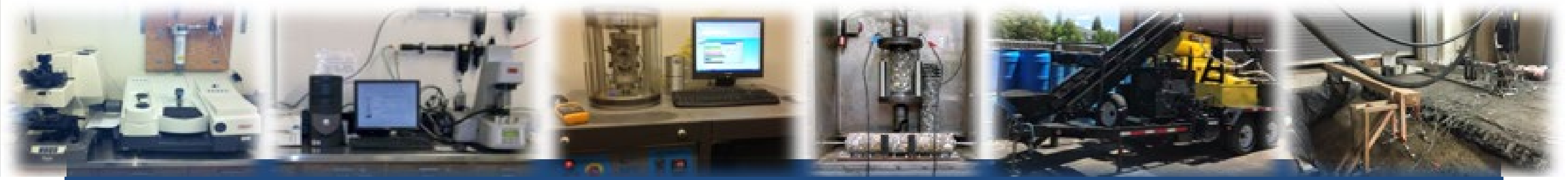


Current Research Update

Adam Hand, PE, PhD

University of Nevada Reno

APAM Annual Conference

February 21, 2023 Mount Pleasant, MI

ASPHALT PAVEMENT ASSOCIATION OF MICHIGAN

Current Research Examples

- NCHRP Project 09-58
- NCHRP Project 09-64
- NCHRP Project 09-69
- NAPA/FAA - AAPTP
- *FHWA DDIAPT Coop*

NCHRP Project 09-58

NATIONAL ACADEMIES Sciences Engineering Medicine

About TRB | Annual Meeting | Calendar | Committees & Panels | Programs | Projects | Publications | Resources & Databases

NCHRP 09-58 [Completed]

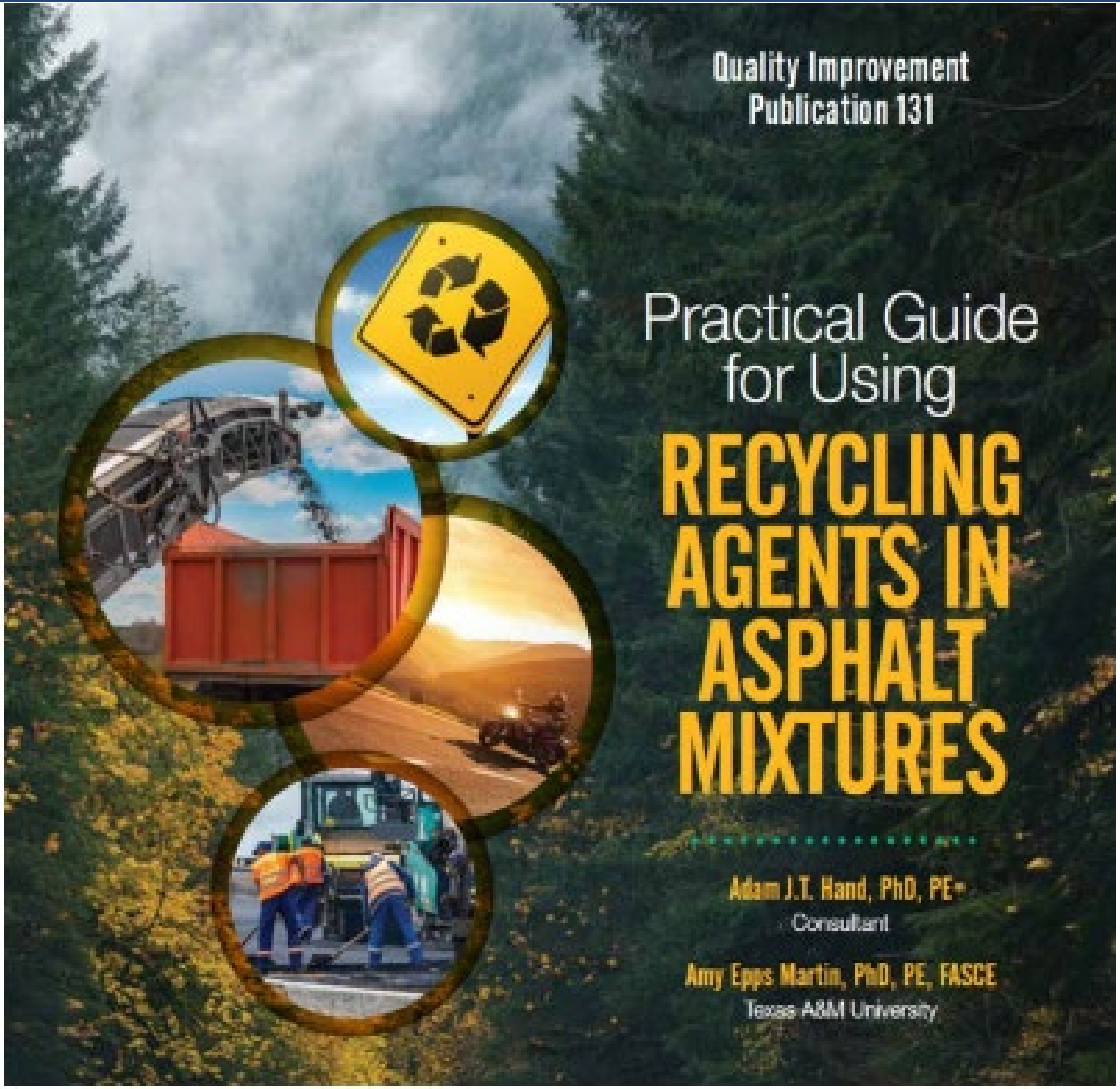
The Effects of Recycling Agents on Asphalt Mixtures with High RAS and RAP Binder Ratios

Project Data	
Funds:	$1,500,000
Research Agency:	Texas A&M Transportation Institute
Principal Investigator:	Amy Epps Martin
Effective Date:	5/2/2014
Completion Date:	11/30/2018

- The **objective** of this research are to (1) evaluate the effectiveness of recycling agents in HMA and WMA mixtures with high RAS, RAP, or combined RAS/RAP binder ratios through a coordinated program of laboratory and field experiments; (2) propose revisions to several relevant AASHTO specifications and test methods; and (3) develop training and workshop materials and deliver one workshop

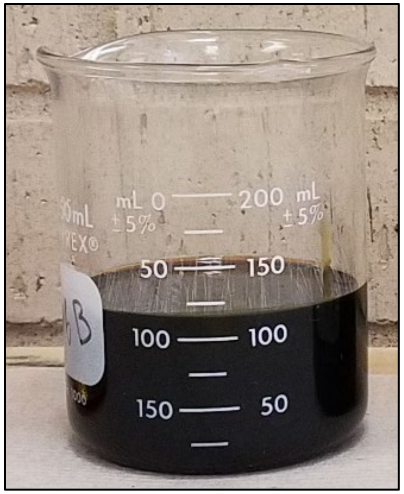
https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3645

Practical Guide for Using
Recycling Agents in Asphalt Mixtures



Outline

- Introduction
- Recycling Agents (RA)
- Mix Design Using Recycling Agents with Examples
- Practical Consideration when Producing & Placing Mixtures with RAs
- Other NAPA Resources
- Summary
- Q&A



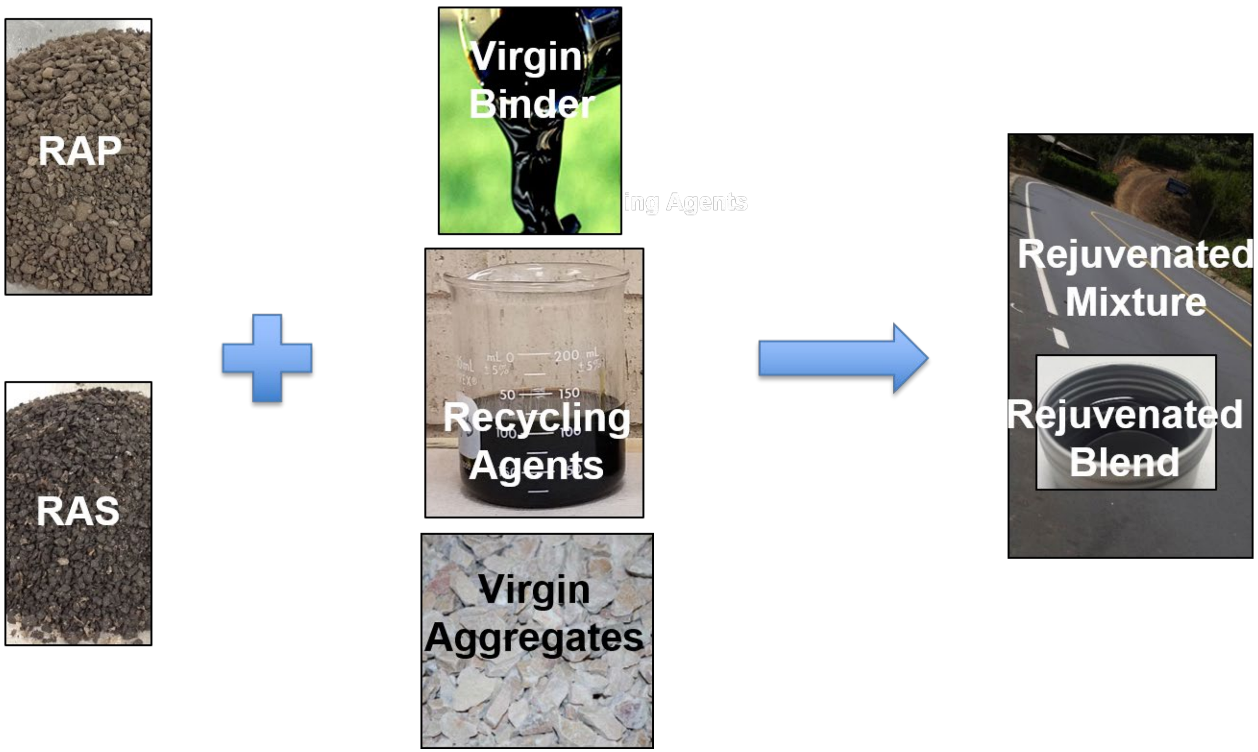
Introduction/Background

- Asphalt Industry is Sustainability Leader
  - RAP #1 Recycled Material in the U.S. (NAPA IS-138)
- Recycling & RA Focus
  - 1970's & 1980's Oil Embargoes: RAs Introduced
  - Late 2000's Binder Cost Increase: RAM use Increased
  - Early 2010's High RAM Durability Challenges & Solutions
    - Adequate and Softer PG Virgin Binders
    - Recycling Agents
- Primary RA Uses
  - Meet BMD Durability Requirements at Current RAM Level
  - Increase RAM Level, Other Benefits
- Economics of Increasing RAM *Very* Market Dependent
  - Urban vs. Rural, Specifications, S&D Commodity Prices, …

Recycling Agents

- Terminology Can Be Confusing, RA (ASTM D4552)
  - Softeners
  - Rejuvenators
  - Not Appropriate for Bio-Based RA
- Basic Types
  - Petroleum Products, Recycled Oils
  - Bio-Based (plant, vegetable, biomass, byproducts, “green,”…)
  - Not All Equal – NCHRP Project 09-58
- Import to Consider RA Stiffness, Brittleness and Compatibility
  - Several Recent & On-going Efforts to Better Classify RAs Defining Chemical, Physical and Engineering Properties
- Some Formulated to Incorporate WMA and/or Anti-Strip Benefits
- For Consistency We Used:
  - RA Doses are by Weight of Total Binder (virgin + recycled)
    - Example Calculations
  - RBR = Recycled Binder Ratio
    - Typically ≤ 0.30 with RAP = X% and RAS = Y%
    - Future ≤ 0.50, 0.65, 100?

