LADOTD Balanced Mixture Design

Samuel Cooper III , Ph.D., P.E.
Materials Research Administrator, LADOTD

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Acknowledgements

- LTRC Asphalt Research Group
  - Jeremy Icenogle, Patrick Frazier, Willie Gueho, David Mata, Bill King
- LADOTD Materials Lab
  - Chris Abadie, Jason Davis
- EMCRF
  - Dr. Louay Mohammad , Dr. Minkyum Kim
- Louisiana HMA Producers

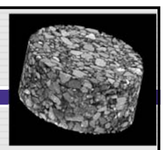
Introduction

- LADOTD's conventional design practice:
  - Gradation
  - AC Content
  - VFA, VMA, % Air Voids
  - Moisture Susceptibility Test (Modified Lottman), and
  - Roadway Parameters: Density, Smoothness
- Increases in recycled material content
- Methods to evaluate mixture performance indicators
  - Determine Asphalt Quality vs Quantity

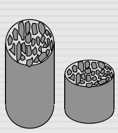
Objectives of Mixture Design

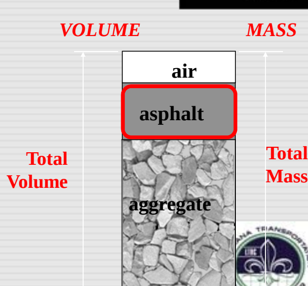
- Perform
  - permanent deformation
  - fatigue cracking – repeated load
  - low temperature cracking
  - moisture induced damage
- Safety
  - Resist skid
- Constructible
  - Workability

Asphalt Mixture Design: Concern



- Optimum asphalt cement content
  - Quantity
  - NOT QUALITY
  - RAP and/or RAS



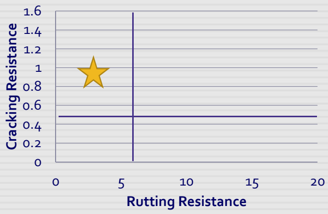


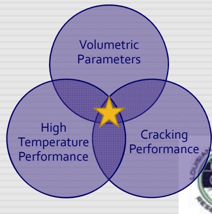
How?

- Laboratory tests to evaluate the as-built pavement qualities.
- The test will screen materials prone to rutting, cracking and alternative moisture damage indicators.
  - Create a Balanced Mixture Design

How?

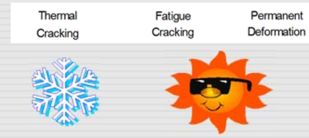
- What is a balanced mixture design?
  - Process to ensure adequate resistance to both rutting and cracking distresses
- Laboratory testing:
  - Rutting and Cracking





How?

- Mechanistic Tests
  - Pavement Performance
- Intermediate Temperature
  - Fatigue endurance
- High Temperature
  - Permanent deformation
- Features
  - Fundamental
  - Easy to Use
  - Reliable
  - Cost

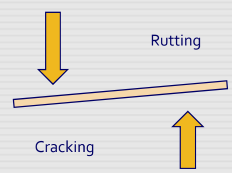


Major Issue

- Current LADOTD volumetric specifications created stiff mixtures very strong vs rutting failure.
- Concerns that the mixtures are too dry and too stiff.
  - Early cracking and durability
- Two research projects to create new specification parameters
  - LTRC Project 11-3b
  - LTRC Project 10-4b

LTRC Research Project 11-3b

- To implement the Loaded Wheel Tracking (LWT) test as a measure of mixture rutting resistance.
- To evaluate Semi-Circular Bend (SCB) test for intermediate temperature cracking resistance.



