

# Paving the Way for the World's Roadways

Arizona Pavements/Material Conference

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# Outline

- **Introduction**
- Background
- Asphalt Pavement Technology Changes
- Present Status and the Future







# Technologies



- Artificial Intelligence
- Image Recognition
- Connectivity
- Autonomous Systems
- Big Data
- Electrification
- Complex Data Analytics
- Virtual Reality
- Blockchain Technology
- Advanced Materials
- Cybersecurity



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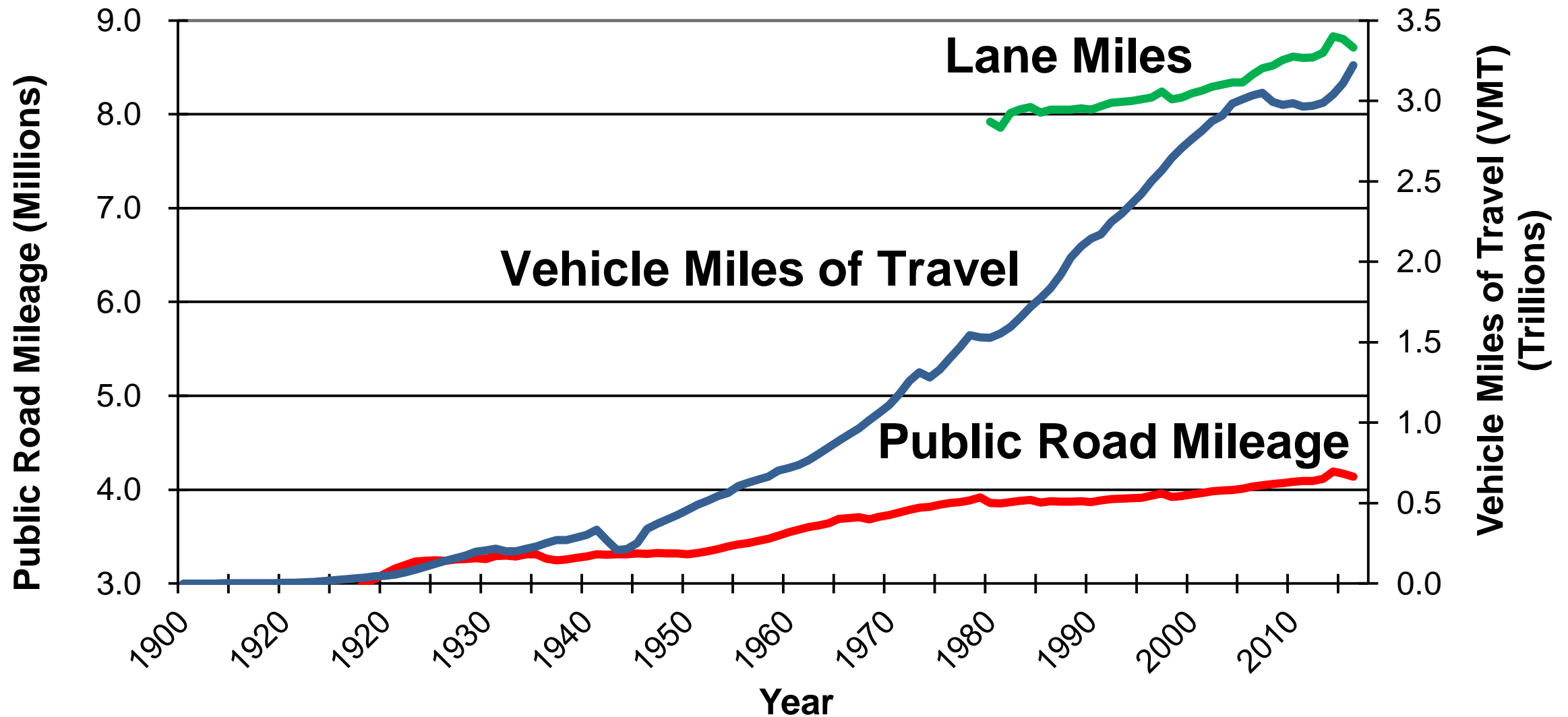
# U. S. Roadways



- 4.1 Million Miles
- 2.7 Million Miles Paved Surfaces
- 2.5 Million Miles Paved with Asphalt



# Public Road Mileage - VMT – Lane Miles 1900 - 2016





# Annual Highway Expenditures – U. S.

- \$235 Billion
- \$158 Billion - Manage, Plan, Design, Construct, Maintain
- \$ 50 Billion for Pavement Design, Construction, Rehabilitation, and Maintenance





# Annual Hot Mix Asphalt Pavement Expenditures



- 350 – 500 Million Tons Annually
- \$70 per Ton
- \$30 Billion for Hot Mix Asphalt



# Technology Improvement Impacts



■ \$2.5 Billion Annually  
(Extend Life for One Year)

■ \$2.0 Billion Annually  
(Recycling-first Cost)

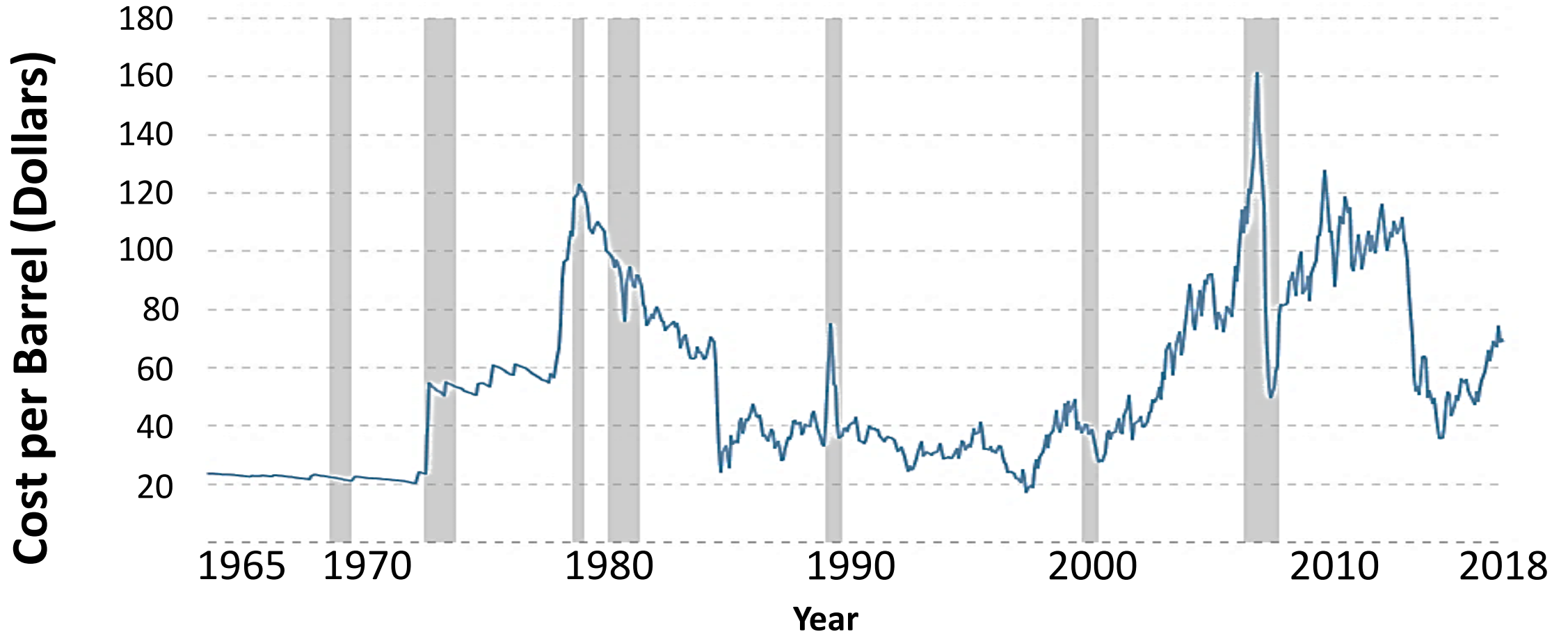




# Historical Perspective

Concerns	1970's	2000's
Price of Asphalt Binder	X	X
Availability of Asphalt Binder	X	X
Environmental Concerns	X	X
Energy Concerns	X	X
Global Warming		X
Limited Funds Available	X	X
Inflation	X	?

# Historical Crude Oil Prices Adjusted for Inflation



\*Macrotrends



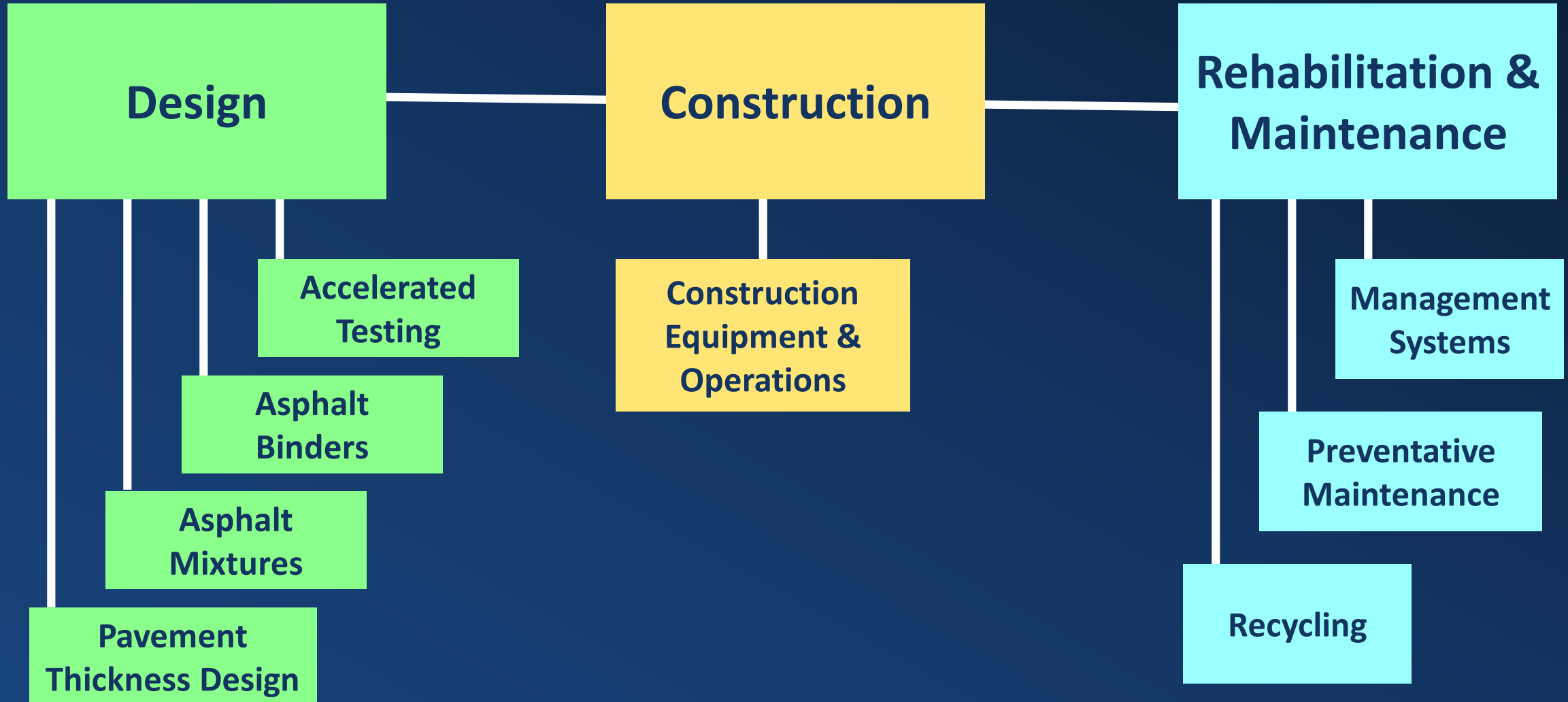


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- Background
- **Asphalt  
Pavement  
Technology  
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# Asphalt Technology Changes