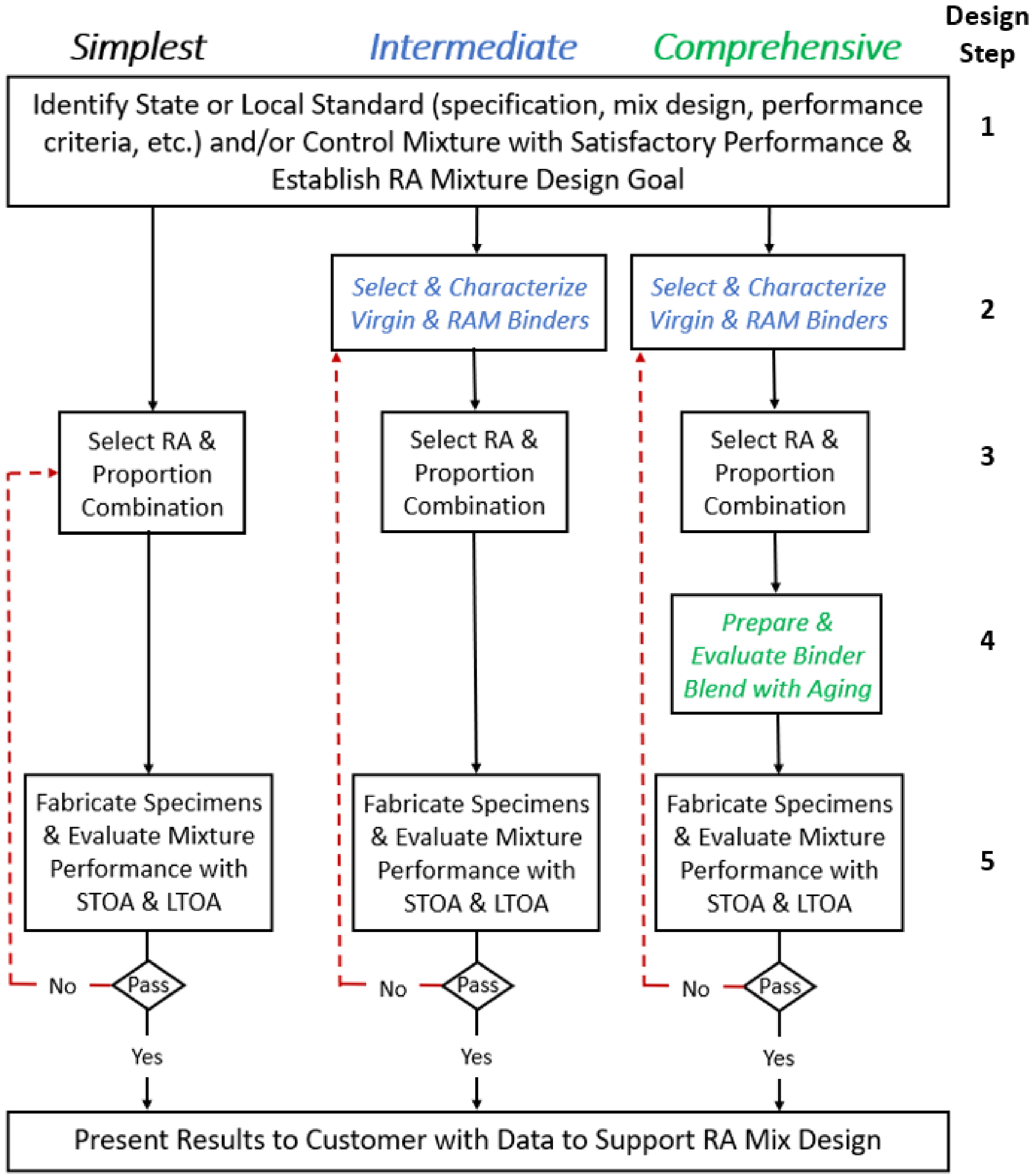
Mix Design


RAP
RAS
Virgin Binder
Recycling Agents
Virgin Aggregates
Rejuvenated Mixture
Rejuvenated Blend

Tiered Mix Design Approaches

Approach	Risks & Resources				Required Testing				
	Field Performance Risk	Mix Design Risk	Time & Equipment Needs	Cost	Virgin Binder	RAP/RAS Binder	Binder Blend	Mixture Rutting	Mixture Cracking
Simplest	Mod	High	Low	Low	No	No	No	Yes	Yes
Intermediate	Mod	Mod	Mod	Mod	Yes	Yes	No	Yes	Yes
Comprehensive	Low	Low	High	High	Yes	Yes	Yes	Yes	Yes

Mix Design


Simplest
Intermediate
Comprehensive
Design Step
Identify State or Local Standard (specification, mix design, performance criteria, etc.) and/or Control Mixture with Satisfactory Performance & Establish RA Mixture Design Goal
1
Select & Characterize Virgin & RAM Binders
Select & Characterize Virgin & RAM Binders
2
Select RA & Proportion Combination
Select RA & Proportion Combination
Select RA & Proportion Combination
3
Prepare & Evaluate Binder Blend with Aging
4
Fabricate Specimens & Evaluate Mixture Performance with STOA & LTOA
Fabricate Specimens & Evaluate Mixture Performance with STOA & LTOA
Fabricate Specimens & Evaluate Mixture Performance with STOA & LTOA
5
No
Pass
No
Pass
No
Pass
Yes
Yes
Yes
Present Results to Customer with Data to Support RA Mix Design

Mix Design

- Volumetrics
  - Consider effects of absorbed binder
    - $VMA = AV + V_{be} = f(G_{sb})$
    - $DP = p_{200} / P_{be}$
  - Reduce recycled binder availability
  - Increase effective binder
    - Increase OBC, VMA
    - Add RA
    - Specify min OBC
    - Decrease design AV
    - Reduce N

- Strategies for BMD
  - Increase RA dose or Change type
  - Select softer virgin binder or one with lower DT_c
  - Adjust aggregate blend
  - Modify split between RAP_{BR} and RAS_{BR} or reduce RAS_{BR}
  - Reduce overall RBR

Production Considerations – Plant Operations

- Additional Binder and/or Blending Tanks?
- RA can be Dosed at Plant or Terminal/Refinery
  - Flexibility to Adjust to RAM Level if at the Plant
  - Clear Defensible Communication of Dose & Dose Basis is Important
- If Blended at Plant *"On the Fly"* then Interlocked Controls, Calibration, …
  - Eliminates Need for Additional Asphalt Tanks
  - Small Doses: Right Sized Equipment – Pump, Meter, Blending Units Important
  - Temperature Compensation for Viscosity in Cool Climates and Pre-Heats Needed?
  - Adequate Blending Prior to Introduction into Drum Necessary
  - AASHTO M156 if Agencies Don't Have 109 Procedure

Production Considerations – Plant Operations

- Consistent RAP and RAS Production, Handling and Management
  - NAPA QIP-129 Best Practice on RAM Production for Consistency
  - In-Bound Sorting, Crushing, Fractionation
  - Stockpiling BPs
  - Moisture Management, Paving Under, Covering
    - Depends on Geographical Location
    - BPs Vary with Precipitation Levels
  - Feeding Best Practices
  - RAM vs. Virgin Aggregate Bins

Production Considerations – Plant Operations

- Consistent RAP and RAS Production, Handling and Management (Cont.)
  - NAPA QIP-129 Best Practice on RAM Production for Consistency
  - Appropriate Feed Bins with Scalping Screens, Air Cannons, Vibrators, Scalping to Re-Circ Crusher & Screen
  - Multiple Bins
  - Weigh Bridges Guarded from Elements
  - RAS Feed Low Very Percentages/Mass
    - Specialty/Modified Feed Bins
    - Weigh Bridge Sensitivity

Production Considerations – Plant Operations

- Consistent RAP and RAS Production, Handling and Management
  - NAPA QIP-129 Best Practice on RAM Production for Consistency
- Drum and Flighting Modifications?
- High RBR Mixes:
  - Counterflow Drums
  - Drum in Drum
  - Longer Drums
  - RAM % = f(plant type)
  - Fines Management
  - External Mixing Chambers

Production Considerations – Plant Operations

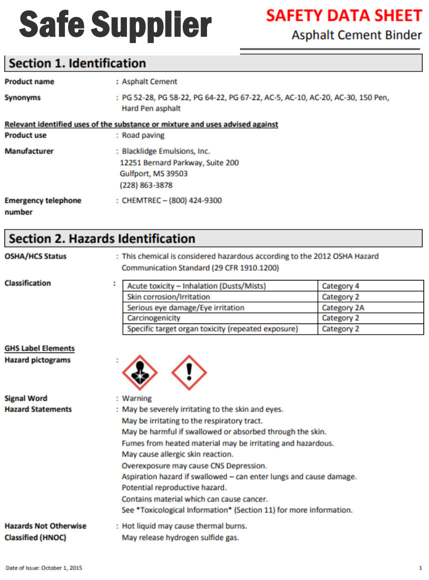
- See NAPA SR-213
- Fines Management
  - Washing Aggregates
  - Especially Crusher Fines
- Primary Collector Role
- Baghouse
  - Collected Fines
  - Metered Return
  - Ability to Waste
  - DP Specifications
  - Environmental Management

Production Considerations – Paving Operations

- Fewer Impacts
- Workability and Density Most Important
  - Can Be Improved with RA?
- Right Resources for the Job
- Cool Weather Paving
- WMA for Environment, Compaction, Moisture Sensitivity?
- Workability, Hand Work, Segregation & Joints – Same Game

