Hot-Mix Asphalt (HMA)

Balancing Risk & Assuring Performance

North-East State Materials Engineers Association
Atlantic City, New Jersey
October 8th 2008

Thomas Harman
Team Leader – Senior Pavement Engineer
Federal Highway Administration - Resource Center
Pavement & Materials TST
The dogmas of the quiet past are inadequate to the stormy present… as our case is new, so we must think anew and act anew.
Our Visit

• Our Nation’s Transportation System
  • **Balancing Risk & Assuring Performance**
    – Need
    – Structural Design & Analysis
      • Pavement Type Selection, RealCost™
    – Materials Characterization & Design
      • Superpave PGx, AMPT, Mix Type Selection Guide, NAPA/FHWA
    – Quality Assurance Systems
      • 6+ Building Blocks
    – Production & Placement
      • Automation, Innovation, & Basics
    – Monitoring & Preservation
      • Thinking about tomorrow to drive today’s decisions

• GOAL: Provide you with resources!
Two Words About Our Nation’s Transportation System
National Statistics:

3,963,262 miles of Roads  590,000 Bridges
2.7 trillion vehicle-miles / year
National Statistics:
3,963,262 miles of Roads

U.S. Public Road Ownership (Centerline Miles)
Urban (Solid) vs. Rural (crosshatched)
US Vehicle Population in 2000

- **Automobiles**: 132,400,000 (61.2%)
- **Buses**: 700,000 (0.3%)
- **Trucks**: 83,100,000 (38.4%)
Truck Distribution

- Light Trucks: 74,000,000 (92%)
- Medium Trucks/Buses: 4,400,000 (6%)
- Heavy Trucks/Buses: 1,700,000 (2%)

Number (in millions of trucks)
Damage vs. Axle Weight

- Remaining traffic
- Cumulative damage

- < 5% of traffic
- 58% of total damage
Damage vs. Axle Weight
5% of traffic causes almost 60% of damage

Traffic distribution

- < 34k: 88%
- 34k to 40k: 7%
- > 40k: 5%

Damage distribution

- < 34k: 25%
- 34k to 40k: 17%
- > 40k: 58%
Networks... Intermodal

Air  Truck  Rail  Water  Pipeline

Highway Network
National Freight Corridors
Commerce

Value of Shipments by Mode: 2002, 2006, 2035

- Pipeline and unknown
- Intermodal
- Air, air & truck
- Water
- Rail
- Truck

Billions of Dollars

2002

2006

2035
In the US, an average 53 million tons of freight was moved each day in 2002…
• An efficient freight transportation system can also improve a State or Region’s ability to attract and retain businesses
CHANGES

• Congestion and Freight are driving factors
• Increased traffic and loadings
• Environmental Concerns (sustainability)
  – ex. Use of bag-houses at production facilities, increase in recycled materials
• Supply sources (asphalt, polymers, aggregates)
  – Escalating materials costs
• Production changes
  – ex. Drum plants vs. batch plants
• Staff reductions
• Shifting roles
• Personnel experience & shortages
Balancing Risk & Assuring Performance

• Risk
  – Risk is the likelihood of a bad or unwanted outcome – such as poor pavement performance or low profit margin (or crap dice)
  – All systems have some inherent Risk, and
  – Changes within a system will either increase, decrease, and/or shift Risk between parties,
    • ex. Owner Agency & Contractor
Balancing Risk & Assuring Performance

- Risk - Law of Unexpected Consequences…

“Sometimes in getting what you ask for you lose what you truly wanted.”
Balancing Risk & Assuring Performance

Innovation

• New materials, testing tools, and production equipment and procedures offer the potential for even greater pavement performance!
Balancing Risk & Assuring Performance

Risk and Innovation

• In developing systems that reduce overall Risk, we can create an environment that does **NOT** foster or reward innovation.
Balancing Risk & Assuring Performance

Get In

Stay In

Structural

Get Out

Stay Out

Materials

Construction

Need

Structure

Materials

Acceptance

Construction

Preservation
Evolution of Pavement Design

Past Practices

Analytical

MLET 2D FEM 3D FEM

State-of-Practice

State-of-Art

Need  Structure  Materials  Acceptance  Construction  Preservation
Evolution of Pavement Design

**Empirical**
- Get a lot of data
- Find a Trend (Hope for)

**Mechanistic**
- Springs
- Dashpots

\[ y = 114.32x - 0.4766 \]
\[ R^2 = 0.934 \]