# Technology Changes

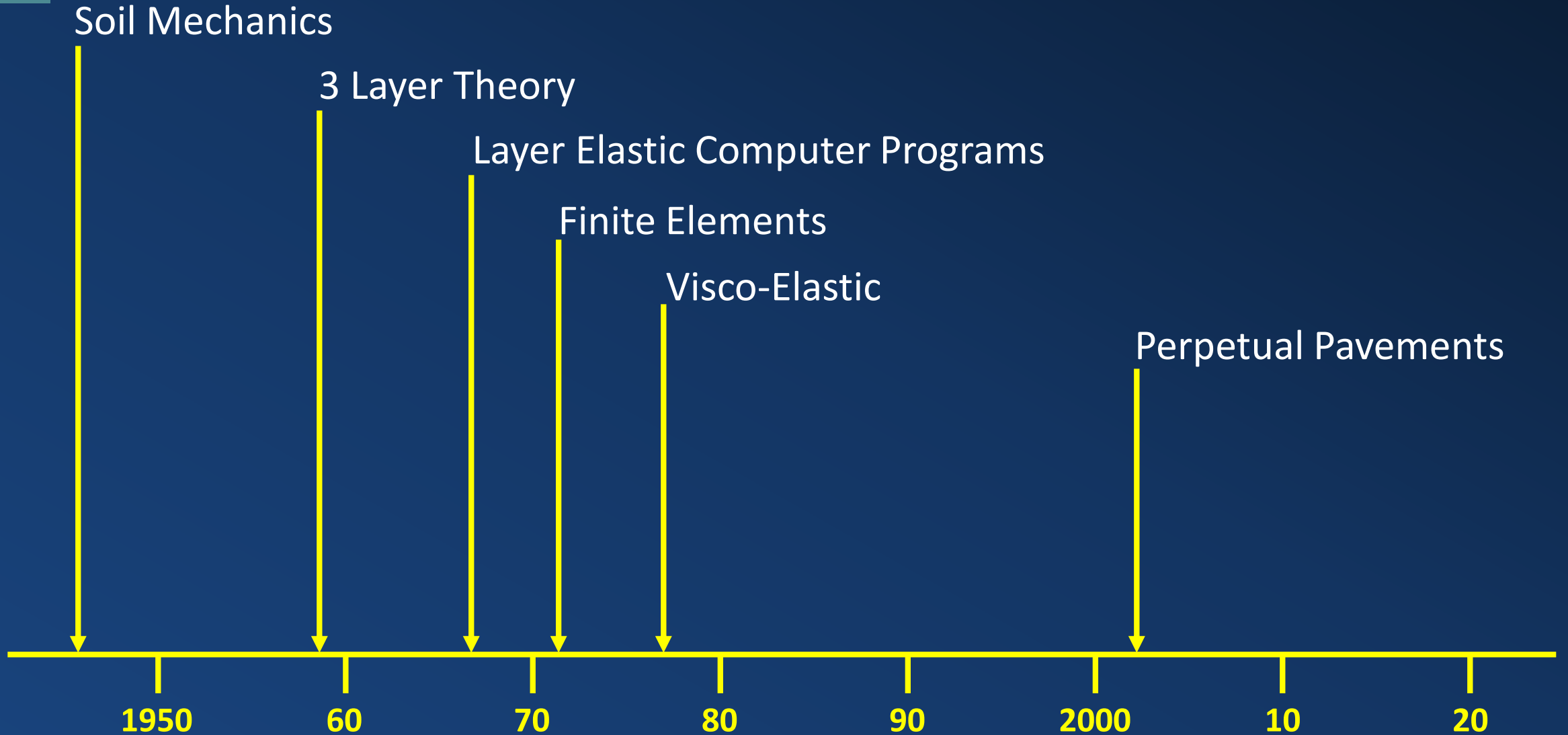
- **Pavement Thickness Design**
- Asphalt Binders
- Asphalt Mixtures
- Recycling
- Preventive Maintenance
- Management Systems
- Accelerated Testing
- Construction Equipment and Operations
- Strategic Highway Research Program



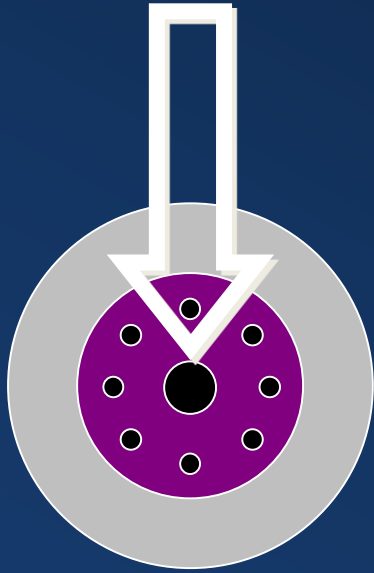
International Conference on the  
Structural Design of Asphalt  
Pavements



# Pavement Thickness Design







Horizontal Tensile Strain

HMA

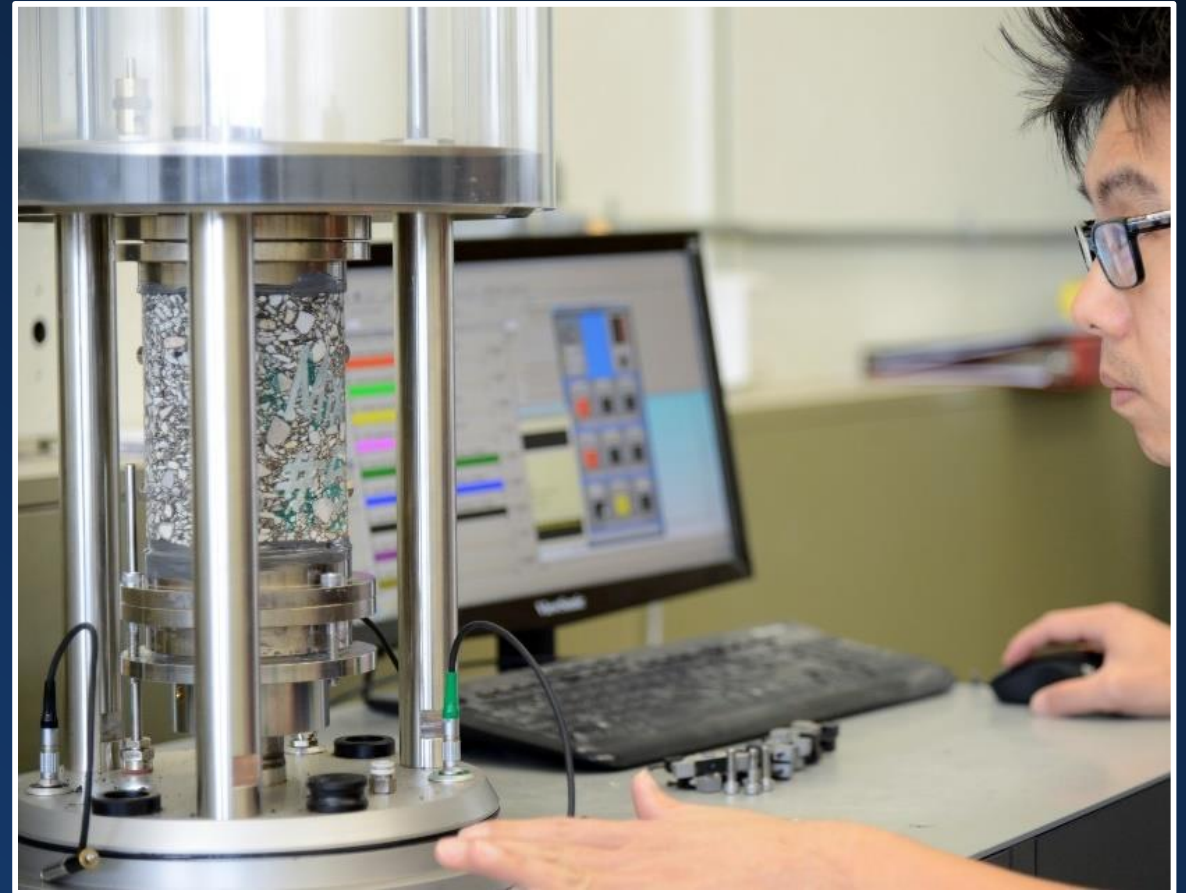


Vertical Compressive  
Stress and Strain

Base-course



Subgrade-soil



Thickness of Material

# Technology Changes

- Pavement Thickness Design
- **Asphalt Binders**
- Asphalt Mixtures
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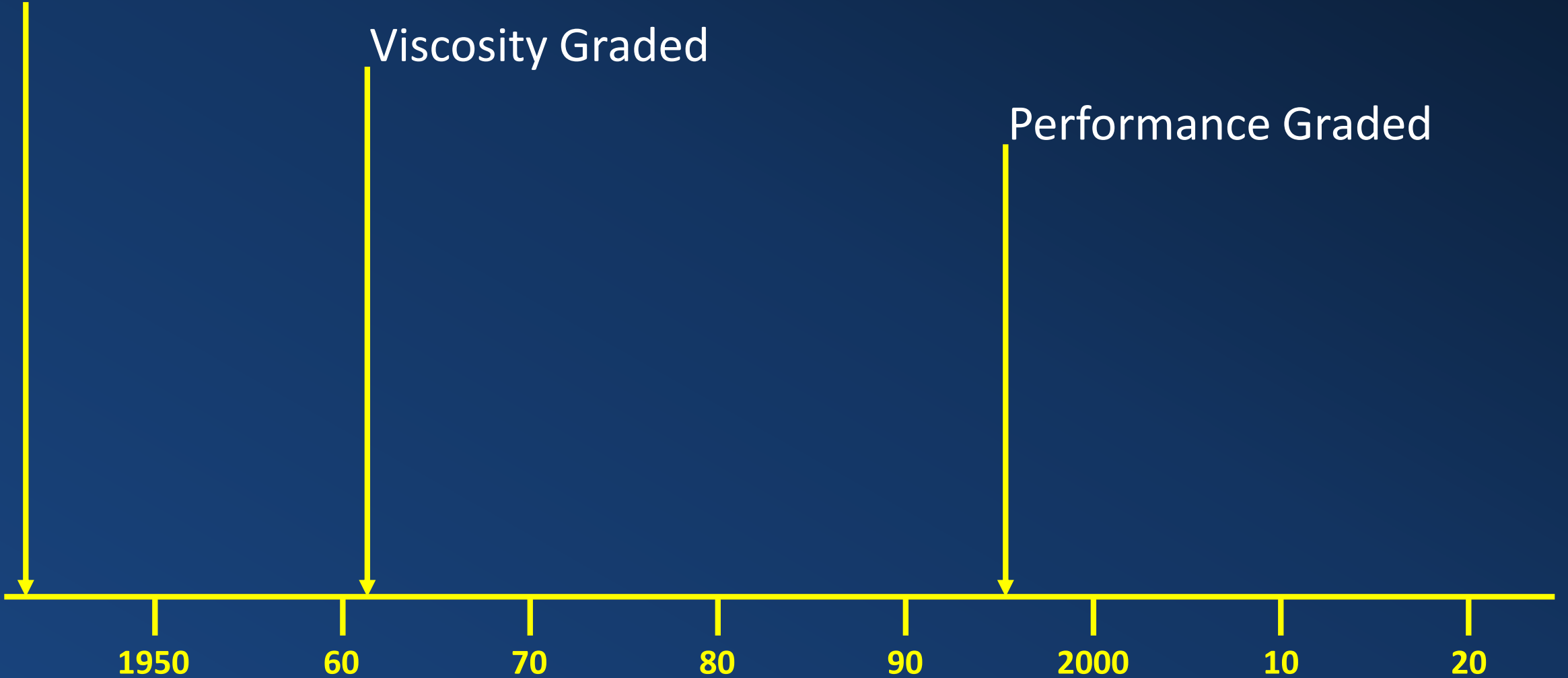
# Asphalt Binders