Production Considerations - EH&S

- As with Any Raw Material Review RA SDS
  - Equipment – pH
- Bio-Based May Pose Lower Risks that Conventional RAs
- EH&S Experts Interviewed Unaware of Any Risks
- Some Comments About Aromas Worth Noting
- Human Detection Level Below Hazardous Level
  - Be a Good Industry Representation and Neighbor
  - Understand and Pro-Actively Communicate



Safe Supplier

SAFETY DATA SHEET
Asphalt Cement Binder

Section 1. Identification

Product name : Asphalt Cement

Synonyms : PG 52-28, PG 58-22, PG 64-22, PG 67-22, AC-5, AC-10, AC-20, AC-30, 150 Pen, Hard Pen asphalt

Relevant identified uses of the substance or mixture and uses advised against

Product use : Road paving

Manufacturer : Blacklidge Emulsions, Inc.
12251 Bernard Parkway, Suite 200
Gulfport, MS 39503
(228) 863-3878

Emergency telephone number : CHEMTREC – (800) 424-9300

Section 2. Hazards Identification

OSHA/HCS Status : This chemical is considered hazardous according to the 2012 OSHA Hazard Communication Standard (29 CFR 1910.1200)

Classification :

Acute toxicity – Inhalation (Dusts/Mists)	Category 4
Skin corrosion/Irritation	Category 2
Serious eye damage/Eye irritation	Category 2A
Carcinogenicity	Category 2
Specific target organ toxicity (repeated exposure)	Category 2

GHS Label Elements

Hazard pictograms :

Signal Word : Warning

Hazard Statements : May be severely irritating to the skin and eyes.
May be irritating to the respiratory tract.
May be harmful if swallowed or absorbed through the skin.
Fumes from heated material may be irritating and hazardous.
May cause allergic skin reaction.
Overexposure may cause CNS Depression.
Aspiration hazard if swallowed – can enter lungs and cause damage.
Potential reproductive hazard.
Contains material which can cause cancer.
See *Toxicological Information* (Section 11) for more information.

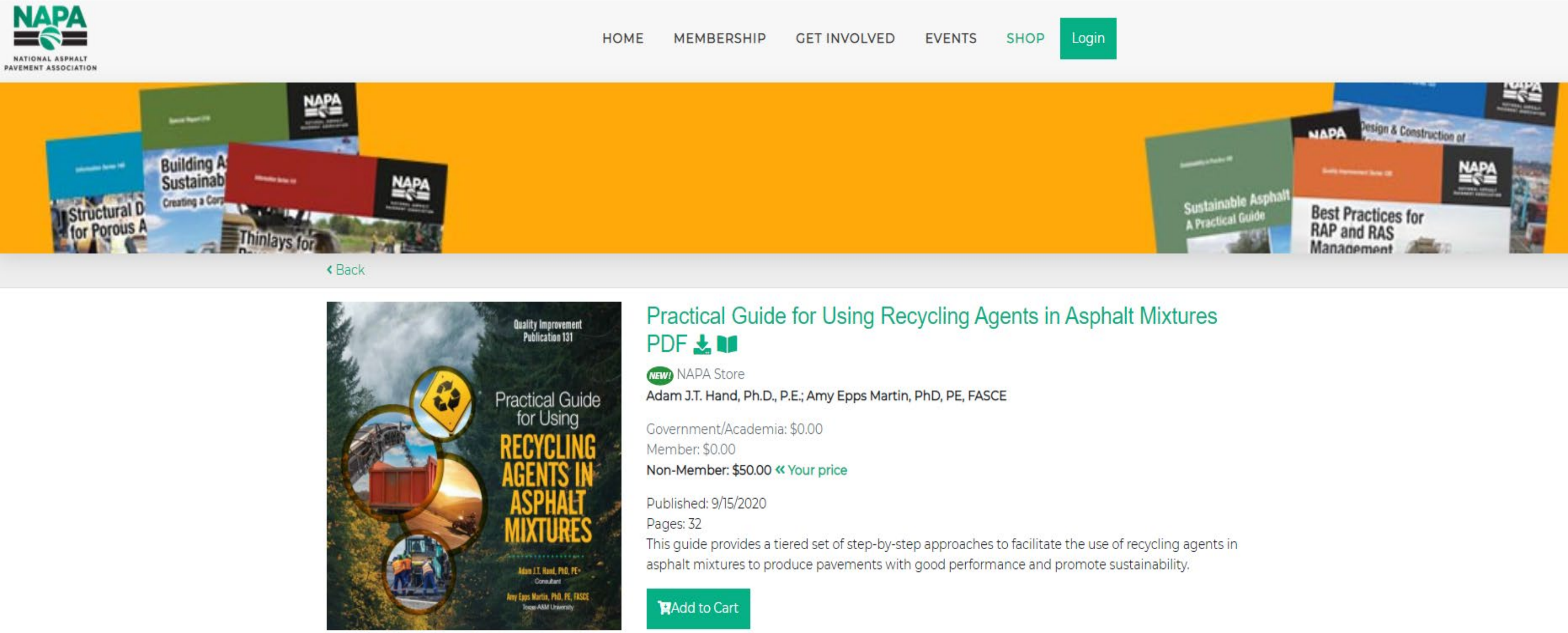
Hazards Not Otherwise Classified (HNOC) : Hot liquid may cause thermal burns.
May release hydrogen sulfide gas.

Date of Issue: October 1, 2015 1

Summary

- RAs can be Used to Produce High RAM Mixes with Good Performance
- Key Considerations Include: Material Selection, Mix Design, Plant Production, Paving Operations, Related Investments, and EH&S
- Producers Need to Balance Rigor/Risk and Cost/Time & Equipment Needs
- Every Contractor's Situation is Unique
- Every Materials Combination is Unique
- Long-term Aged Mixture Cracking Testing is Important
- Don't Lose Sight of Sustainable Benefits for Our Industry
  - They are Significant and Important
  - They Create Value for Businesses, Individuals and the Communities We Live In!
- Promote Responsible High RAM Use and Support Use with Data
- Don't Forget Quantifying Doses and EH&S Considerations
- Demonstrate BPs for Industry and Recycling!

How to Get the Practical Guide



https://member.asphaltpavement.org/Shop/Product-Catalog/Product-Details?productid={C4B79F72-93F7-EA11-A815-000D3A4DF1CD}

Other Related NAPA Resources

- NAPA IS-138 *Annual Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt Usage: 2021, 9th Annual Survey* (2019)
- NAPA QIP-129E *Best Practices for RAP and RAS Management* (2015)
- NAPA IS-136E, 2nd Ed, *Guidelines for the Use of Reclaimed Asphalt Shingles in Asphalt Pavements* (2019)
- NAPA SR-213E *Use of RAP & RAS in High Binder Replacement Asphalt Mixtures: A Synthesis* (2016)
- NAPA QIP-126 *Energy Conservation in Hot-Mix Asphalt Production* (2007/2023)
- NAPA IS-123E *Recycling Hot-Mix Asphalt Pavements* (2007)
- NAPA SIP-100 *Sustainable Asphalt Pavements: A Practical Guide* (2019)

NCHRP Project 09-64

NATIONAL ACADEMIES Sciences Engineering Medicine

About TRB | Annual Meeting | Calendar | Committees & Panels | Programs | Projects | Publications | Resources & Databases

NCHRP 09-64 [Active]

Developing Laboratory Methods and Specifications to Test Tack Coat Materials

Project Data	
Funds:	$500,000
Staff Responsibility:	Edward T. Harrigan
Research Agency:	Univeristy of Nevada--Reno
Principal Investigator:	Adam J.T. Hand
Effective Date:	4/15/2020
Completion Date:	10/15/2022

- The **objective** is to *produce a specification with related laboratory test methods for tack coat materials* that allows prediction of their performance over a range of environments, pavement types, and construction methods. The consider test methods for tack coat characteristics related to bonding, tracking, and durability. The proposed specification shall exclude tests of tack coat materials bonded to asphalt or other substrates.

NEVADA

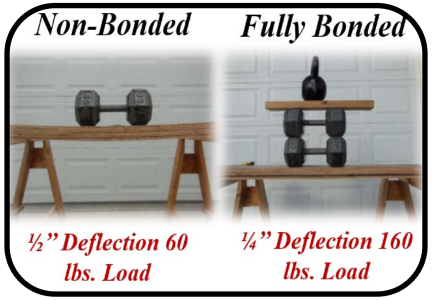
paragon technical services, inc.

https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4748

NCHRP Project 09-64 Motivation / Objective

Improper selection and application of tack coat

Reduces fatigue life



Increases rutting

Shoving

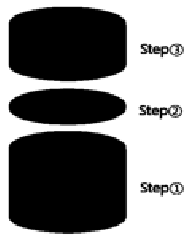
Slippage

NCHRP 09-64 Project Objective

NCHRP Project 09-64

I. AC Sample Preparation
(OBC per Superpave Mix Design)

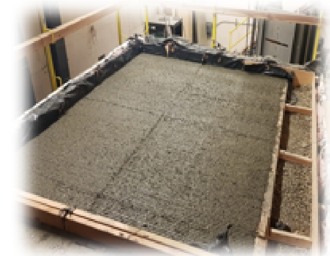
- Compact bottom layer
- Apply tack coat and cure
- Compact top layer
- Condition samples (0°C, 5°C, 25°C, Moisture conditioned)
- Perform Interlayer Shear Strength (ISS) testing
- Correlate ISS Results with fundamental rheological properties



Experimental Matrix

- **5 Surface Types** (New AC, Milled AC, Aged AC, New PCC, Aged PCC)
- **14 Tack Coat Materials** (including emulsions and hot applied binders)
- **4 Asphalt Binders in the Mixture** (PG 64-22(1), PG64-22(2), PG 58-28, and PG64-28NV)
- **3 Application Rate Levels** (Low, Medium, and High)
- **2 Mixture Types** (½ NMAS and ¾ NMAS mixtures)

II. Large Scale AC over PCC Slabs
(using UNR PAVEBOX)



NCHRP Project 09-64

Tack Coat Materials

- SS1(1)_In-spec
- SS1(2)_In-spec
- SS1(OS)_Off-spec
- SS1h(1)_In-spec
- SS1h(2)_In-spec
- SS1h(OS)_Off-spec
- HP NT(1)_In-spec
- HP NT(2)_In-spec
- HP NT(OS)_Off-spec
- PM NT_In-spec
- HPM_In-spec
- PG 67-22_In-spec
- HP NT-HA_In-spec
- PG 64-28 NV

Binders Used in the Mixture

- PG 64-22(1)
- PG 64-22(2)
- PG 58-28

Residue Recovered using:

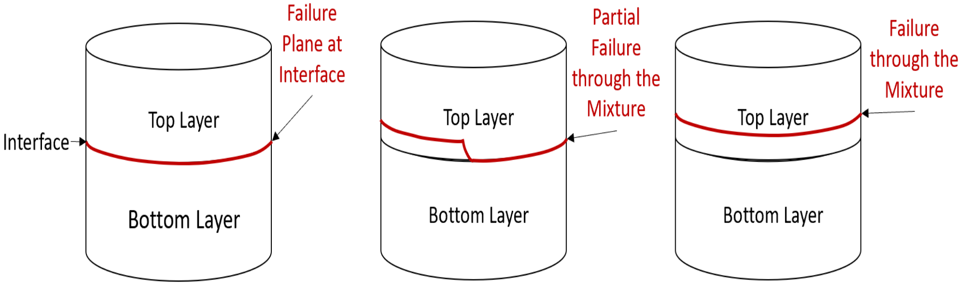
- Distillation Recovery Method
- LTE Recovery Method
- Vacuum Recovery Method

Residue/Binder Performance Tests

- Performance Grading
- Multiple Stress Creep & Recovery (MSCR)
- Crossover Temperature
- Viscosity
- Penetration
- Softening point
- Tackiness Test
- 4 mm DSR on original and RTFO aged residue/binder materials

ISS Bond Strength

- No Tack Coat vs. 13 Tack Coats
- Failure Mechanism
  - –Interface
  - –Through Mixture
- $\text{PGHT}_{\text{Tack Coat}} \geq \text{PGHT}_{\text{Binder in the Mix}}$ to improve interlayer shear strength

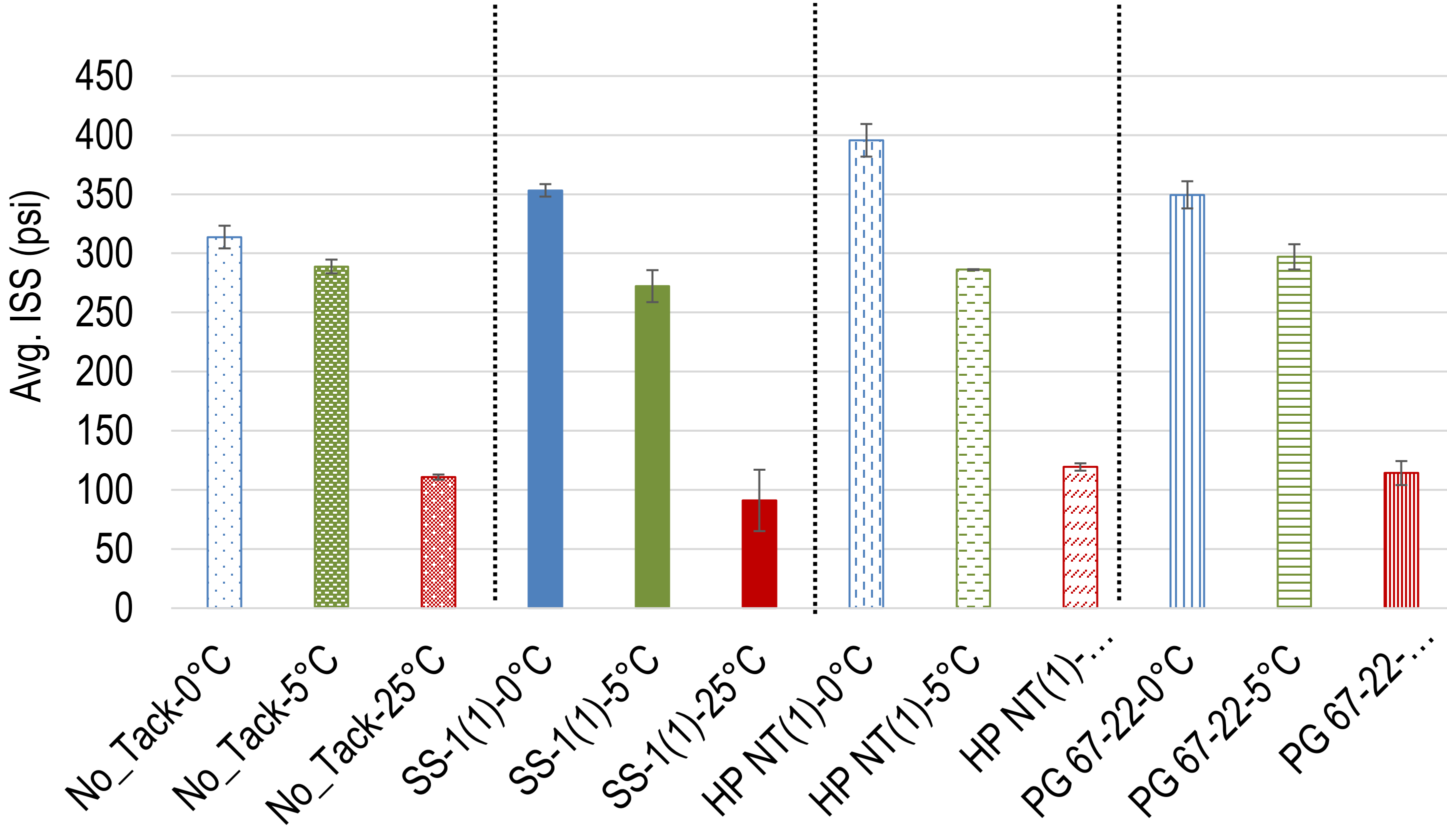


Type A Type B Type C

Type A Type B Type C

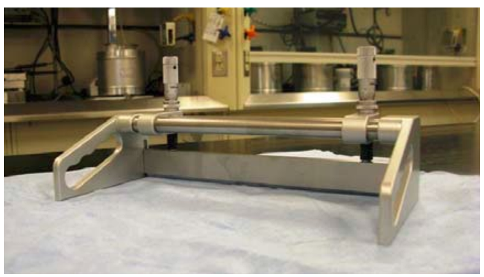
ISS Bond Strength

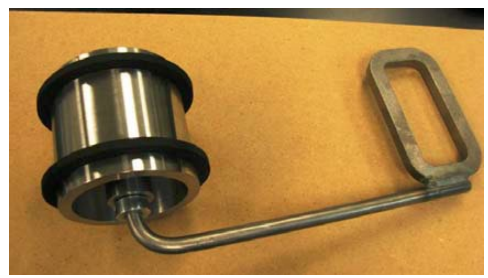
- 25, 5 & 0°C
- Moisture Conditioning (T283 F/T)

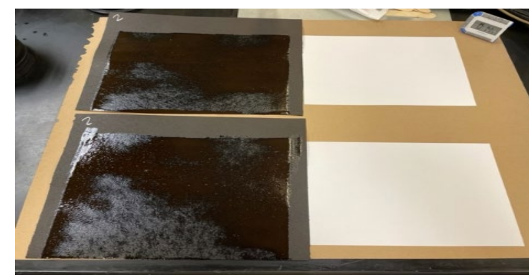


Tracking Tests

- AASHTO DSR: G*, G*/sin δ, Crossover Temperature, …
- ASTM DSR: Tracking Temperature
- BASF Modified ASTM Paint/Coatings Test

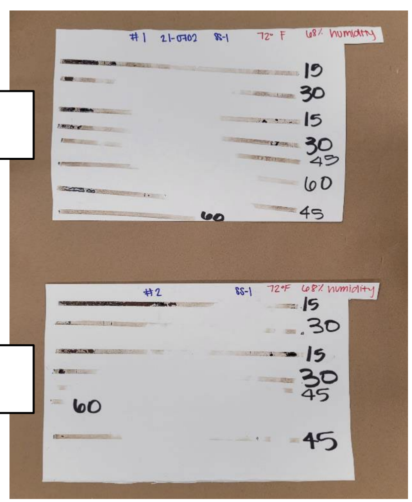


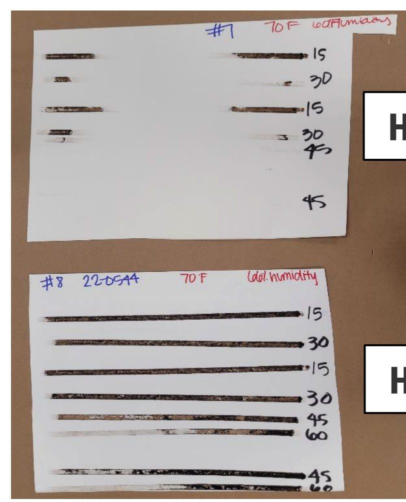




SS1(1)

SS1(2)





HP NT(1)

HP NT(2)

Outcomes

- Specification (AASHTO Format)
  - Bond Strength: *Tack Coat PGHT*
  - Tracking: *Crossover Temperature* > *Onset of Tracking Temperature*
  - Durability: *Aging Index*
  - Emulsion Residue: *Distillation Method*
- National Transportation Product Evaluation Plan (NTPEP) Workplan
  - Defines the evaluation procedures for Asphalt Tack Coats
  - Laboratory testing to determine properties of Asphalt Tack Coats
- Field Validation Work Plan
  - Field Experiment Projects
  - Tack Coat Material Specification and Test Method
  - Tack Coat Construction Specifications
  - Pavement Bond Strength Sampling and Testing
  - Documentation, Communications and Reporting

NCHRP Project 09-69

NATIONAL ACADEMIES Sciences Engineering Medicine

About TRB | Annual Meeting | Calendar | Committees & Panels | Programs | Projects | Publications | Resources & Databases

NCHRP 09-69 [Active]

Verifying Quantities of Materials Used in Asphalt Mixtures at Production Facilities

Project Data	
Funds:	$350,000
Staff Responsibility:	Amir N. Hanna
Research Agency:	University of Nevada, Reno
Principal Investigator:	Adam J. T. Hand
Effective Date:	6/28/2022
Completion Date:	10/28/2024

