Paving the Way for the World’s Roadways

Arizona Pavements/Material Conference
November 20-21, 2019

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Outline

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

- Autonomous Vehicles
- Connected Vehicles
- Mobility on Demand
- Regulatory Compliance
- Drone Delivery
- Vehicle Electrification
- Sharing Systems
- Safer Roads with Electronic Devices
- Low Cost Airplanes
Technologies

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

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

<table>
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<tr>
<th>Concerns</th>
<th>1970’s</th>
<th>2000’s</th>
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<td>Price of Asphalt Binder</td>
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<td>Availability of Asphalt Binder</td>
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<td>Environmental Concerns</td>
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<td>Energy Concerns</td>
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<td>Global Warming</td>
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<td>Limited Funds Available</td>
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<td>Inflation</td>
<td>X</td>
<td>?</td>
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</table>
Historical Crude Oil Prices Adjusted for Inflation

*Macrotrends*
Outline

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

Design
- Accelerated Testing
- Asphalt Binders
- Asphalt Mixtures
- Pavement Thickness Design

Construction
- Construction Equipment & Operations

Rehabilitation & Maintenance
- Management Systems
- Preventative Maintenance
- Recycling
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

- Soil Mechanics
- 3 Layer Theory
- Layer Elastic Computer Programs
- Finite Elements
- Visco-Elastic
- Perpetual Pavements

Time:
- 1950
- 60
- 70
- 80
- 90
- 2000
- 10
- 20
Thickness of Material

Horizontal Tensile Strain

Vertical Compressive Stress and Strain

HMA

Base-course

Subgrade-soil
Technology Changes

- Pavement Thickness Design
- **Asphalt Binders**
- Asphalt Mixtures
- Recycling
- Preventive Maintenance
- Management Systems
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Asphalt Binders

Penetration Graded

Viscosity Graded

Performance Graded
Classification of Paving Asphalts

3 classification systems
1. Penetration
2. Viscosity
3. Performance (SHRP Superpave)

Historical Development

Original

Long-term Aging

Short-term Aging

Stiffness

Temp

-20 F  77 F  140 F  275 F

Low Pavement Temp  Avg Pavement Temp  High Pavement Temp  Construction
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
- Recycling
- Preventive Maintenance
- Management Systems
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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
- Asphalt Binders
- Asphalt Mixtures
- **Recycling**
- Preventive Maintenance
- Management Systems
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Recycling

Hot
- Central Plant
- In-Place (HIR)

Cold
- Central Plant (CCPR)
- In-Place
  - Partial Depth
  - Full Depth
    - CIR
    - FDR
Hot In-Place

Typical Heater Scarifying Operation

Two-Step Process

Heater-Planer

Unit A

Unit B

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

- Pavement Thickness Design
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- Recycling
- **Preventive Maintenance**
- Management Systems
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Preventive Maintenance
Technology Changes

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Management Systems
Technology Changes

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- **Accelerated Testing**
- Construction Equipment and Operations
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Technology Changes

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- Preventive Maintenance
- Management Systems
- Accelerated Testing
- **Construction Equipment and Operations**
- Strategic Highway Research Program
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

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

- Pavement Performance Problems
- STRS Committee Formed
- Preliminary Research Program
- STRS Report
- SHRP Report
- Funding
- Research Report
- Implementation

Year:
- 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
SHRP Program

- 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)

SHRP Executive Committee, circa 1988
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
Outline

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

Peak-Period Congestion on NHS

- 2011
- 2040
Interest in Accelerated Construction

- Visibility to Public
- Safety
- Economics
Accelerated Construction

Construction Methods

Traffic Management

Work Zone Safety

Equipment

Materials

Economics
Katy Freeway Economics

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