Penetration Graded

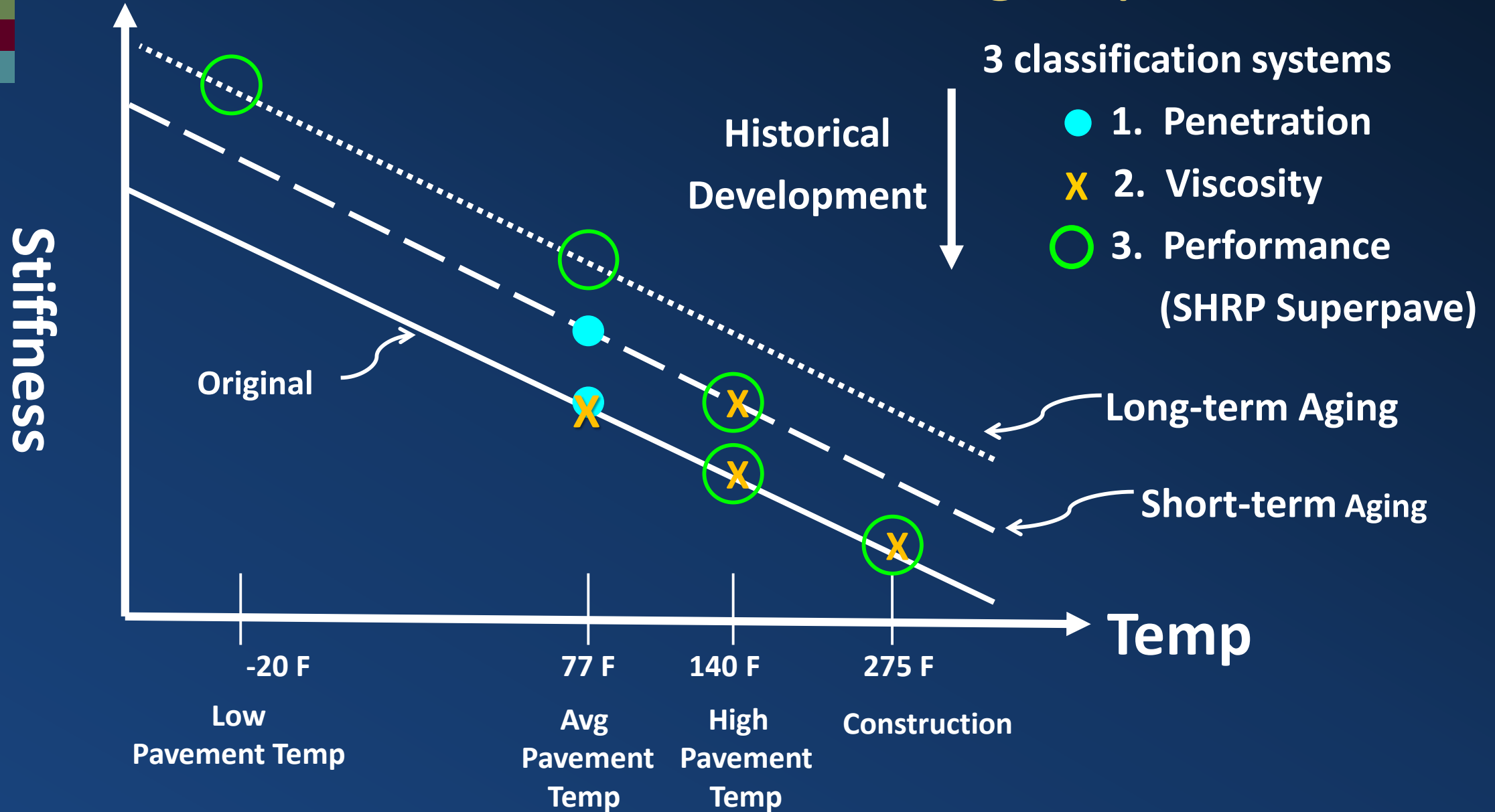
Viscosity Graded

Performance Graded





# Classification of Paving Asphalts





# Asphalt Binders

- Refining and Production Practices
  - Straight Run
  - Blending
- Additives/Modifiers
  - Polymers
  - Crumb Rubber
  - Warm Mix Asphalt
  - Recycling Agents
  - REOB
  - PPA
  - Other



# Technology Changes

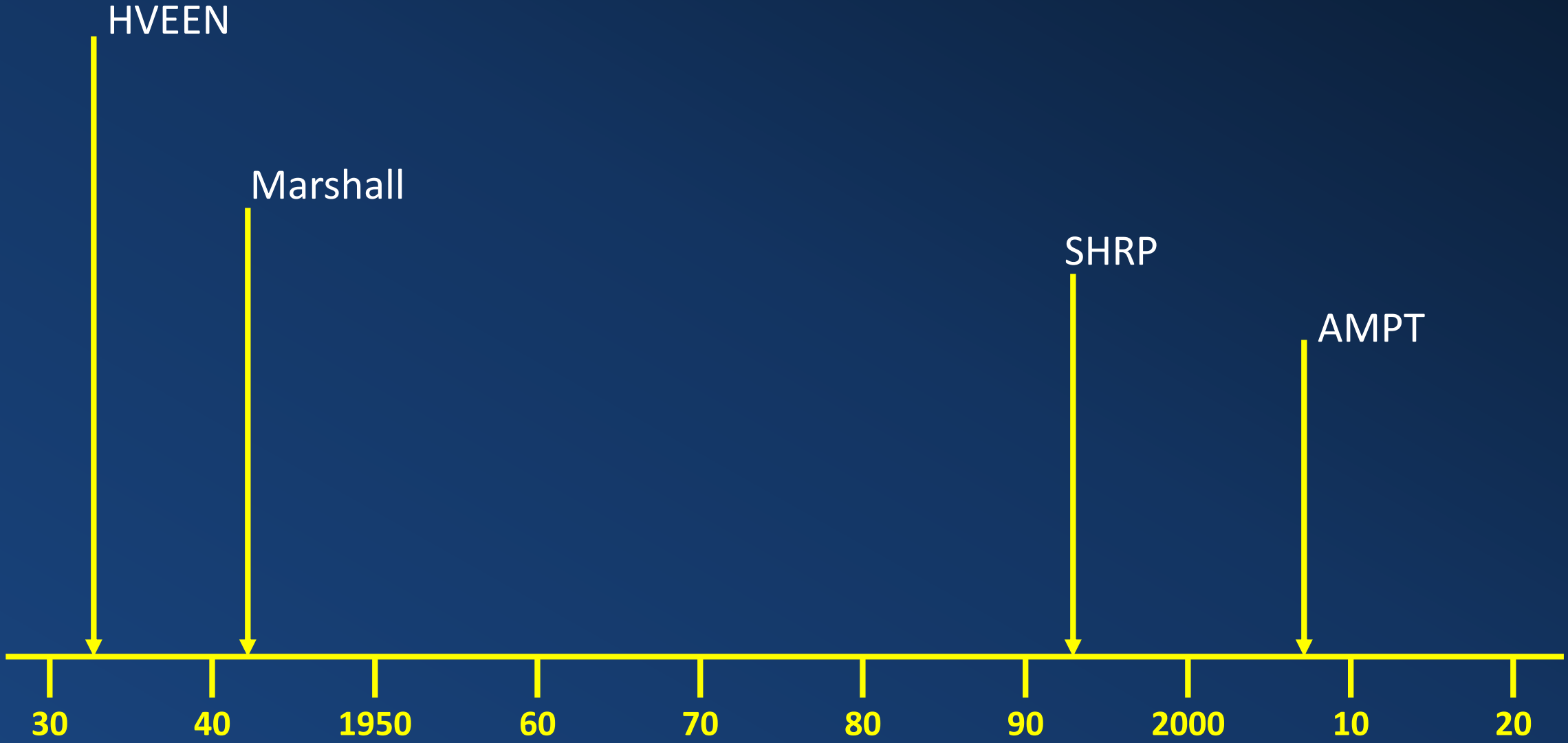
- Pavement Thickness Design
- Asphalt Binders
- **Asphalt Mixtures**
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# Asphalt Mixtures





# Mixture Tests



- Bending Beam Fatigue – 1960's
- Resilient Modulus – 1960's
- Direct Tension – 1960's
- Texas Overlay – 1970's
- Indirect Tension – 1970's
- Thermal Stress Restrained Specimen – 1990's
- Repeated Shear – 1990's
- Disc-shaped Compact Tension (DCB)
- Semi-circular Bending (SCB)
- Simplified Visco-elastic Continuum Damage (S-VECD)
- Repeated Direct Tension
- Others





# Ideal Mixture Test

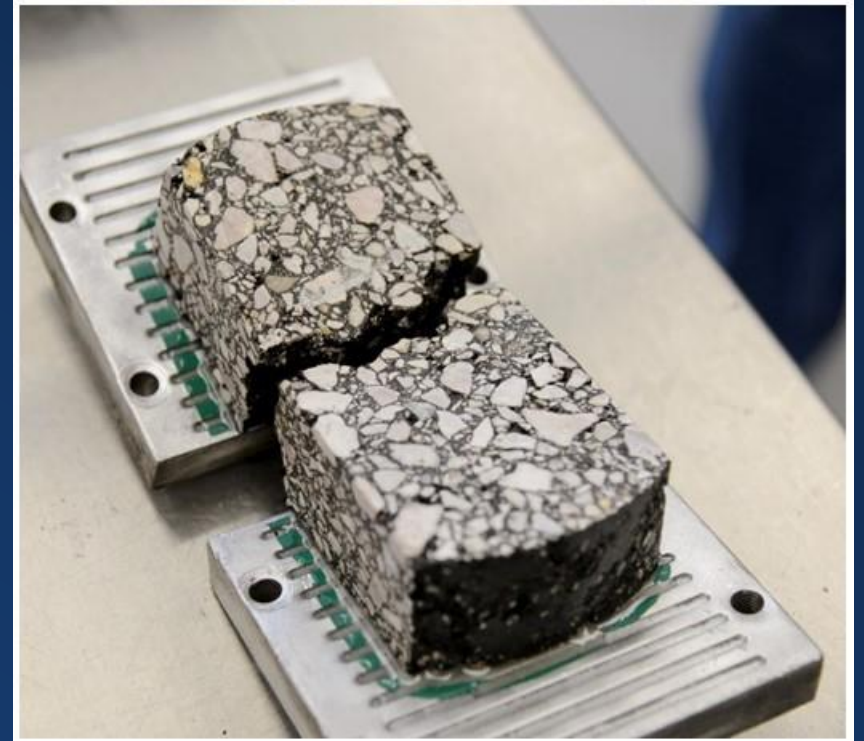
- Mixture Design
- Pavement Design
- QC/QA
- Within and Between Lab Variability
- Bias
- Related to Pavement Performance