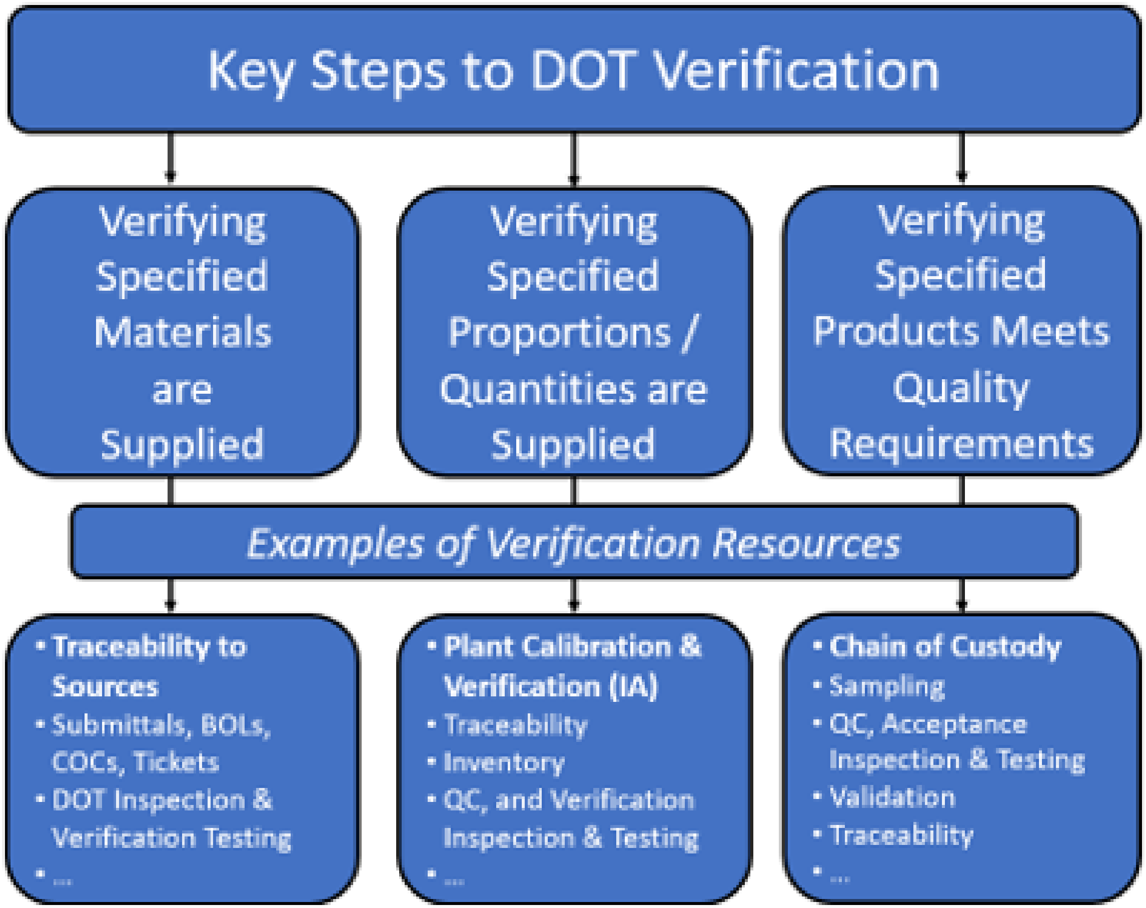
- The objectives of this research are to (1) *recommend procedures for verifying quantities* of materials used in asphalt mixtures at production facilities and (2) prepare *guidelines for their application*.

NEVADA | ATS Asphalt Testing Solutions & Engineering | National Center for Asphalt Technology NCAT at AUBURN UNIVERSITY

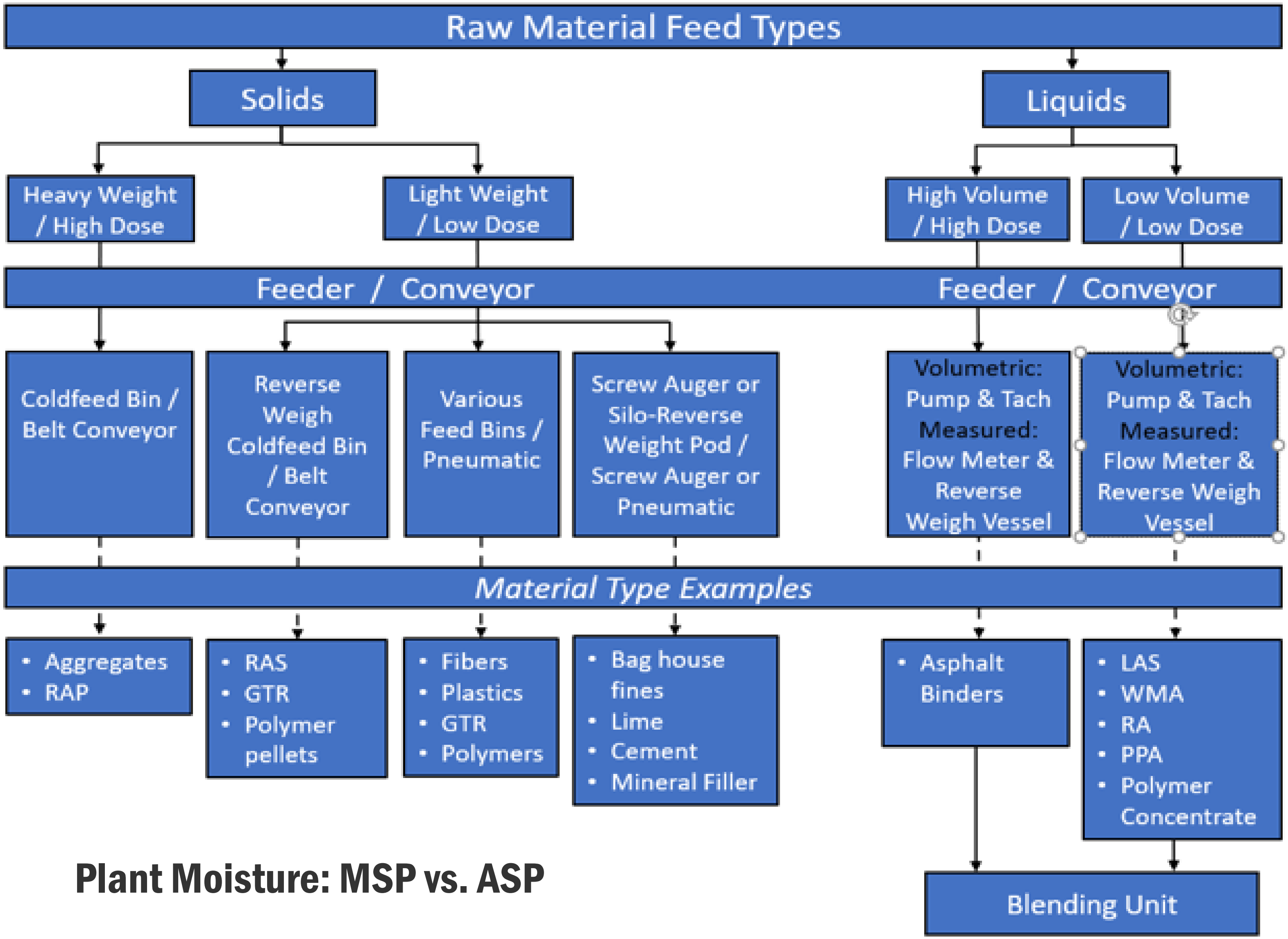
https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=5142

NCHRP Project 09-69

- Example Entities
  - Georgia DOT
  - Illinois DOT
  - Maine DOT
  - Oregon DOT
  - Texas DOT
  - Utah DOT
  - FAA & USACOE



NCHRP Project 09-69



Plant Moisture: MSP vs. ASP

NCHRP Project 09-69

- Early in Project
- Summer 2023
  - Procedures: Weight Basis
  - Apply at Hot Plants

NCHRP Project 09-69

NAPA/FAA AAPTP Coop

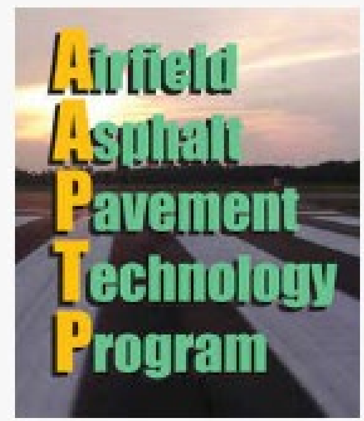
NATIONAL ASPHALT PAVEMENT ASSOCIATION

AIRPORT ASPHALT PAVEMENT TECHNOLOGY PROGRAM (AAPTP)

AAPTP Airport Asphalt Pavement Technology Program

REQUESTS FOR PROPOSALS | CURRENT PROJECTS | PROJECT COORDINATION GROUP

- NAPA FAA Partnership
- Management / Benefits
- 9 On-going Projects
- $3M more Appropriated
- ? Future Projects
- *Research Panel Participants*



https://www.asphaltpavement.org/expertise/engineering/airports/current-projects

AAPTP On-Going Projects

1. Guidance on Selection of Asphalt Binder Grades
2. Asphalt Mixtures Paving Handbook Revision
3. BMD Evaluation of Cracking Tests for Airfields
4. BMD Evaluation of Rutting Tests for Airfields
5. Improving Performance of Longitudinal Joints in Airfield Pavements
6. Mitigation of Plastic Flow & Delamination at High-Speed Exits
7. Feasibility of Cold Central Plant Recycling (CCPR) Asphalt Mixtures for Airports
8. Validation of Gyration Level for Superpave Gyratory Compactor (SGC) for Mix Design and Control of Airport Asphalt Mixtures
9. P-401 Mixtures: Aggregate Gradation Bands

https://www.asphaltpavement.org/expertise/engineering/airports/current-projects

AAPTP On-Going Projects

1. Guidance on Selection of Asphalt Binder Grades
2. Asphalt Mixtures Paving Handbook Revision
3. BMD Evaluation of Cracking Tests for Airfields
4. ***BMD Evaluation of Rutting Tests for Airfields***
5. Improving Performance of Longitudinal Joints in Airfield Pavements
6. Mitigation of Plastic Flow & Delamination at High-Speed Exits
7. ***Feasibility of Cold Central Plant Recycling (CCPR) Asphalt Mixtures for Airports***
8. ***Validation of Gyration Level for Superpave Gyratory Compactor (SGC) for Mix Design and Control of Airport Asphalt Mixtures***
9. ***P-401 Mixtures: Aggregate Gradation Bands***

https://www.asphaltpavement.org/expertise/engineering/airports/current-projects

Airport Asphalt Pavement Technology Program Balanced Mix Design: Rutting Performance Tests

- **Objectives:** Develop new FAA specs for using rutting tests as part of the new mix design process for airfield asphalt mixtures, based on the Balanced Mix Design methodology
  - Proper selection of rutting tests & associated test criteria
  - Use at the mix design phase & during production

NEVADA · Texas A&M Transportation Institute · Rutgers The State University of New Jersey · RDM Engineering Technology Research · DUVAL ENGINEERING

- Collaborating with BMD Cracking Test Research Team
  - Project Sampling, Protocols, …

Balanced Mix Design: Rutting Performance Tests

- Rutting Performance Test Methods

HT-IDT

Ideal-RT

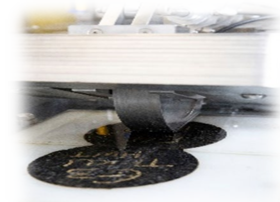
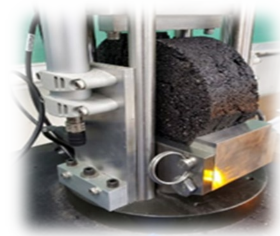
$APA_{100\ \&\ 250psi}$