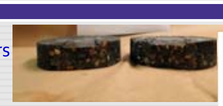
Rutting Resistance: LWT Test

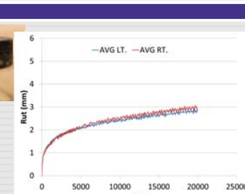
- Performance Indicator
  Resistance to Rutting and Moisture Sensitivity
- Test Protocol
  AASHTO T324
- Temperature
  50°C
- Loading

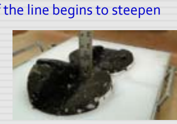
Wheel Diameter: 203.5 mm (8 inch)
Wheel Width: 47mm (1.85 inch)
Fixed Load: 703 N (158 lbs)
Rolling Speed: 1.1 km/hr
Passing Rate: 52 passes/min

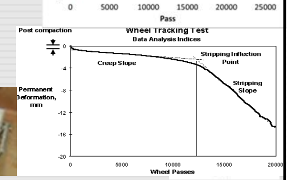
Rutting Resistance: LWT Test

- Performance Indicators
  Resistance to Rutting and Moisture Sensitivity
- Rutting Indicator:
  - Plot Rut Depth vs Number of Passes
  - Report Rut Depth at
    - 1000, 5000, 7500, 10000, 15000, and 20000 Passes
- Moisture Sensitivity Indicator
  - Determine Stripping Inflection Point
    - The point where slope of the line begins to steepen









Cracking Test?

- Several options available
  - Bending Beam Fatigue, SVECD, Overlay Tester, Intermediate Temperature SCB, Energy Ratio, Fracture Energy (ITS)
- Which one is best?
  - Each has advantages and disadvantages
- LADOTD selected Intermediate Temperature SCB
  - LADOTD TR 330
  - ASTM 8044

NCHRP Project 9-57
Experimental Design for Field Validation of Laboratory Tests to Assess Cracking Resistance of Asphalt Mixtures

Cracking test selection workshop-IV

- Workshop outcome: 7 cracking tests

Items	Reflection Cracking	Fatigue cracking	Thermal Cracking	Top-down Cracking
Selected cracking tests	1. OT 2. SCB-LTRC 3. BBF	1. Beam fatigue 2. SCB-LTRC 3. OT*	1. DCT 2. SCB-IL 3. SCB-TP105	1. SCB-LTRC 2. IDT-Florida
7 cracking tests	1. DCT 2. Three SCBs: SCB-TP105, SCB-LTRC, and SCB-IL 3. OT 4. Beam fatigue 5. IDT-Florida			

Zhou, F. , et. al., **Selection and Preliminary Evaluation of Laboratory Cracking Tests for Routine Asphalt Mix Design, AAPT, 2016**

Why SCB?

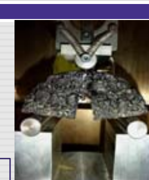
- Intermediate Temperature test for Intermediate Fracture
- Gyratory and field core
- Simplicity of testing equipment
  - can be adapted to plant lab
- History of forensic success and field correlation
- Fundamental fracture mechanics principles
- Test procedure
- Repeatable
  - Reporting COV of fracture energy less than 15%

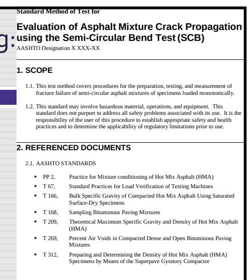
Intermediate Temperature Cracking: SCB Test

- Performance Indicator
  Resistance to Crack Propagation
- Test Protocol
  TR 330
- Temperature
  25°C
- Loading
  0.5 mm/min vertical deformation
- The Critical Value of Fracture Resistance,

$$J_c = -\left(\frac{1}{b}\right)\frac{dU}{da}$$

b = sample thickness,
a = notch depth,
U = strain energy to failure




Standard Method of Test for

Evaluation of Asphalt Mixture Crack Propagation using the Semi-Circular Bend Test (SCB)

AASHTO Designation X XXX-XX

1. SCOPE

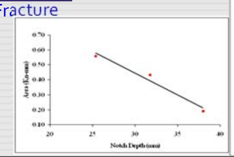
1.1. This test method covers procedures for the preparation, testing, and measurement of fracture failure of semi-circular asphalt mixtures of specimens loaded monotonically.

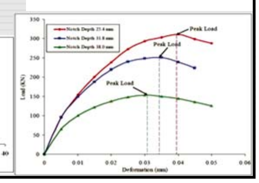
1.2. This standard may involve hazardous material, operations, and equipment. This standard does not purport to address all safety problems associated with its use. It is the responsibility of the user of this procedure to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.