# Ideal Mixture Test

- Fundamental Engineering Properties
- Low Cost Equipment
- Simple
- Quick
- Qualifications of Technicians





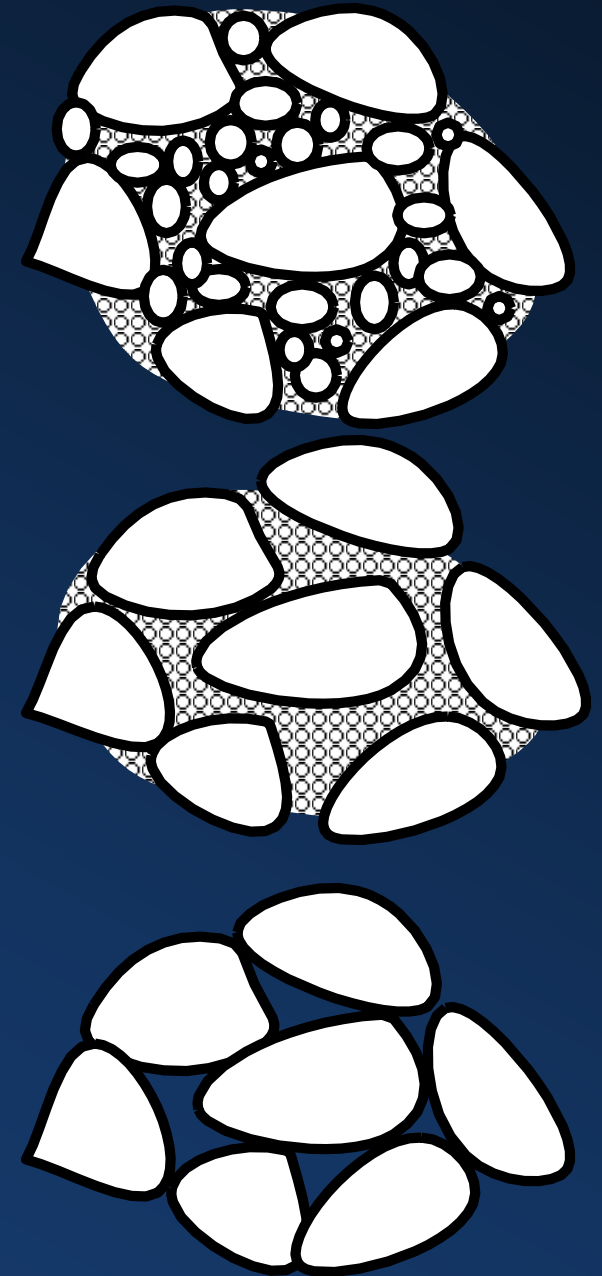
# Sample Preparation

- Lab Mixed – Lab Compacted
- Field Mixed – Lab Compacted
- Field Mixed – Field Compacted
- Conditioning
  - Aging
  - Water Exposure



# Mixture Types

- Dense Graded
- Gap Graded – Stone Mastic Asphalt
- Single Size
  - Open Graded
  - Porous Friction Course
- Reflection Cracking



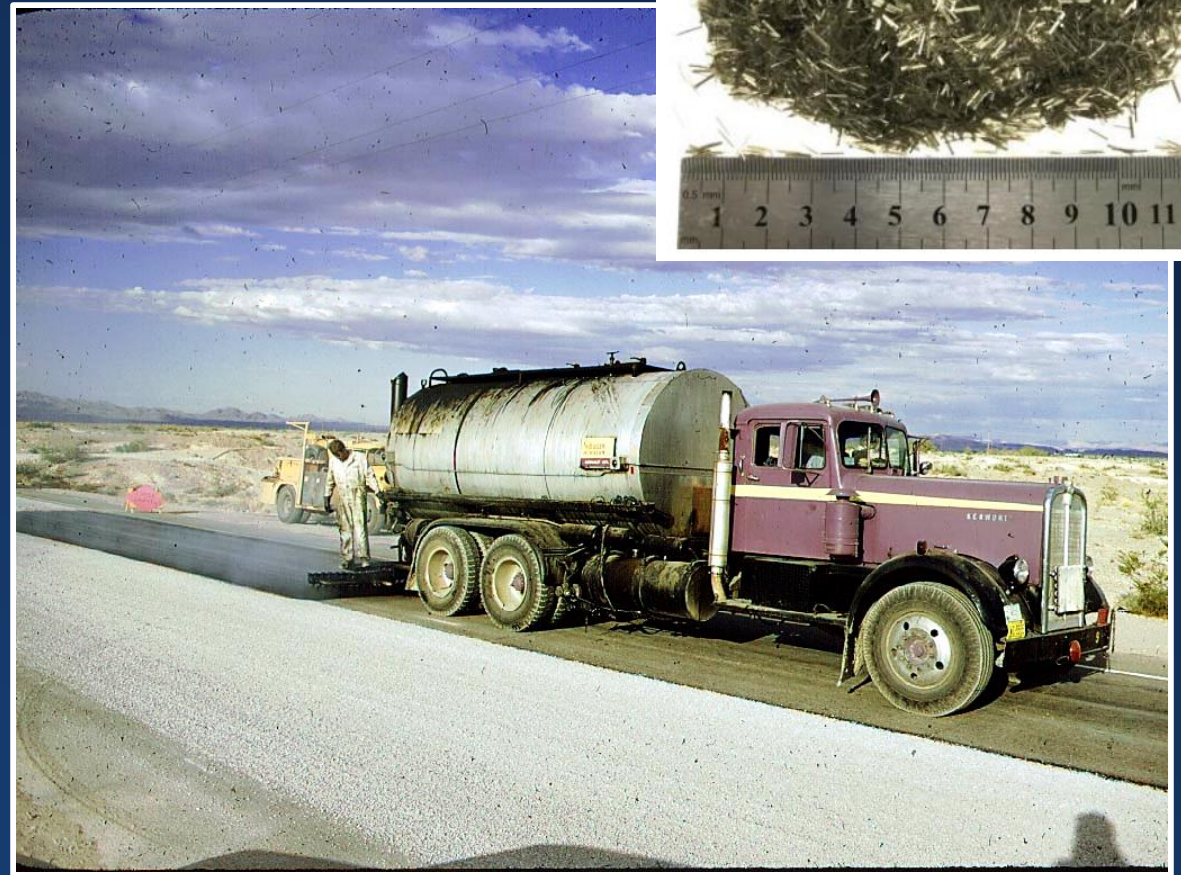
# Safety

- Type of Aggregate
- Wet Surface
- Drainage
- Hydroplaning



# Asphalt Mixture Modifiers

- Anti-strip Chemicals
  - Liquids
  - Lime
  - Portland Cement
- Fibers
- Crumb Rubber
- Warm Mix Additives

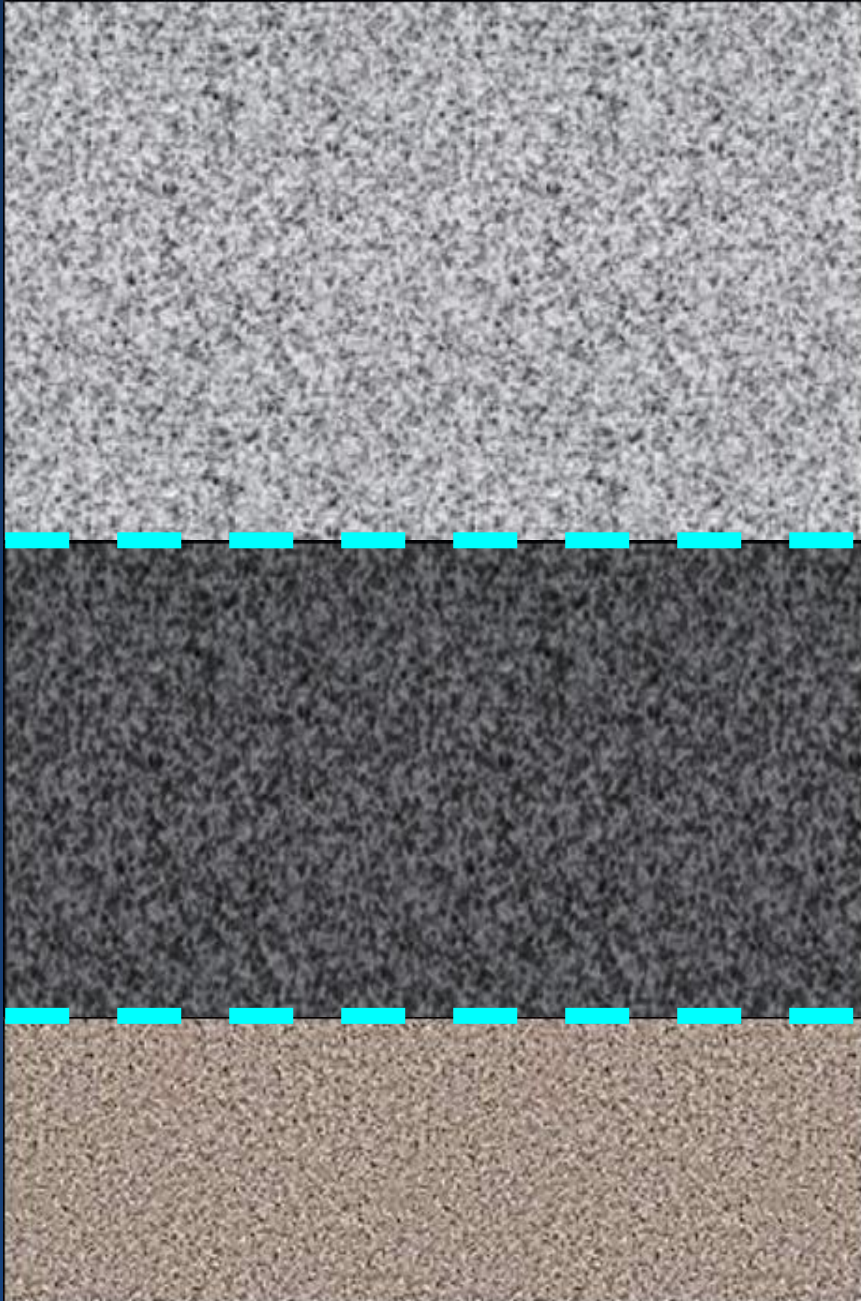






## Asphalt Mixtures & Pavement Design

- Multi-layer Specialty Asphalt Mixtures
- Perpetual Pavement



- Friction/Splash/Spray/Noise
- Permanent Deformation
- Thermal Cracking
- Water Susceptibility