RLT

HWTT

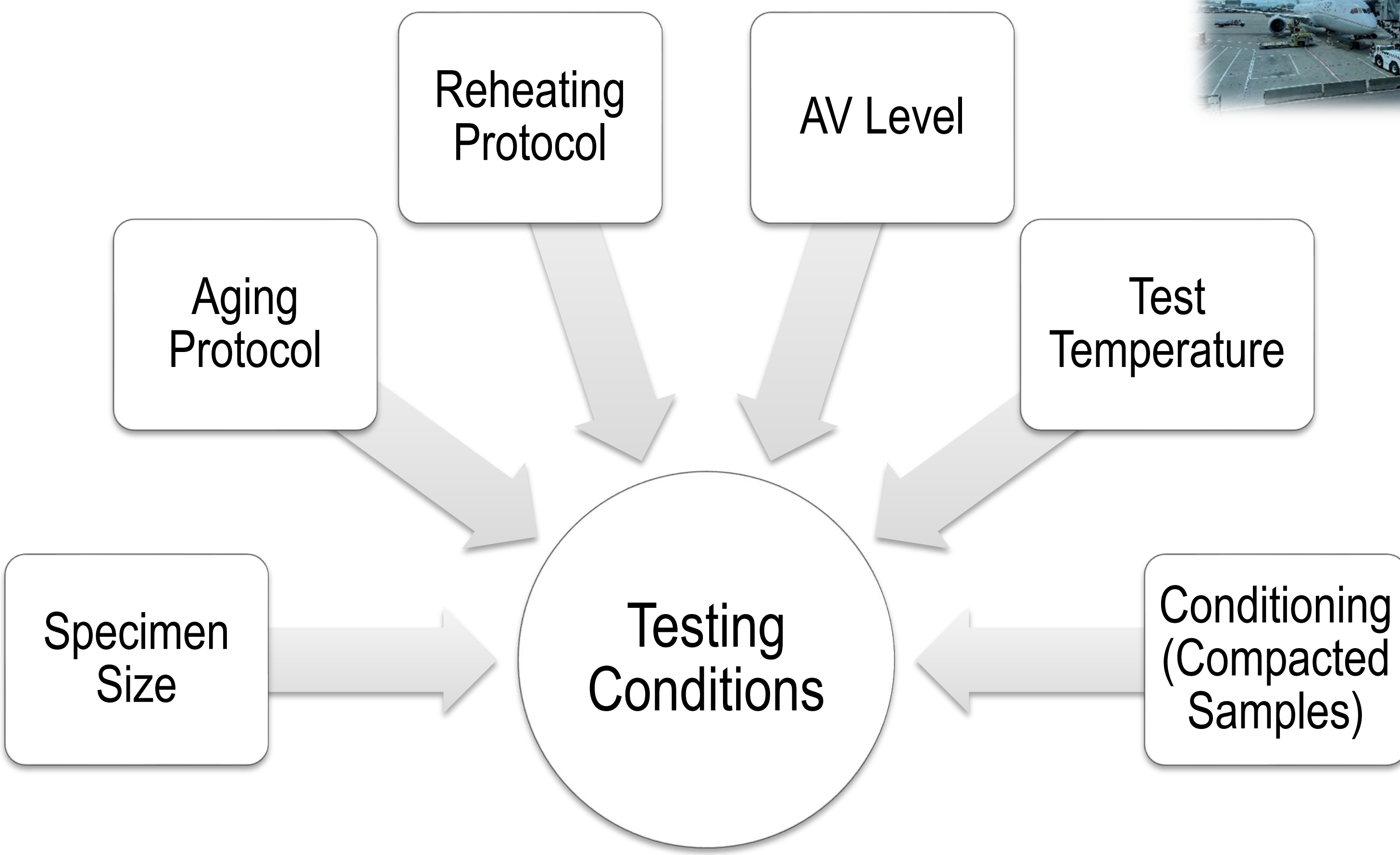
AMPT SSR

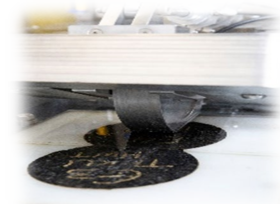
Implementable
&
Fundamental to Validate Only

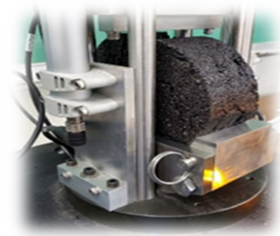




Airport Asphalt Pavement Technology Program
Balanced Mix Design: Rutting Performance Tests

- Rutting Performance Testing Conditions







Validation of Gyration Level for SGC for Mix Design and Control of Airport Asphalt Mixtures

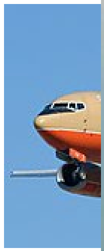
- **Objective:** Determine the numbers of gyrations with an SGC to achieve mixture volumetric properties equivalent to those using 50- and 75-blows with a Marshall hammer

National Center for Asphalt Technology NCAT at AUBURN UNIVERSITY

NEVADA

- Collaborating with BMD Rutting Project Research Team
  - Project Sampling, Protocols, …

Aircraft <60,000 lbs. & >60,000 lbs.



Bo
MTO

Boeing C-17 Travis AFB

00
0 lbs.

MTOW = Maximum Take-off Weight

Background

- FAA specifications (P401 and P403) allow the engineer to select compaction by either Marshall hammer or SGC
  - 75 blows or gyrations for aircraft weight >60,000 lbs
  - 50 blows or gyrations for aircraft weight <60,000 lbs
- Marshall hammer compaction used successfully for many decades prior to SGC, but SGC is now method of choice. Sometimes difficult to find labs with Marshall equipment.
- Concern remains that specimen densities from Marshall and SGC compaction are not equivalent, and the differences result in airfield asphalt mixtures with different in-service performance

Experimental Plan

Collect airfield asphalt mixes (Plant-produced)

Marshall Compacted Mixtures

- Marshall 75 or 50 Blows (JMF)
- Trial SGC Gyrations
  - $N_{EQ/M70}$ or $N_{EQ/M50}$ (from Phase I)

Evaluate G_{mb} and G_{mm}, determine $\%G_{mm}$

SCG Compacted Mixtures

- SCG 75 or 50 Gyrations
- Marshall blows
  - 75 if (JMF Ndes=75); 50 if (JMF Ndes=50)

Evaluate G_{mb} and G_{mm}, determine $\%G_{mm}$

Compact at another gyration (N) to match $\%G_{mm}$ of Marshall samples

Analyze $\%G_{mm}$ vs. Number of Gyrations (Figure A)

Determine second SGC Compactive Effort to Bracket Marshall G_{mb} for each Mixture

Analyze Statistics of all 50 Mixtures (Figure B)

Recommend appropriate $N_{EQ/75M}$ and $N_{EQ/50M}$ considering all mixtures

Laboratory Testing and Data Analysis

- Each mixture analyzed to find equivalent gyrations that provide same $\%G_{mm}$ (volumetrics) as the corresponding Marshall compaction (Figure A).

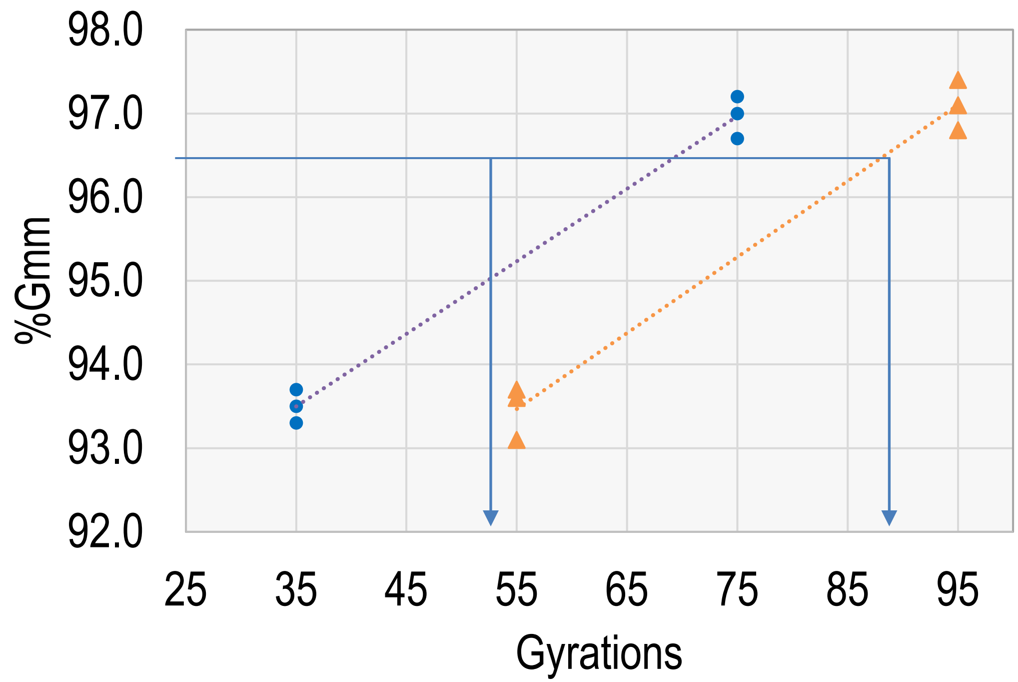


Figure A. Analysis of $\%G_{mm}$ vs. gyrations

Laboratory Testing and Data Analysis

- N_{EQ} results for all mixtures plotted on a cumulative distribution function to analyze statistics to aid in recommending the N_{EQ} (Figure B).