2. REFERENCED DOCUMENTS

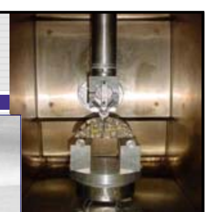
2.1. AASHTO STANDARDS

- PP 2, Practice for Mixture conditioning of Hot Mix Asphalt (HMA)
- T 67, Standard Practices for Load Verification of Testing Machines
- T 166, Bulk Specific Gravity of Compacted Hot Mix Asphalt Using Saturated Surface-Dry Specimens
- T 168, Sampling Bituminous Paving Mixtures
- T 209, Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt (HMA)
- T 269, Percent Air Voids in Compacted Dense and Open Bituminous Paving Mixtures
- T 312, Preparing and Determining the Density of Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor

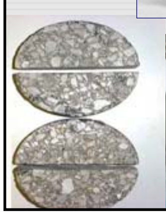


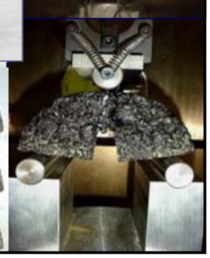


SCB Sample Preparation



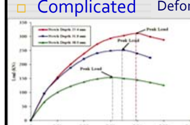
150mm x 57mm

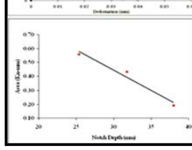




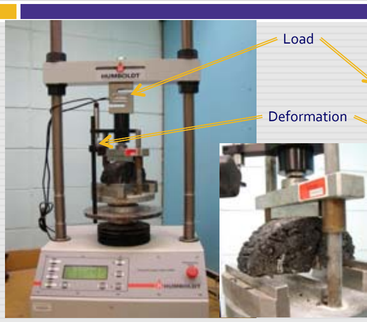
Conventional SCB Test

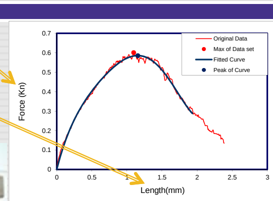
- Servo Hydraulic Test System
- Environmental Chamber
- Expensive
- Complicated

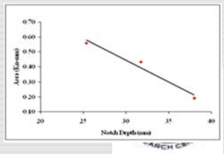




Modified SCB Test

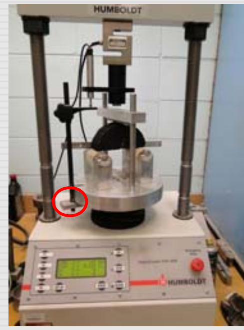


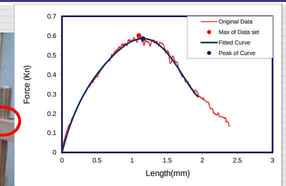


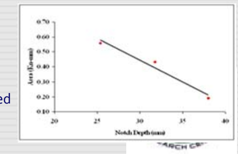


$$J_c = -\left(\frac{1}{b}\right)\frac{dU}{da}$$

Modified SCB Test







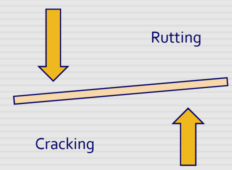
$$J_c = -\left(\frac{1}{b}\right)\frac{dU}{da}$$

*Temperature is controlled using an external environmental chamber

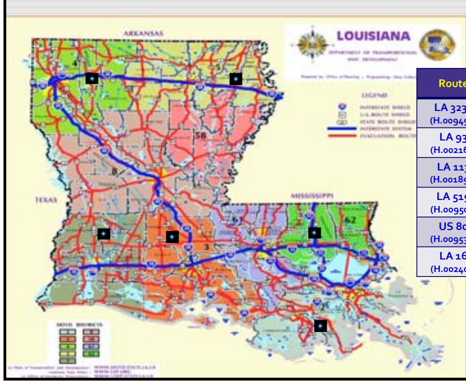
Test Equipment -- Development

LADOTD Specification Changes

- Lowered Gyrations (Level 1 and Level 2)
  - L1: 55 Gyrations N_d
  - L2: 65 Gyrations N_d
- VTM Remains
  - 3.5%
- Raised design VFA
  - 72%
- Raised VMA
  - 0.5% Increase for each NMAS