![Graph showing performance parameter vs. load applications](image)
Evolution of Pavement Design

• Mechanistic-Empirical
  – Combines mechanistically based models (equations) with empirically derived models (equations)

\[ y = 114.32x - 0.4766 \]
\[ R^2 = 0.934 \]

\[ \begin{align*}
0 & \quad 20 & \quad 40 & \quad 60 \\
5 & \quad 10 & \quad 15 & \quad 20 \\
0 & \quad 20 & \quad 40 & \quad 60 \\
\end{align*} \]

\[ 0 \quad 5 \quad 10 \]

Performance Parameters

Load Applications (thousands)
FOREWORD

This interim guide for the design of pavement structures is based on data from the AASHO Road Test at Ottawa Illinois. In those areas not covered by the Road Test, theoretical analysis and experience have been utilized.

It is essential that the user of the guide understand its limitations, which are: ...
Environmental Section is still in-place today.

Fred Finn – Bituminous Engineer for the Track
New AASHTO M-E Pavement Design Guide

- Need
- Structure
- Materials
- Acceptance
- Construction
- Preservation
New M-E Pavement Design Guide

- Need
- Structure
- Materials
- Acceptance
- Construction
- Preservation
Life-Cycle Cost Analysis Software
RealCost™

Probabilistic Life-Cycle Cost Analysis

http://www.fhwa.dot.gov/infrastructure/asstmgmt/lcca.cfm
Pavement Design Resources

- FHWA: http://www.fhwa.dot.gov/pavement/
- National Asphalt Pavement Association http://www.hotmix.org/
- Asphalt Pavement Alliance (APA) http://www.asphaltalliance.com/index.asp
Balancing Risk & Assuring Performance

Structural

Materials

Construction

Need  Structure  Materials  Acceptance  Construction  Preservation
Balancing Risk & Assuring Performance

Superpave®

Performance-Based
Purchase Specification
Design and Analysis Tool
Why SHRP?

• In the 1980’s procedures and practices could not assure performance.

• Unacceptable Risk

• Distress…
  – Rutting
  – Fatigue cracking
  – Low-temperature cracking

2 Weeks Old!
Major Steps in Superpave Mix Design

1. Selection of Materials,

2. Selection of a Design Aggregate Structure,

3. Selection of the Design Binder Content,

4. Evaluation of Moisture Sensitivity of the Design Mixture, and

5. Performance Characterization.
Superpave Gyratory Compactor
ONGOING Refinement

- Understanding Modifiers, PGx
- Asphalt Mix Performance Tester
- Equipment Calibration
- Understanding acid
- Improved moisture test

- Construction Quality
- Link to Pavement Design
- Communication!

Need Structure Materials Acceptance Construction Preservation
Imperfection should never stall implementation.

You can still drink from a chipped cup.
Challenges

- Achieving VMA
- Suitability of Gyratory Compaction Levels
- Issues of Durability & Binder content
- Need for a Moisture Sensitivity Test
- Deployment of a Performance/Strength Test
NCHRP 9 – Bituminous Materials

• RAP Characterization, 9-12
• Gyratory Level, 9-9, 9-16, 9-19
• Volumetric Requirements, 9-25, 9-31
• Performance Testing, 9-19, 9-29
• Mixture Design Manual, 9-33
New Asphalt Mix Performance Tester
AMPT
AMPT – Pooled Fund Study

- POC: Dr. Audrey Copeland, FHWA
  - Audrey.Copeland@dot.gov
SHRP Asphalt Program Coordinator

“One of the principal goals of the SHRP asphalt program is to reduce or eliminate the proliferation of asphalt binder specifications.”

Dr. Thomas Kennedy
Growing Trend from 2002 to 2005

- 34 States with Plus Specs (67%)
- 13 States Straight M 320
- 21 Different Pluses
- 4 Duel / Hybrid
- The Winner! – M 320 with 13 Pluses

As is M320  Plus Spec.'s
PG Grade Specifications

Number of States

0 5 10 15 20 25 30 35

2002 2005

Need Structure Materials Acceptance Construction Preservation
Superpave® Plus

WHY?
High-Temperature Performance
I-80, Nevada

Same gradation - different binders.