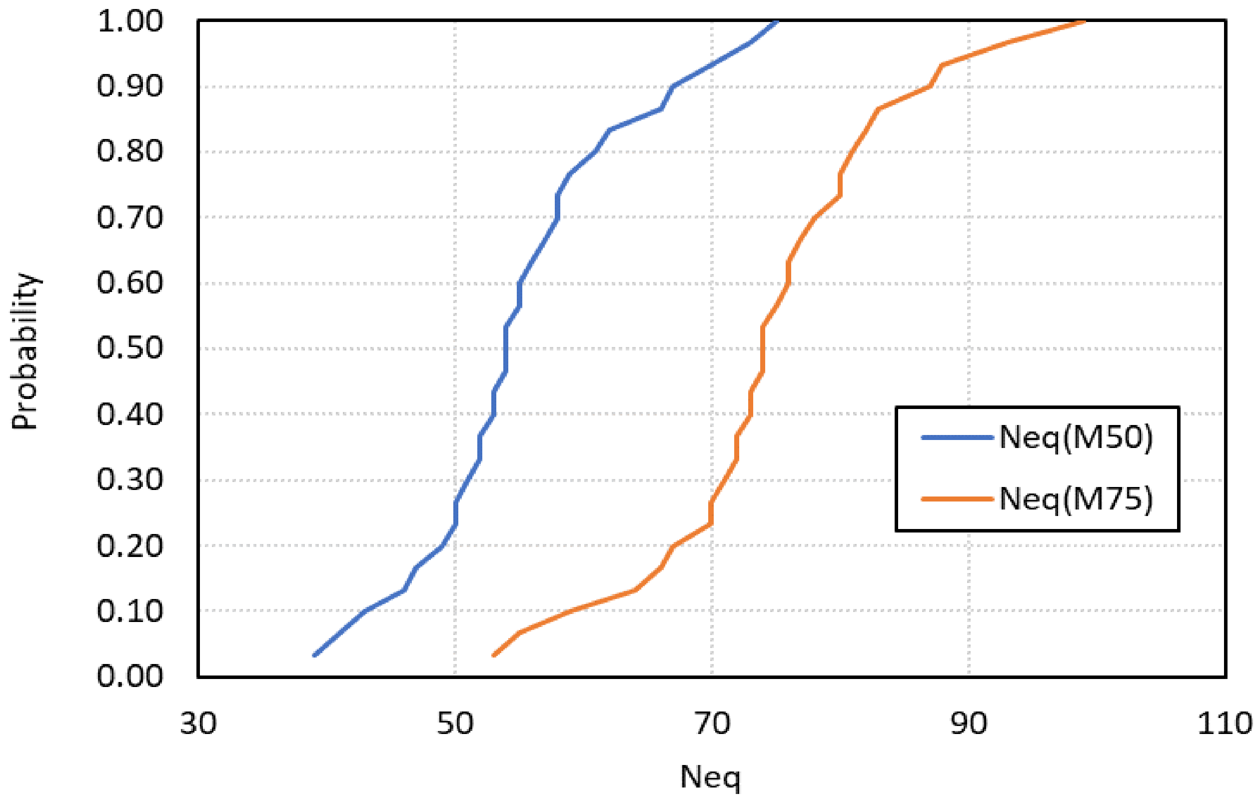
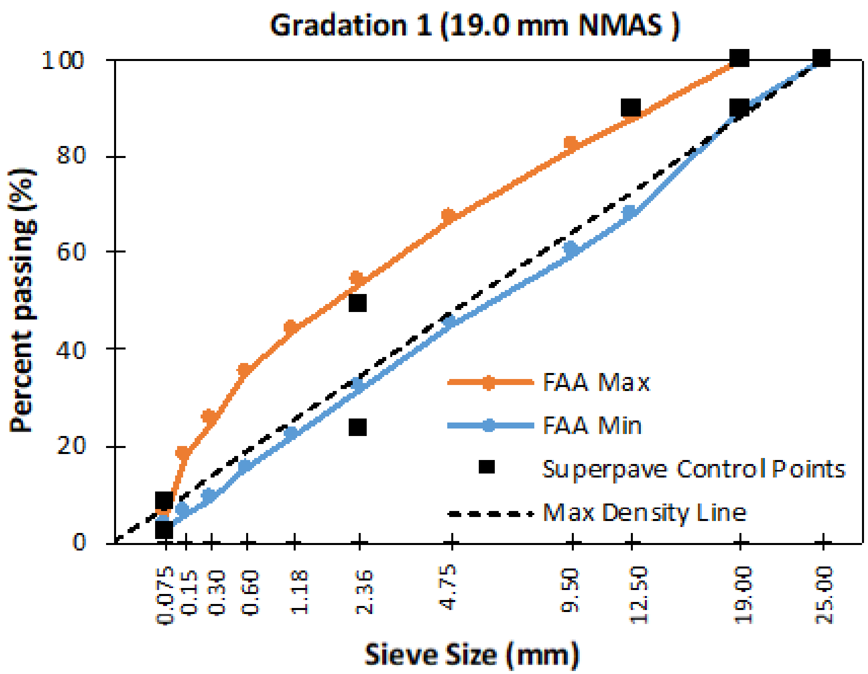


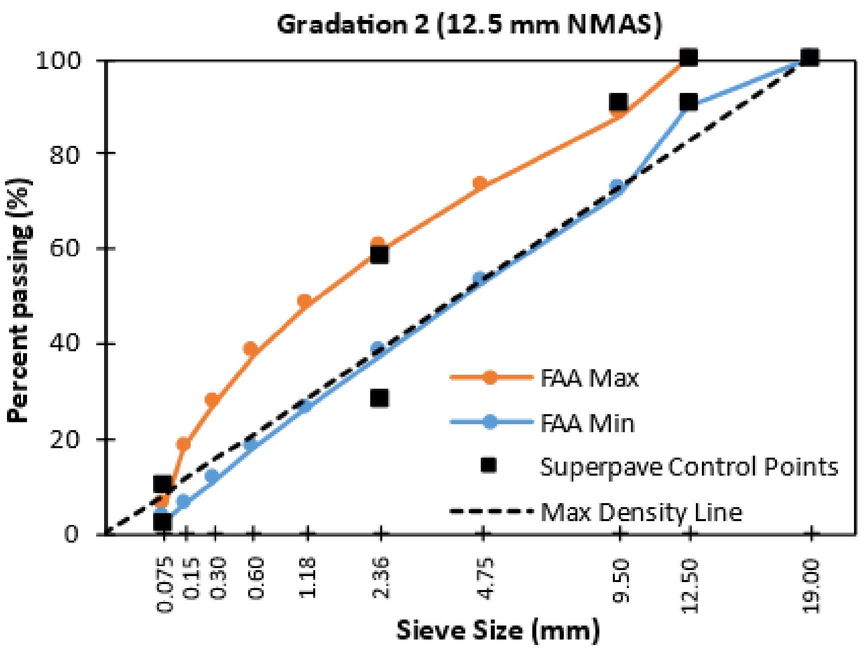
Figure B. Example Cumulative Distribution Functions for N_{EQ} Considering All Tested Mixtures

P-401 Mixtures: Aggregate Gradation Bands

- **Objective:** The outcome of this project will be to ensure that the FAA has **recommended gradation band requirements based on how mixture gradation is related to lab mix performance**. The recommended gradation band requirements should be the **least restrictive** allowable while maintaining the performance expectation for P-401 specified FAA mixtures. The recommended gradation band adjustments are not expected to impact other P-401 mixture property requirements. The research findings may include necessary adjustments to mix property requirements beyond gradation provided those adjustments will not negatively impact asphalt mixture performance. The recommended gradation band requirements should **focus on critical sieves and provide ranges that allow mix designers to use the most cost effective and environmentally friendly resources possible without pavement quality concerns** related to mixture gradation. The project will develop resources for mix designers to evaluate mixture gradation and the impacts on mixture performance within the recommended gradation bands. **A process and procedure that ensures asphalt mixture performance, but allows for modification of aggregate gradation requirements on a regional basis** will be included with the new gradation band requirements

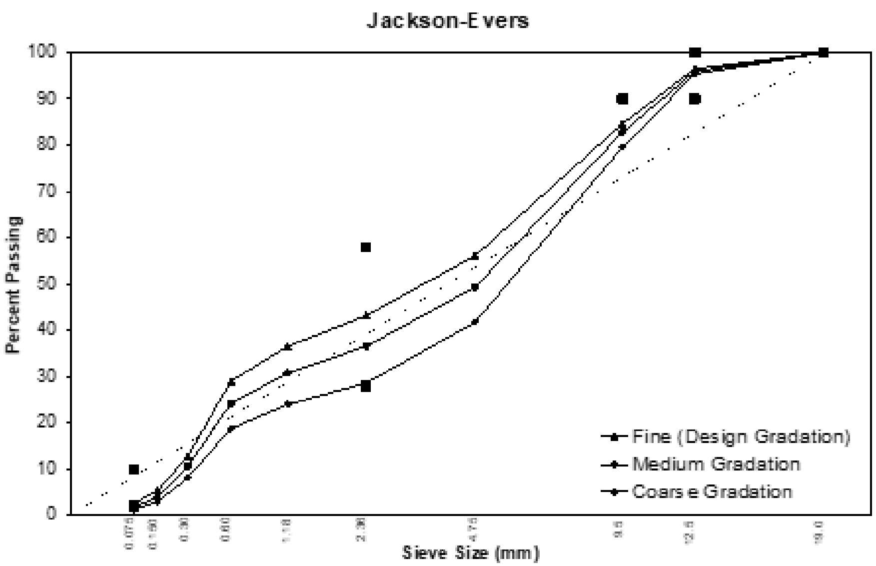
Current FAA Gradation Specifications



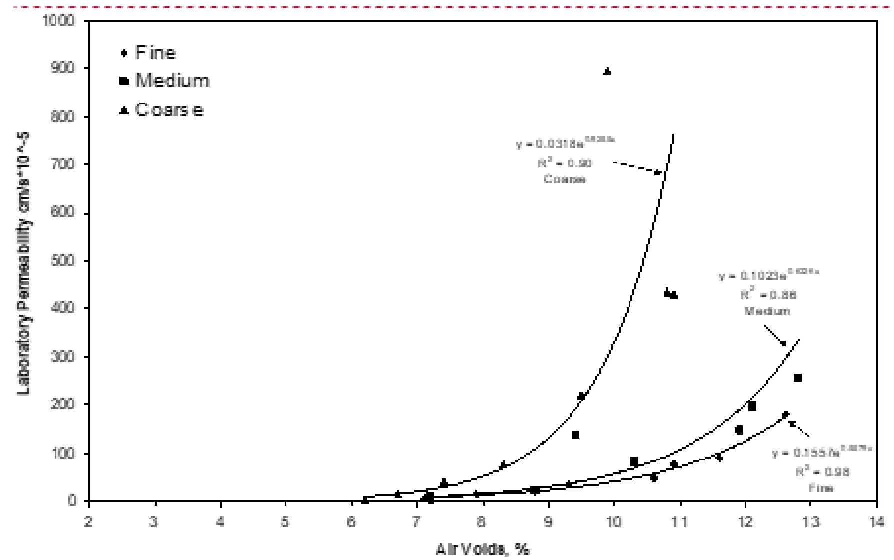


FAA Historic Durability Concerns

- Design %AV = 3.5% vs. 4.0%
- VMA = M323 +1.0%
- Gradation Bands = Reduce Permeability