- Stiffness
- High RAP/RAS
- Permanent Deformation

- Fatigue Resistance
- Water Susceptibility

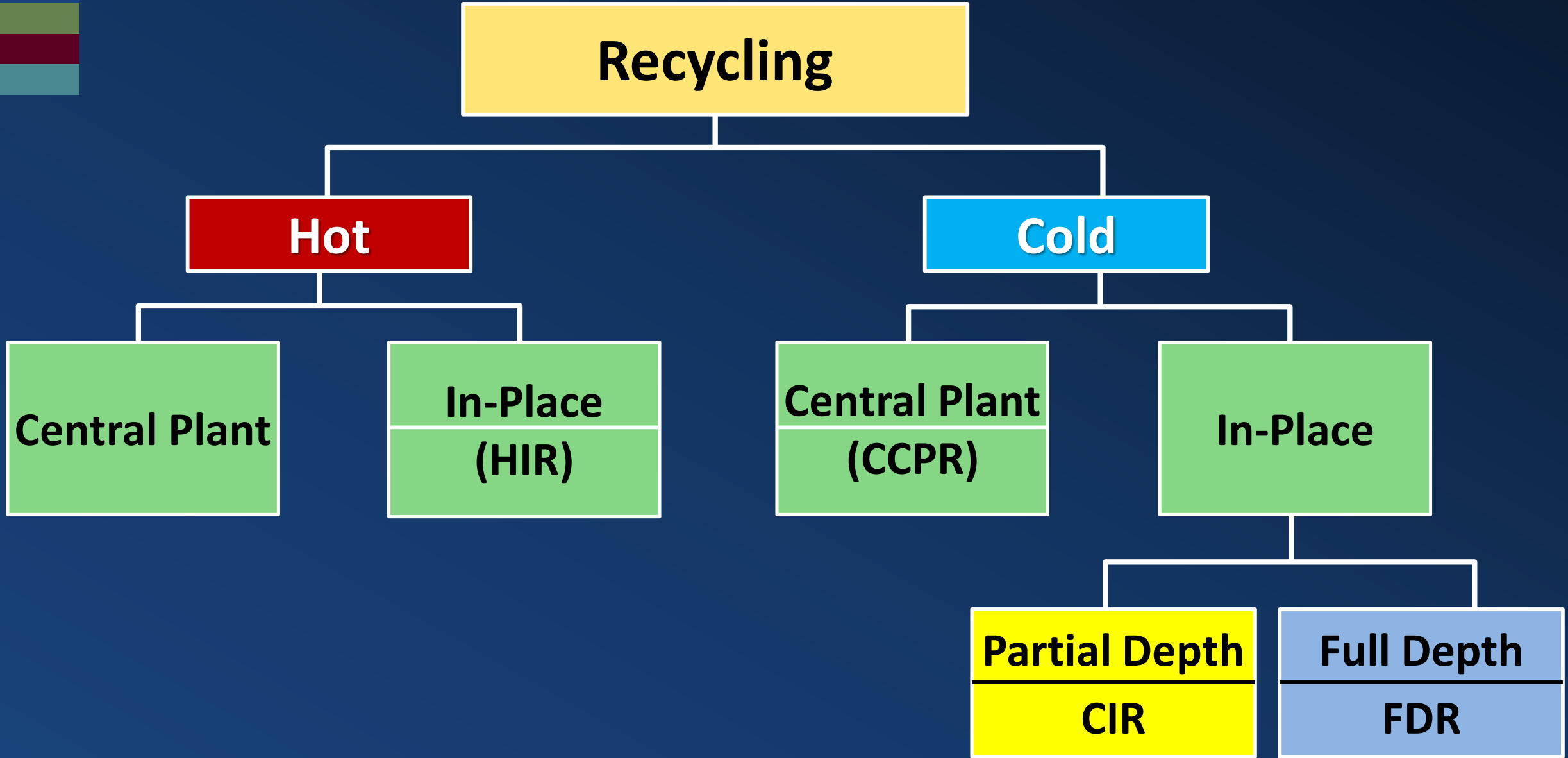


# Technology Changes

- Pavement Thickness Design
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# Recycling



HOT Central Plant

Cold In-Place

Hot In-Place

Hot Central Plant

Cold In-place

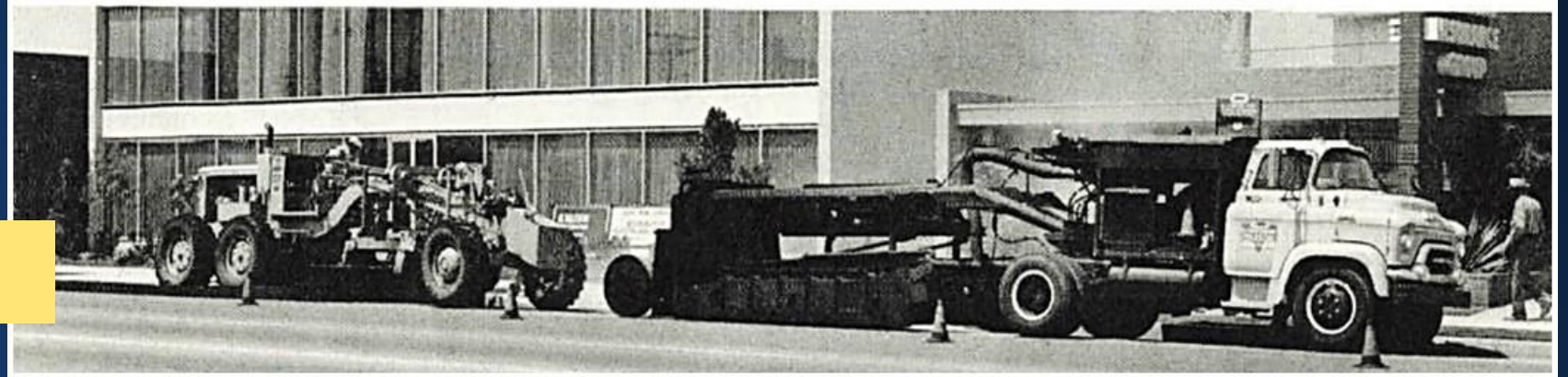
Hot in-place





# Hot In-Place

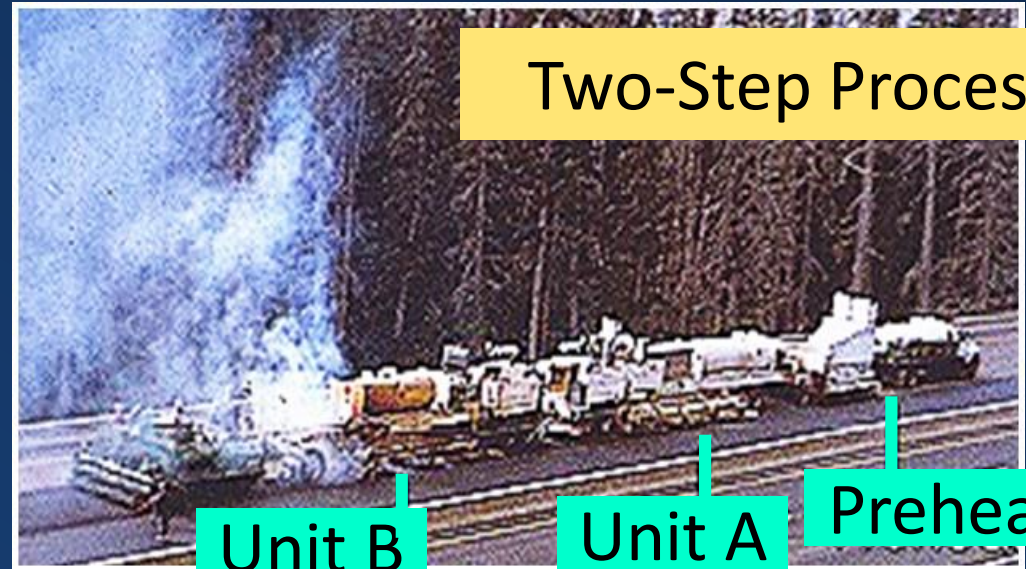
Heater-Planer



Typical Heater Scarifying Operation



Two-Step Process



Unit B

Unit A

Preheater

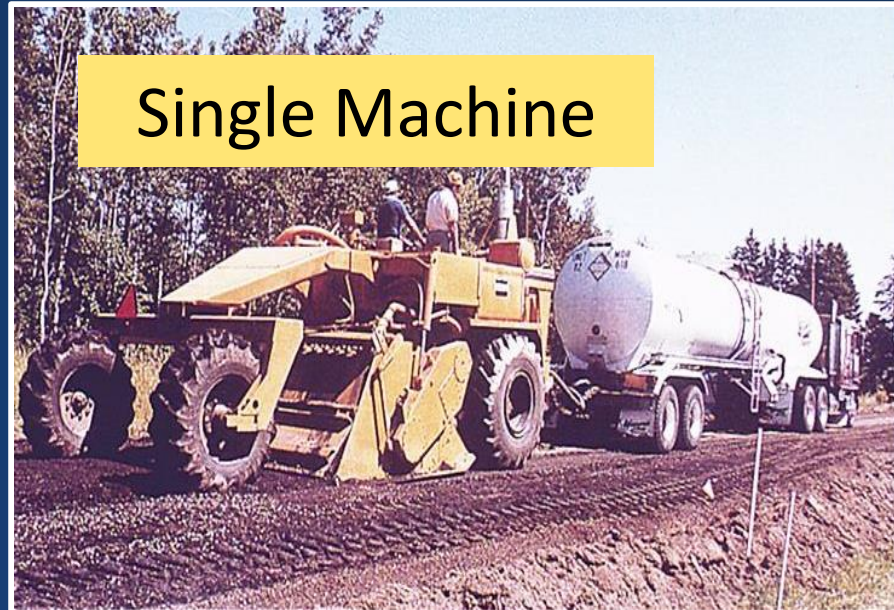
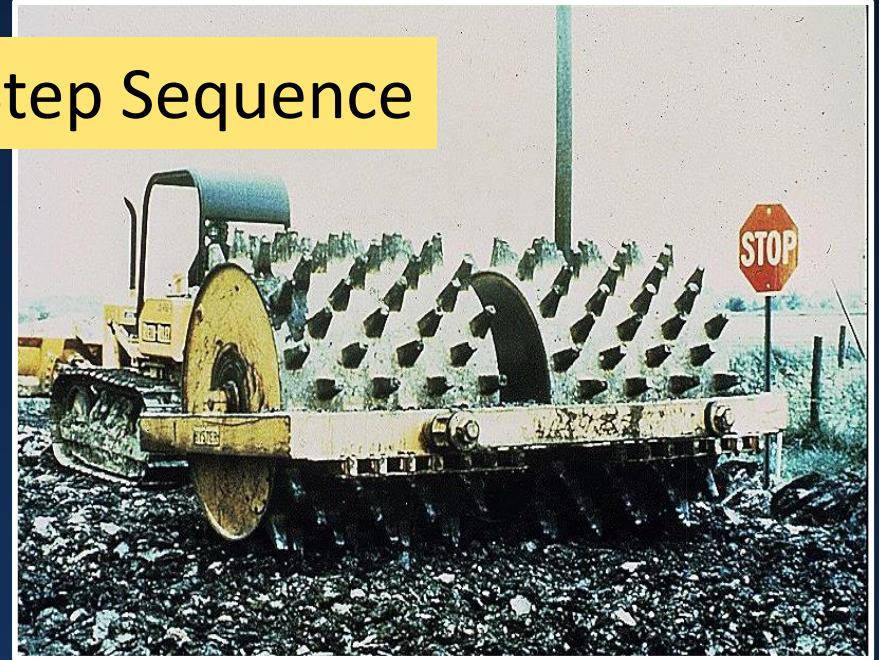