PG 63-22 modified
No rutting

PG 67-22 unmodified
15mm of rutting
High Temperature (Rutting)
Repeated Creep Recovery Test

PG 67-22 Neat AC

PG 63-22 Modified

Strain, (%)

Time, (seconds)

0 200 400 600 800 1000 1200

Balancing Risk & Assuring Performance
New Superpave Tool… PGx (Table 3)

- Original Spec was based on Modulus, $G^*$ is Stress / Strain

- Compliance, $J_{NR}$ is Strain / Stress
  - $x$: Standard, Heavy, Very Heavy
  - Eliminates grade-bumping
  - Accounts for traffic level through Jnr criteria
Materials Resources

- FHWA: http://www.fhwa.dot.gov/pavement/
- NCHRP, 9-series http://www.trb.org/mepdg/
- National Asphalt Pavement Association http://www.hotmix.org/
- Asphalt Pavement Alliance (APA) http://www.asphaltalliance.com/index.asp
- Asphalt Institute http://www.asphaltinstitute.org/
• **Contacting Mechanisms**
  – Design Standards (ex. Superpave) to Performance Specifications to Warranties to Public-Private-Partnership

• **Quality Assurance Systems**
  – Ex. Percent Within Limits (PWL)

• **Compaction & Intelligent Construction Systems (ICS)**
  – Longitudinal Joints, Automated Plants, IC Rolls, Infrared Cameras, Real time project information…

• **Warm Mix Asphalt Technologies**

• **HIGH RAP Materials**
FHWA
Quality Assurance Assessment
FY 2008
What it is **NOT** and what it **IS**…

• The Assessment is **NOT**…
  – A “Gotcha”
  – A way to compare States
  – A indication of pavement performance
  – Perfect

• The Assessment is…
  – A tool to identify potential areas of RISK
  – A tool to identify “successful practices”
  – A tool to prioritize training
  – A tool to guide specification refinement
Driving Factors

• Quality Assurance Reviews (HIPT)
  – State Agency Compliance with CFR

• National Review Program: Quality Assurance in Materials & Construction (Division Office Assessment of Risk)
  – Kevin McLaury (MT), Team Leader, Max Grogg (IA), Mike Praul (ME), Brad Neitzke (WFL), Ken Jacoby (HIAM), Pete Kulyk (HPC), & Tamiko Burnell (HSA)
National Review Program: Quality Assurance in Materials & Construction

Six Building Blocks…

1. Contractor Quality Control
2. Agency Acceptance
3. Independent Assurance
4. Dispute Resolution
5. Laboratory Accreditation and Qualification
6. Personnel Qualification/Certification, and
7. RISK
Risk-based Process

Risk-based Assessment Tool -> Benchmark -> Report

- Prioritize Areas of Risk
- Identify Successful Practices
- Conduct Training / Roundtables
- Refine QA Specifications

Action Plan

Balancing Risk & Assuring Performance 55
Division Office Interview (Mike/Lee/Dennis)
Assessment of RISK (QA System)

• 18 Questions…
  – Covers the Six Building Blocks
  – Questions Weighted
  – 1, 2, 3, 5, & 7

• Frequency
  – 52 in FY 2008
  – Updated… TBD
Two desired outcomes…

• We get what we pay for… Balanced, low-risk system

• Create a culture of Trust
Definitions

• **Advanced States**
  – Those States that have highly developed QA programs that demonstrate their capability for measuring the quality of their construction and materials programs. An advance QA program includes highly developed Contractor Quality Control, Agency Acceptance, Dispute Resolution, Independent Assurance, Technician Certification or Qualification, and Laboratory Certification programs.

• **Intermediate States**
  – Those States that have substantially demonstrated an effective QA program for measuring quality and includes most of the QA elements of an advanced QA program.

• **Opportunity States**
  – Those States that have a demonstrated a weakness in their construction and materials programs to measure quality or have a weakness in their program that could lead to fraud.
NPM – A low rating is not a compliance issue with 23 CFR 637.
Distribution of Rating

Histogram of QA System Rating - FY 2008

Number of Agencies

QA System Rating

10%  25%  40%  55%  70%  85%  100%
% of Agencies Needing Advancement

FALCON 5 - Gap Analysis
QA Assessment of RISK

Weighting Factors: Yellow-7, Orange-5, Green-3, Blue-2, Brown-1

Balancing Risk & Assuring Performance
FALCON 5 - Gap Analysis
QA Assessment of RISK using Weighting Factors

Weighting Factors: Yellow-7, Orange-5, Green-3, Blue-2, Brown-1

1. Materials Management System
2. Control of Random Sampling Location
3. Immed. State Possession of Verf. Tests
4. HMA Quality Char.
5. PCC Quality Char.
6. Bridge Quality Char.
7. Lot Size
8. PWL/PD
9. Use of F&t
10. PWL Risk Analysis
11. Continuous Equations
12. NTPEP
13. Warranties
14. Limited use of visual acceptance
15. System IA with 90% tech checked.
16. Formal Dispute Resolution
17. Project Field Labs Approval
18. Personnel Qualification.