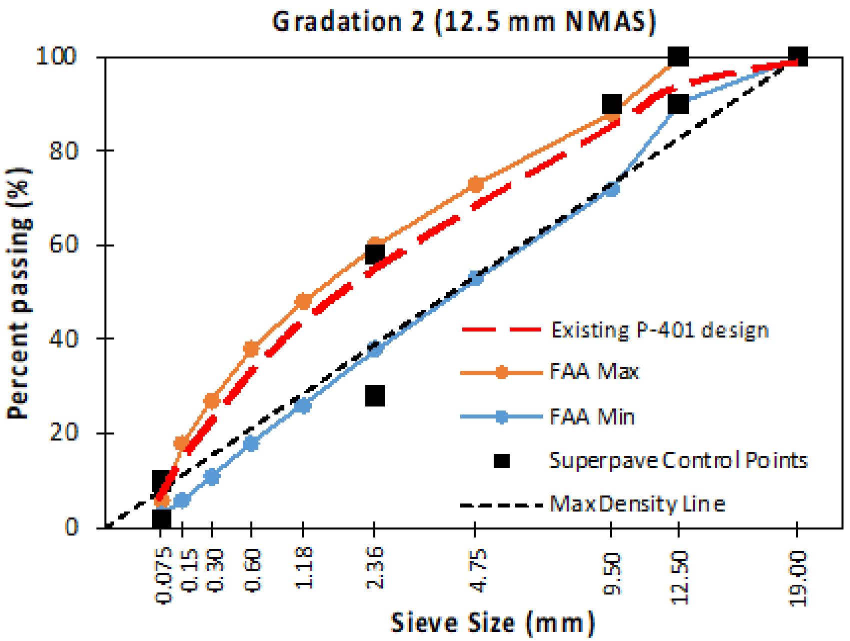


(a) Design and Altered Gradations

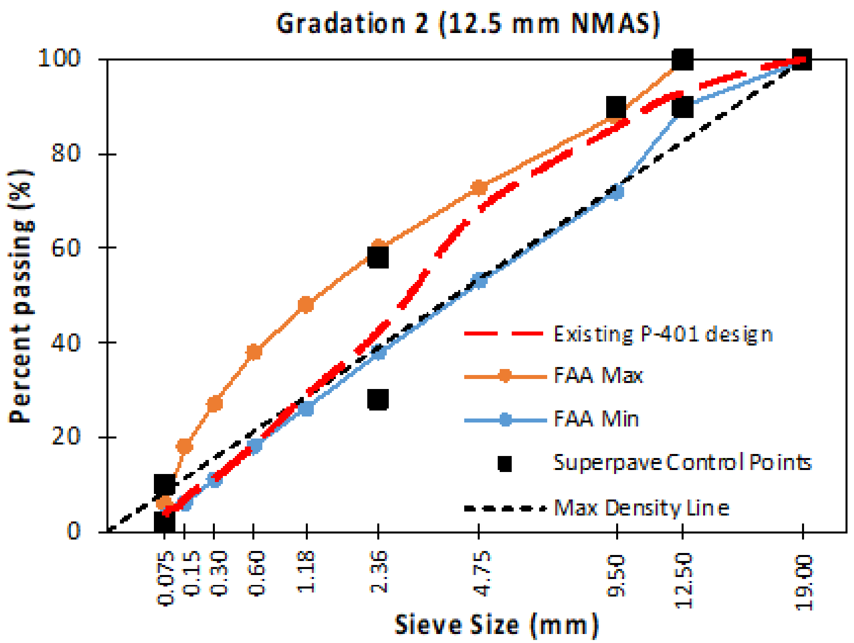


(b) Permeability vs. Air Voids

Example FAA Gradations (1/2" NMAS)



(a) Design Gradation Close to Upper Limits



(b) S-Curve Design Gradation Changing from Upper Limits (Coarse) to Lower Limits (Fine)

Work Plan

P-401 Mix Design (currently meeting FAA performance expectation) → New Mix Design (gradation deviating outside P-401 bands while still meeting all volumetric requirements) → If performance test results are equal or meet specified criteria, gradation of new mix design can be used to adjust gradation limits

Mixture Performance	Mixture Test	Aging Condition	Test Parameters	Test Standard
Rutting	APA	P-401 requirement or used in AAPTP BMD Rutting Test	Rut depth	AASHTO T 340 at 250 psi hose pressure
	HWTT		Rut depth	AASHTO T 324
Moisture Susceptibility	TSR	P-401 Requirement	TSR	AASHTO T283
Top-down Cracking	I-FIT	Following the procedure used in AAPTP BMD Cracking Test	FI	AASHTO T 393
	IDEAL-CT		CT_{Index}	ASTM D8225
Low-temperature Cracking	DCT		Fracture Energy (G_f)	ASTM D7313
Durability	Cantabro		Mass loss	AASHTO T401
Permeability	Florida Permeability Test	Short-term Aging	Permeability coefficient (k)	FM 5-565

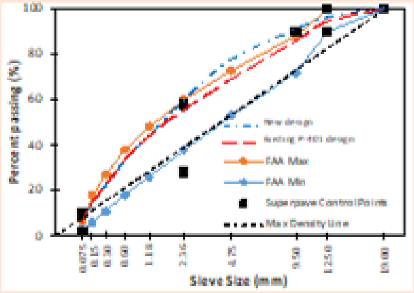
1. Input Existing Mix Design Information

- ❑ Asphalt binder
- ❑ Aggregate
  - Gradation
  - Consensus properties
  - Source properties
- ❑ Mixture type
  - Compaction method & effort
  - NMAS
  - Gradation type
- ❑ Volumetric properties
  - Binder content
  - Air voids
  - VMA, VFA & D/P
- ❑ Performance test results
  - APA or HWTT
  - TSR
  - Cracking test(s)
  - Permeability test

2. Adjust Aggregate Gradation

Agg.	Existing Design	Adjusted Design
#1	X_1%	Y_1%
#2	X_2%	Y_2%
...	X_3%	Y_3%
New	X_4%	Y_4%

Existing vs. Adjusted Gradation



3. Estimate Changes in Volumetric Properties

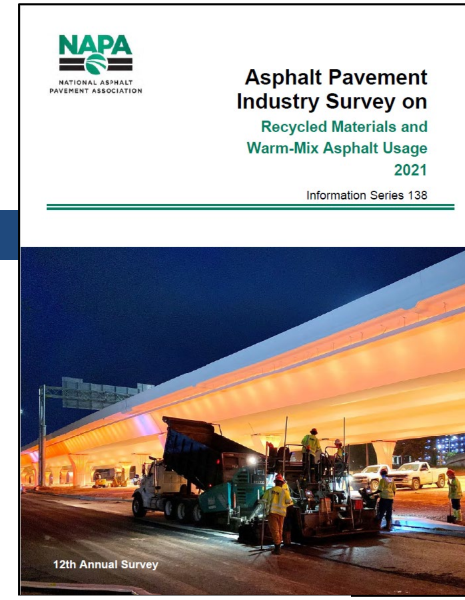
- ❑ Binder content
- ❑ Air voids
- ❑ VMA
- ❑ VFA
- ❑ D/P

⇧ ⇩

4. Estimate Changes in Performance Properties

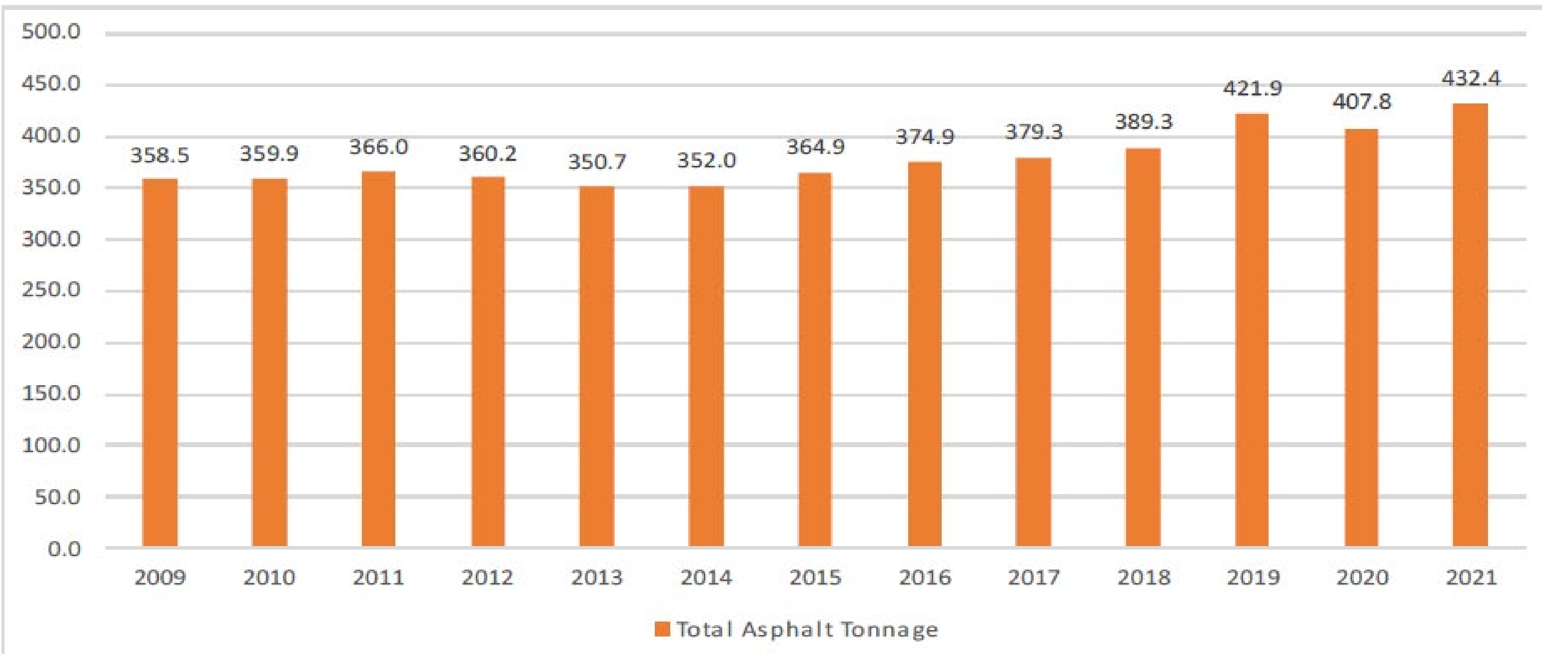
- ❑ Rutting resistance
- ❑ Cracking resistance
- ❑ Moisture susceptiblity
- ❑ Permeability

Reminder



NAPA IS-138 Publication

- 2021 Just Published
- 2022 Survey Coming Soon



https://www.asphaltpavement.org/expertise/sustainability/sustainability-resources/recycling

Q&A

Adam Hand
University of Nevada, Reno
Email: adamhand@unr.edu
Phone: (775) 742-6540