# Cold In-Place



Old Multiple Step Sequence



Single Machine



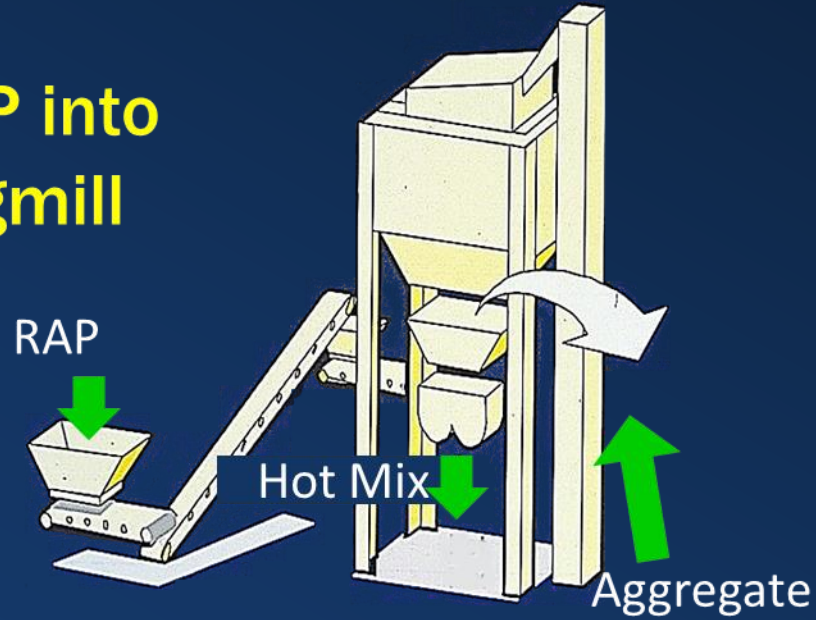
Equipment Train



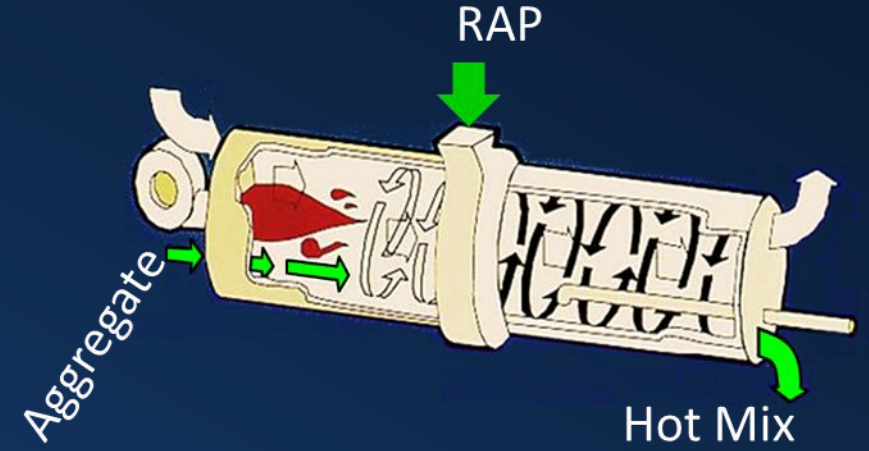


# Hot Central Plant

## RAP into Pugmill



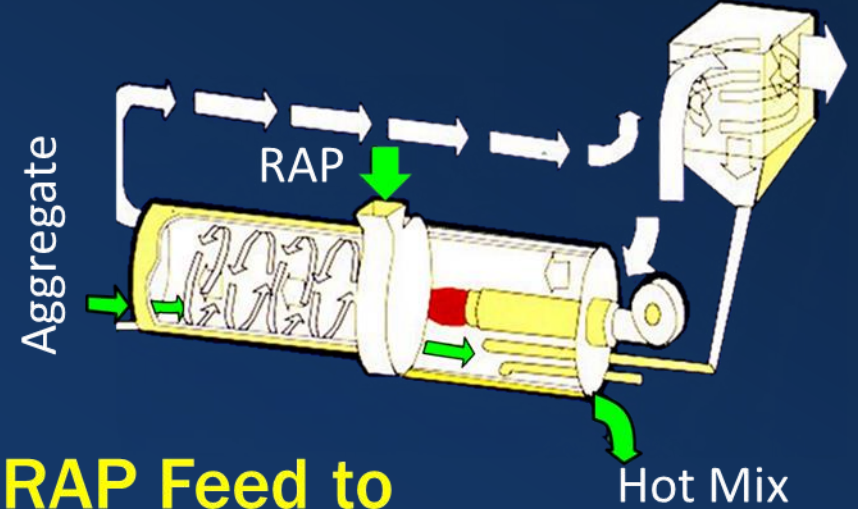
## RAP Feed to Parallel Flow Drum Mixer



## RAP Added to Continuous Mixer



## RAP Feed to Counter Flow Drum Mixer



# Technology Changes

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# Preventive Maintenance





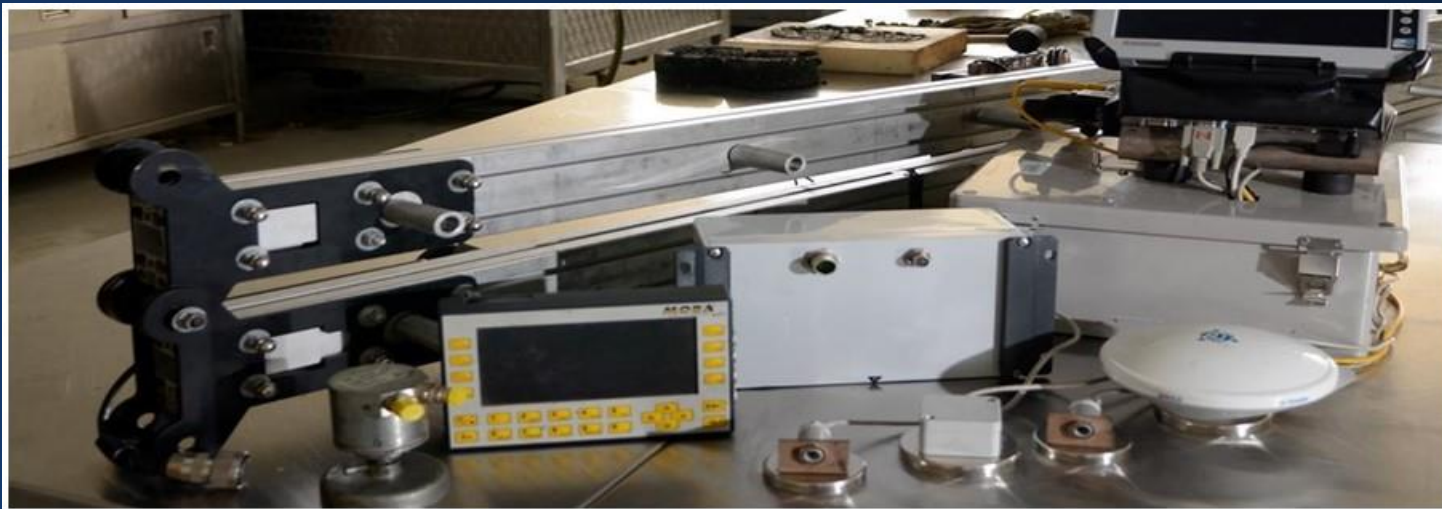
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# Management Systems