Percent of Agencies Requiring Improvement x Weighting Factor

Increasing RISK
National Performance Measure (SIP)

FALCON 5 - QA National Performance Measure

QA Assessment of RISK

Overall Rating

Fiscal Year

Balancing Risk & Assuring Performance
Gaps for Average Division Office

FALCON 5 - Gap Analysis
QA Assessment of RISK
Weighting Factors: Yellow-7, Orange-5, Green-3, Blue-2, Brown-1

- General Risk Areas
- Moderate Risk Areas
- Higher Risk Areas

1. Materials Management System
2. Control of Random Sampling Location
3. Immed. State Possession of Verf. Tests
4. HMA Quality Char.
5. PCC Quality Char.
6. Bridge Quality Char.
7. Lot Size
8. PWL/PD
9. Use of F&t
10. PWL Risk Analysis
11. Continuous Equations
12. NTPEP
13. Warranties
14. Limited use of visual acceptance
15. System IA with 90% tech checked.
16. Formal Dispute Resolution
17. Project Field Labs Approval
18. Personnel Qualification.
Activities to Address Gaps

Risk Areas Identified

- Q-7 (Lot Size)
- Q-8 (PWL/PD)
- Q-9 (F & t tests)
- Q-10 (Risk Analysis)
- Q-11 (Continuous Pay Equations)
- Q-15 (System AI 90% tech checked)
- Q-16 (Formal Dispute Resolution)

Products & Services

- PWL Workshop
- SpecRisk Workshop
- Topical web-based manual on Quality Assurance
- Quality Assurance for Field Engineers training course
- Provide Examples of SUCCESSFUL PRACTICES
Risk-based Process

Risk-based Assessment Tool → Benchmark → Report

Action Plan

Prioritize Areas of Risk
Identify Successful Practices
Conduct Training / Roundtables
Refine QA Specifications

Balancing Risk & Assuring Performance
Intelligent Construction Systems

Reducing Risk
100% Sampling
Link to PMS
Intelligent Compactors
(aka Smart Rollers)

• Soils and Asphalt
• Intelligent
  – Measures a parameter that relates to performance (density/stiffness)
  – Adjusts compaction effort based on measure response
  – Provides real-time graphical information
  – Records response tied to location (GPS)
HMA Compaction

Good Performing Longitudinal Joints are not an “Accident!”

6 year old pavement
© Courtesy of A Heritage Group Company
Low Density Joint

Day after a hard rain –
Trapped Moisture

1 year old pavement
© Courtesy of A Heritage Group Company
Low Density Joint

Premature Joint Failure
Joint Life = Pavement Life
(i.e. 10 yrs vs. 15 yrs)
National RAP Expert Task Group
Advance the use of RAP in asphalt paving applications by providing highway agencies with critical information regarding the use of RAP, technical guidance on high-RAP projects, and direction on research activities.

The members consist of representatives from highway agencies, industry, and academia.

Website: www.ncat.us/rap/rap
RAP Resources

- New Expert Task Group on High RAP
- FHWA
  - [www.fhwa.dot.gov/pavement/recycling](http://www.fhwa.dot.gov/pavement/recycling)
- Recycled Materials Resource Center
  - [www.rmrc.unh.edu](http://www.rmrc.unh.edu)
- Green Highways Partnership
  - [www.greenhighways.org](http://www.greenhighways.org)
- FHWA R&D
The Pavement Preservation Concept
Thinking about tomorrow to drive today’s decisions
Acceptance & Construction Resources

• FHWA: Asset Management

• National Asphalt Pavement Association
  – http://www.hotmix.org/

• Asphalt Pavement Alliance (APA)

• Asphalt Institute
  – http://www.asphaltinstitute.org/

• Foundation for Pavement Preservation
  – http://fp2.org/
Balancing Risk & Assuring Performance

Structural

Materials

Construction

Need

Structure

Materials

Acceptance

Construction

Preservation
Risk and Innovation

- Systems like Superpave reduces the Risk of poor pavement performance, and
- Are adapting to address innovative materials and other evolving technologies.
Questions?