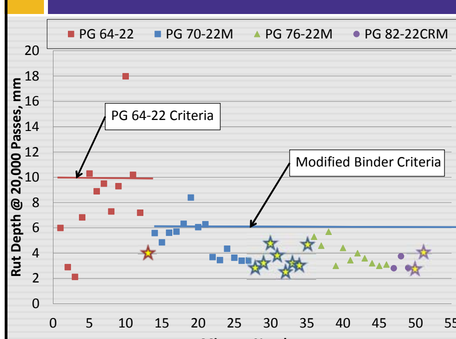


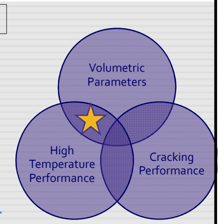
2013 Pilot Projects

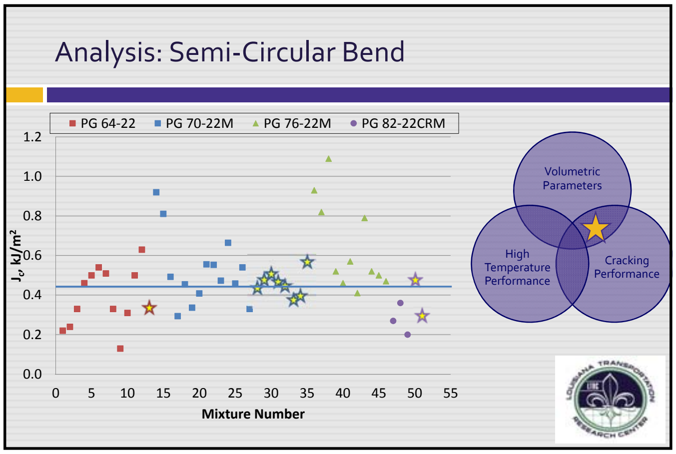


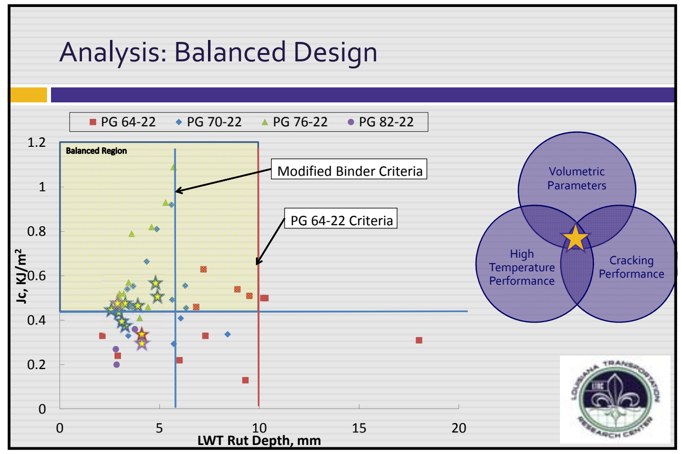
Route	DOTD Dist.	Description
LA 3235 (H.009491)	02	2" Lvl 1 BC 1.5" Lvl 1 FWC
LA 93 (H.002161)	03	3" Lvl 1 BC 2" Lvl 1 WC
LA 113 (H.001890)	07	2" Lvl 1 BC 2" Lvl 1 WC
LA 519 (H.009501)	04	2" Lvl 1 WC
US 80 (H.009536)	05	2.5" Lvl 1 BC 2" Lvl 1 WC
LA 16 (H.002403)	62	2" Lvl 2 BC 1.5" Lvl 2 FWC