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WesTrack



MNRoad



UC Davis  
HVS



NCAT Test  
Track





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# Construction Equipment



Batch Plants

Laydown Floating Screed

Drum Mixer with Emulsion

Bag House

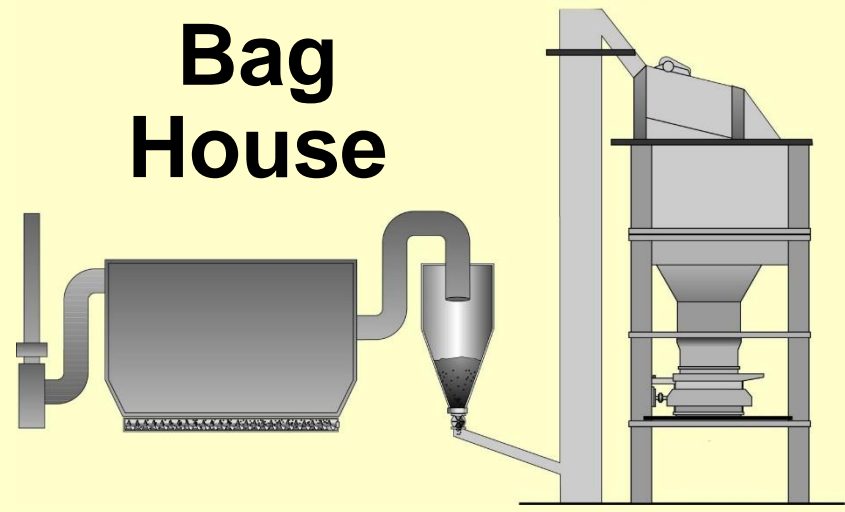
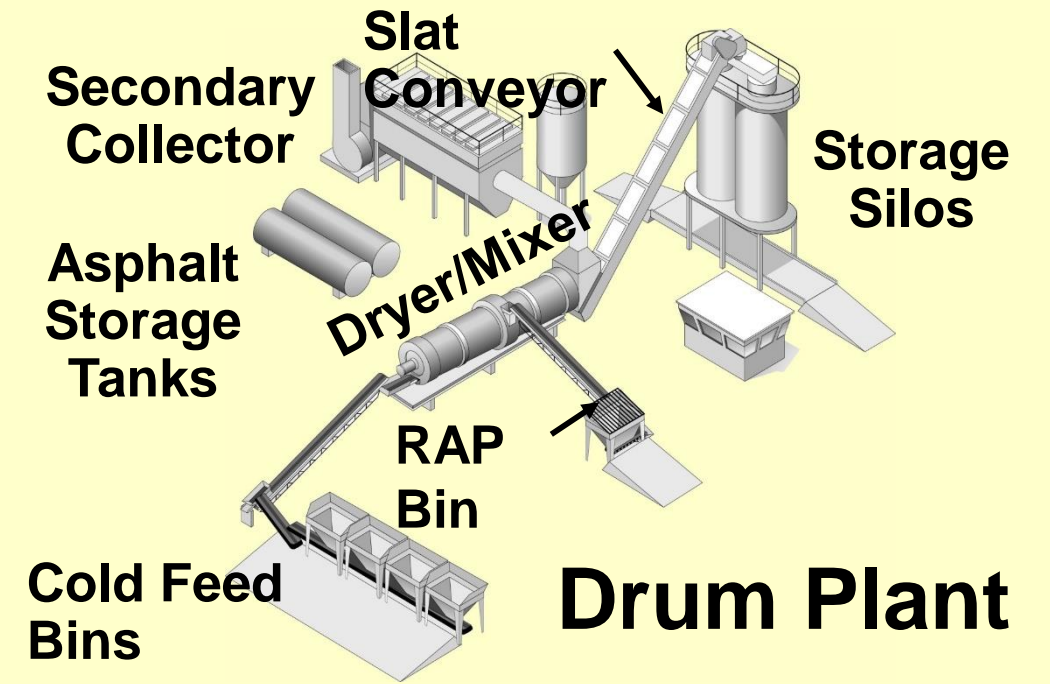
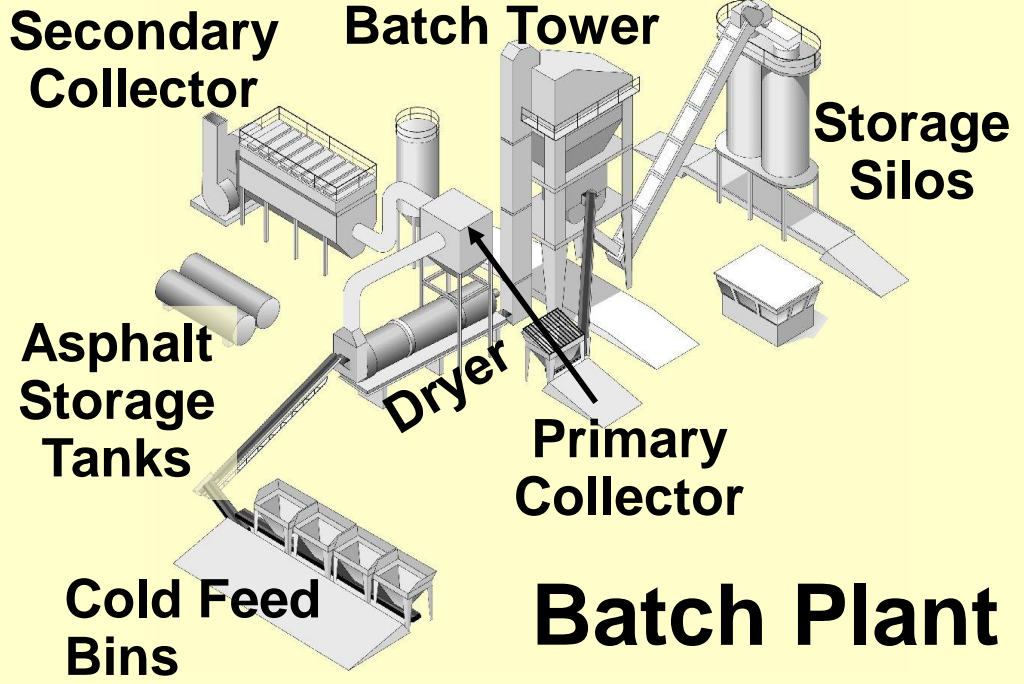
Drum Mix Plant

In-place Recycling

Vibratory Compactors

Material Transfer Device











# Technology Changes

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- **Strategic Highway Research Program**

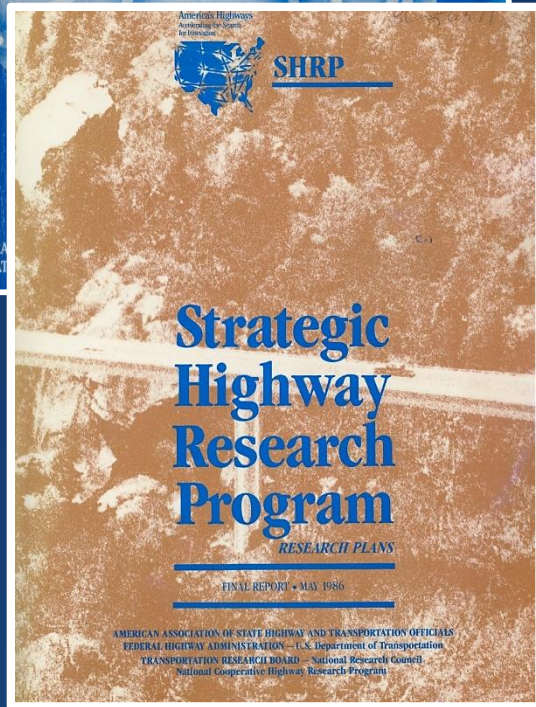




Special Report 202

# America's Highways

Accelerating the Search  
for Innovation



# SHRP

Pavement Performance Problems

STRS Committee Formed

Preliminary Research Program

STRS Report

SHRP Report

Funding

Research Report

Implementation

60

70

80

90

2000

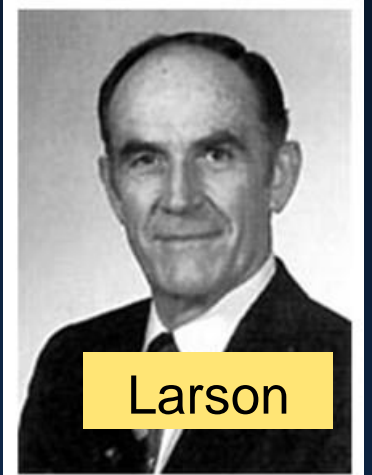






# Key Individuals

- Tom Larson-Penn State U. /Penn DOT/FHWA
- FHWA-Les Lamm/Ray Barnhart
- AASHTO-Frank Francois
- TRB-Tom Deen
- State DOT's
- Industry
- Consultants-Gary Byrd, Fred Finn



Larson



Barnhart



Finn



Deen



Francois



# SHRP Program



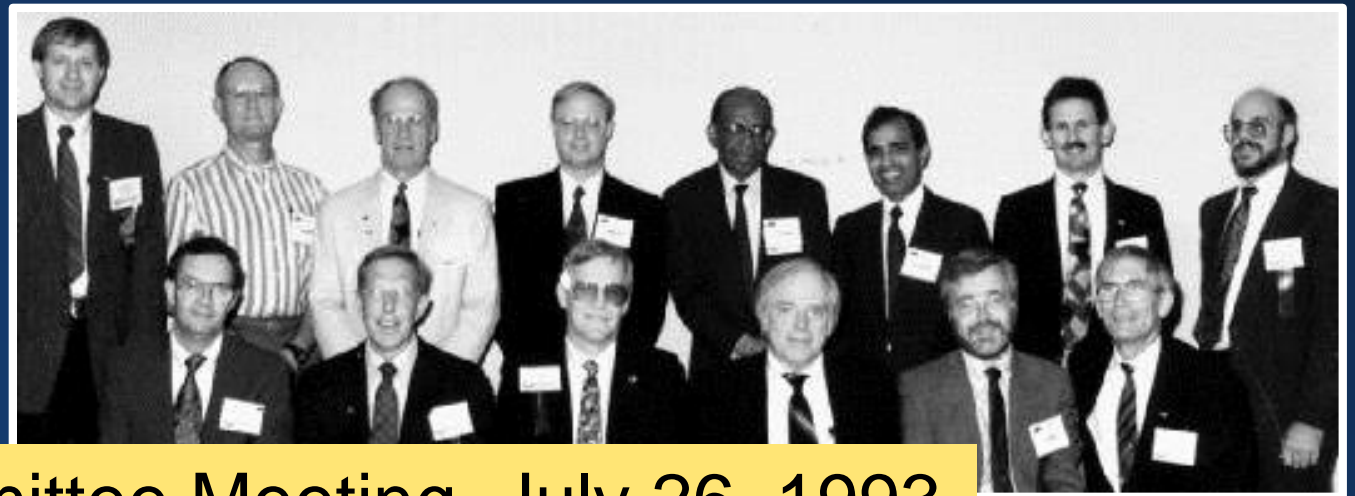
SHRP Executive Committee,  
circa 1988

- Asphalt Binder Properties (\$22 Mil)
- Performance Based Testing Systems (\$15 Mil)
- Pavement Performance Studies (\$4.5 Mil)
- Performance Based Specifications (\$5 Mil)
  - Asphalt Binders
  - Asphalt Aggregate Systems
- Coordination (\$3.5 Mil)



# Lessons Learned

- Decision based on Political, Organizational and Technical Input
- Team Building/Consensus Important
- Objective Clear/Flexibility in Research
- Large Projects Very Important to Future of Industry
- Relationships between Material Properties and Performance Remain Illusive



SHRP Asphalt Advisory Committee Meeting, July 26, 1993



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# Asphalt Binders

- Improved Specifications
- Benefits of Additives and Modifiers
- Aging
- Chemical Characteristics
- Recycling Agents
- Performance Relationships







# Asphalt Mixtures

- Rutting Not Common
- Cracking a Concern
- Sample Fabrication and Conditioning
  - Aging
  - Water Sensitivity
- Fundamental Mixture Properties
- Balanced Mix Design
- Performance Related
- Rapid QC/QA Tests



- Recycle, Higher RAP and RAS Quantities
- Recycling Agents
- Equipment Improvements
- Improve In-place Recycling Technology

## Recycling





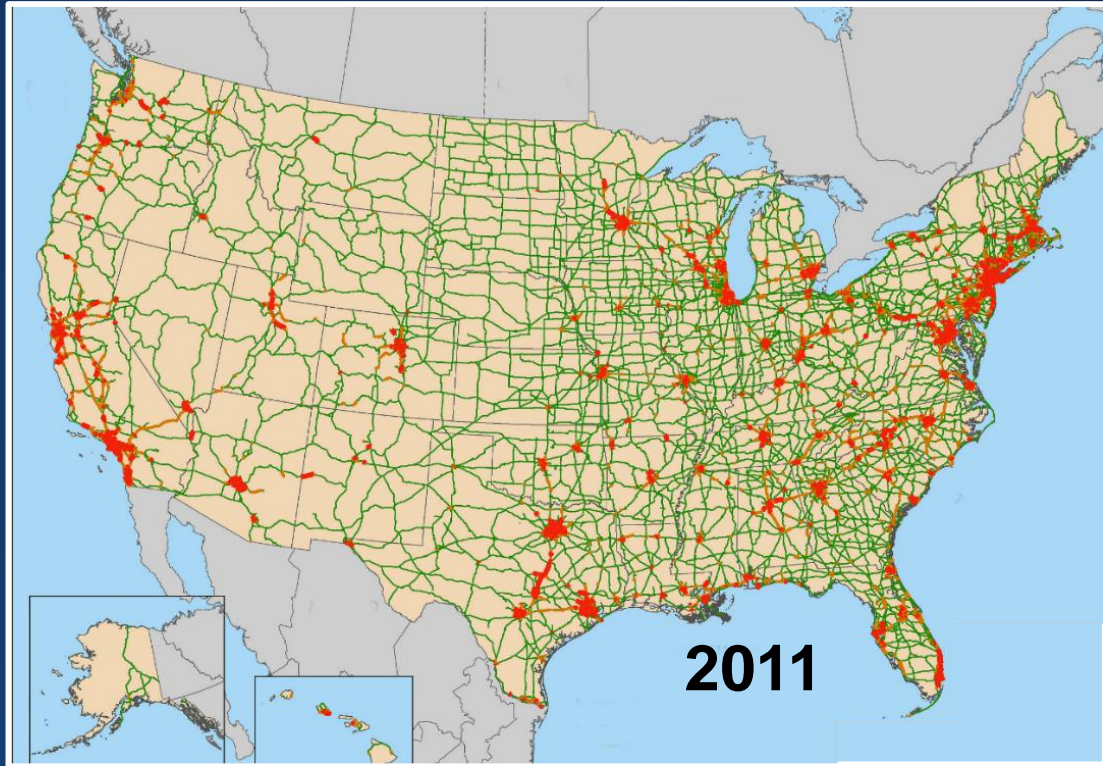


# Management Systems

- Data Presentation for Users
- Data Use by High Level Decision Maker
- QC/QA Data to Control Construction Operations





