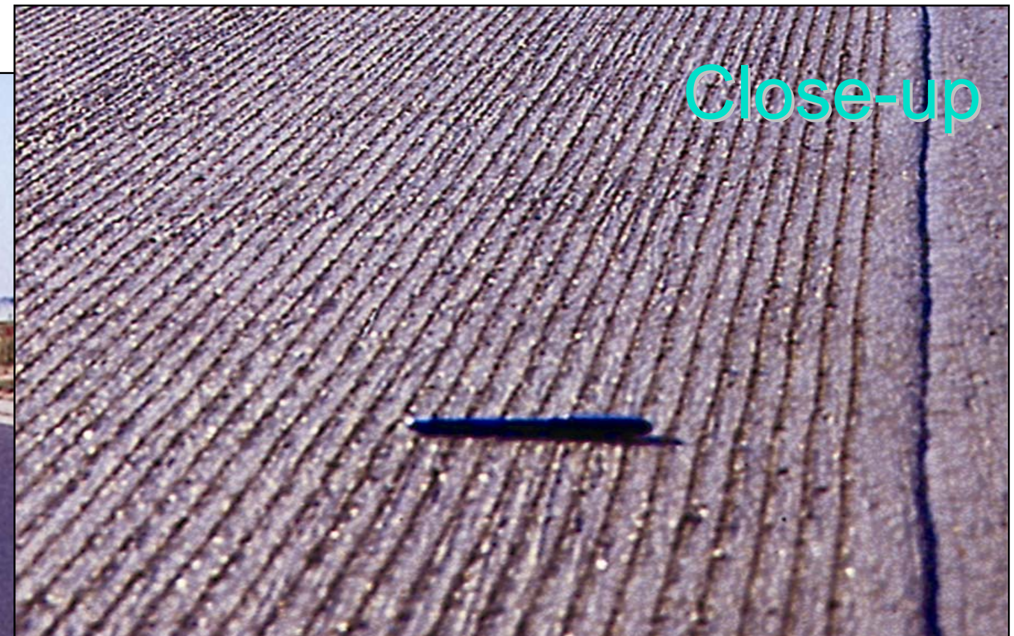
Magnum

Target

Other sections were
Seal / No Seal

Kansas HPCP Demonstration





Kansas HPCP Demonstration

Fiber Reinforced Concrete

3M Polyolefin Fibers

Kansas HPCP Demonstration

Two lift construction

With RAP

Kansas HPCP Demonstration

Two lift construction

With High Absorption Limestone

How long will Kansas HPCP last?

- Looking for 30-50 years.
- Pavement life is measured in terms of vehicle loading as well as time.
  - If subjected to a higher (or heavier) traffic than designed for, the service life will probably be shorter than expected.

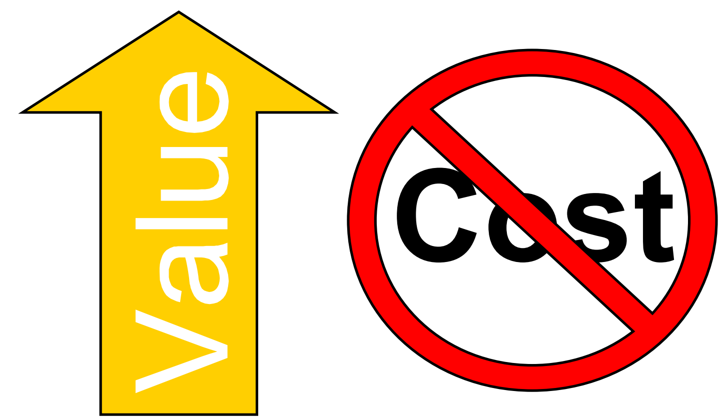
Summary

- Long-life has different meanings
- Getting there requires improving design, materials and construction
- Lessons from HPCP work are of value
- Concrete is the long-life pavement

Industry Perspective

Make the Goal of Long-Life Pavement:

- Structurally superior pavement
- Environmentally sound pavement
- Safer and quieter pavement
- Smoother pavement
- Cost-optimized pavement



Additional Information

- Contact ACPA
- Phone: 847-966-2272
- www.pavement.com

THANK YOU!