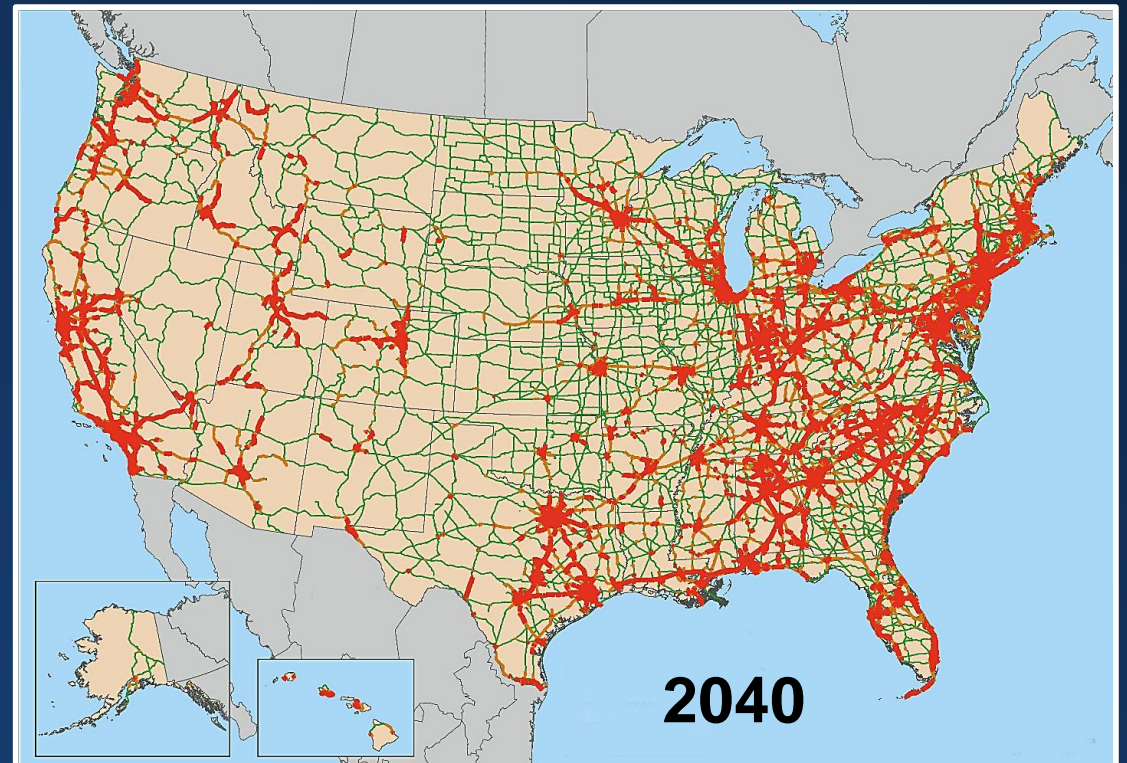


## Recurring Peak-Period Congestion

-  Uncongested
-  Congested
-  Highly Congested

# Construction

## Peak-Period Congestion on NHS





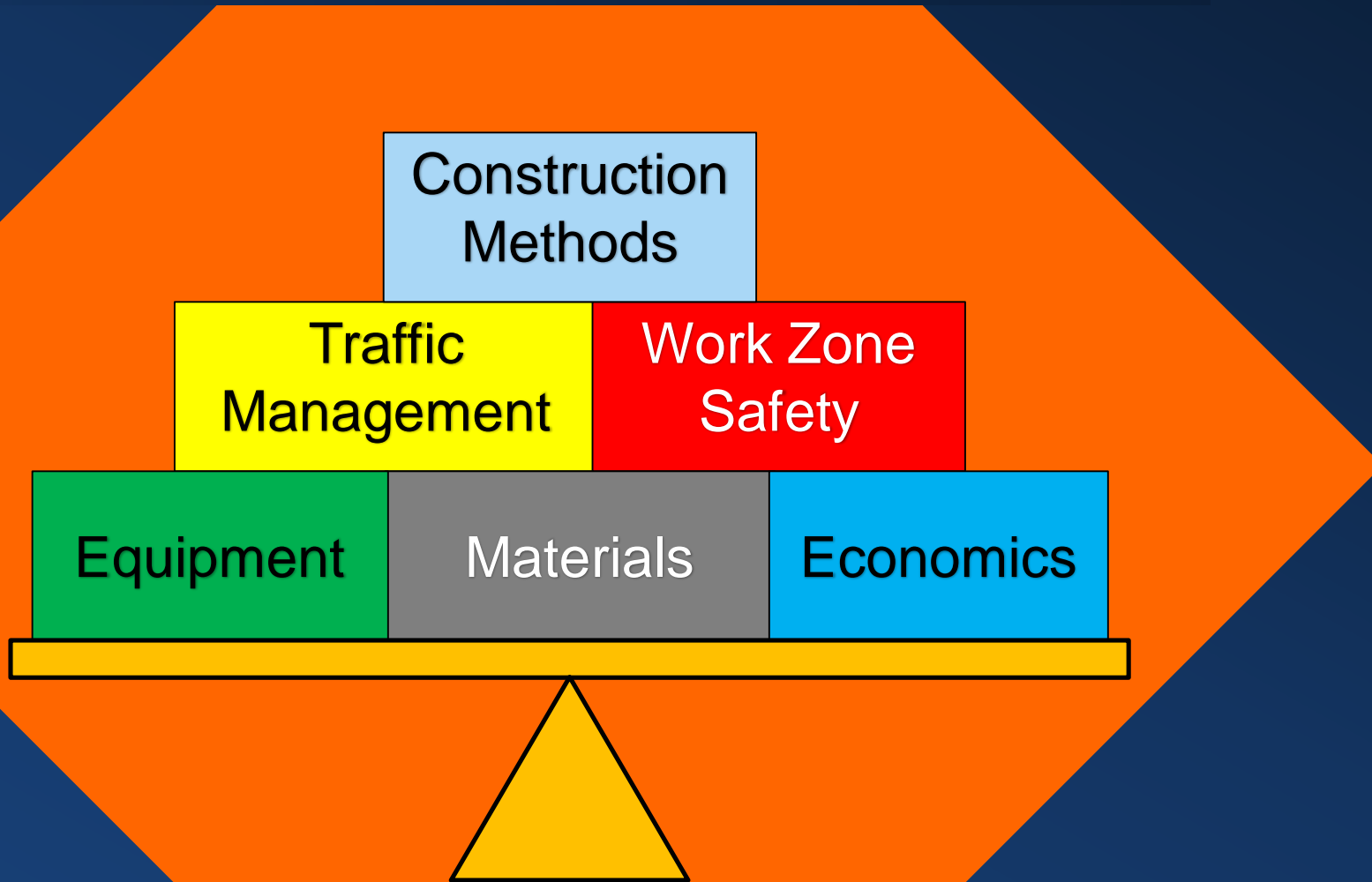


# Interest in Accelerated Construction

- Visibility to Public
- Safety
- Economics



# Accelerated Construction



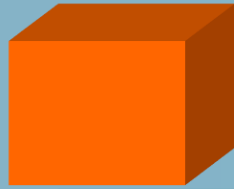




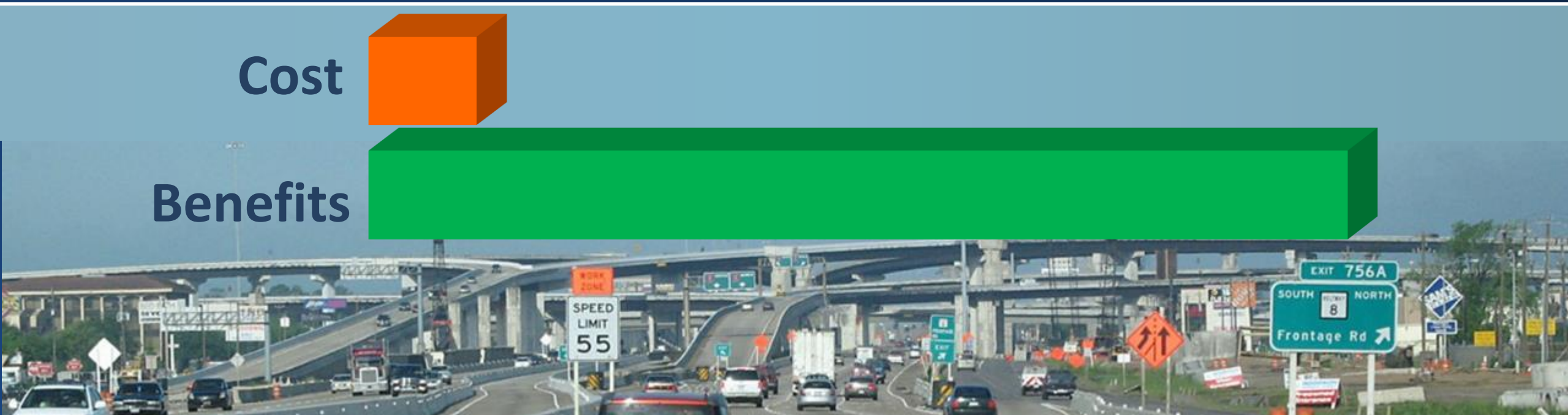
# Katy Freeway Economics

- Accelerated Construction Benefit - \$2.8 Billion
- Cost of Accelerated Construction - \$309 Million
- B/C Ratio – 9.0

Cost



Benefits





# Keys to Accelerated Construction

- Consider Accelerated Construction in Planning Stage
- Isolate Construction Work from Traffic
- Reuse Existing Materials on Site
- Maintain Lane Closure as Long as Possible
- Innovative Approaches to Traffic Handling







# Workforce

- Reduced Numbers
- Loss of Experience



# Research

- Incremental Improvement – Large Savings
- Large Well Funded Projects
- Deployment
- Local Governments
- Universities' Role







# Lessons Learned

- Volunteer
- Be a Finisher, On Time and Focus
- Details Are Important
- Hire Someone Better than You
- Move Away from Your Thesis/Dissertation Topic
- Understand Your Customer's Problem
- Don't Develop Solutions Looking for a Problem
- Someone Had the Same Novel Solution before You Developed Your Original Idea
- You Can Do Everything - You Cannot Do It All the Time

Questions?