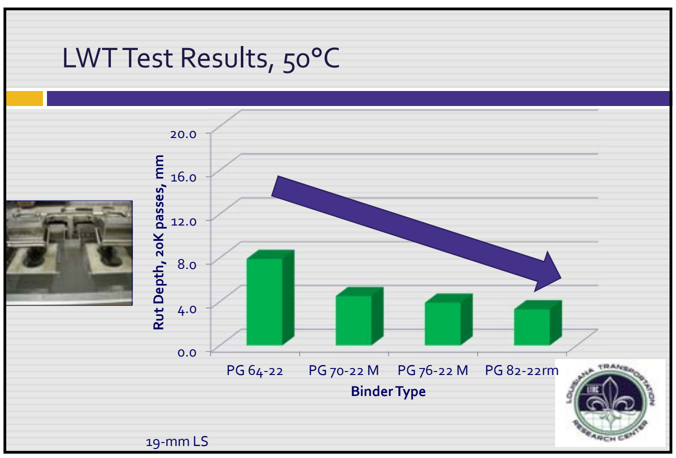
Analysis: Loaded Wheel Tester

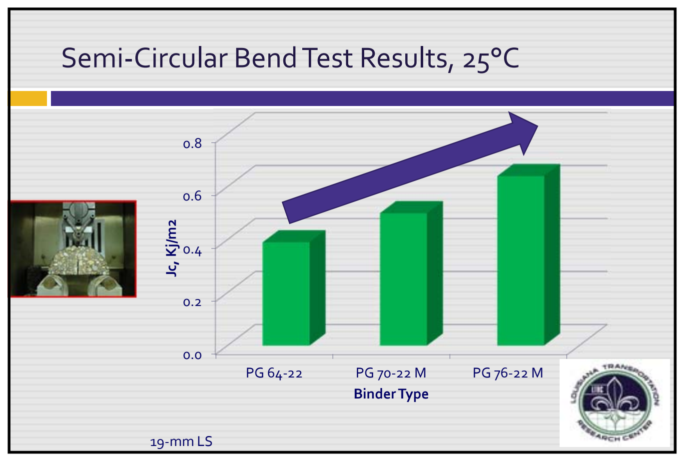


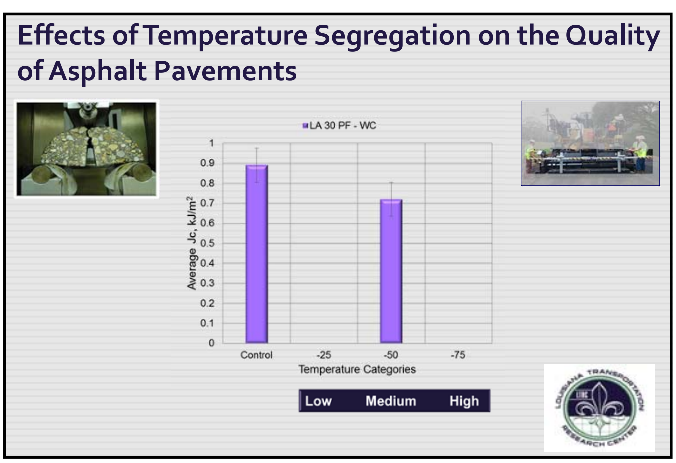


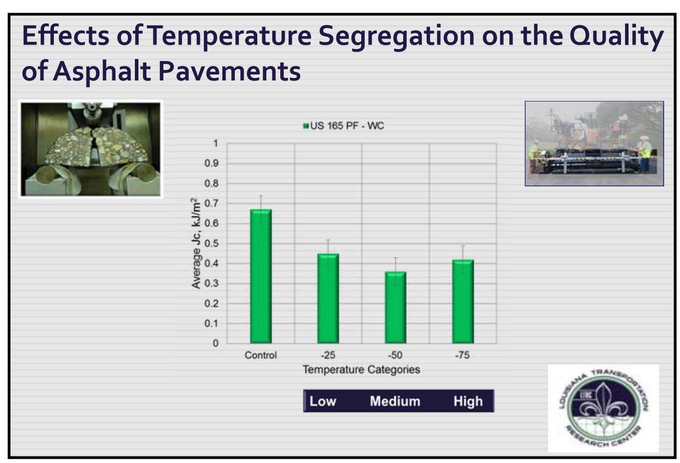

Analysis: Semi-Circular Bend
PG 64-22
PG 70-22M
PG 76-22M
PG 82-22CRM
Jc, kJ/m²
Mixture Number
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
5
10
15
20
25
30
35
40
45
50
55
Volumetric Parameters
High Temperature Performance
Cracking Performance


Analysis: Balanced Design
PG 64-22
PG 70-22
PG 76-22
PG 82-22
Balanced Region
Modified Binder Criteria
PG 64-22 Criteria
Jc, KJ/m²
LWT Rut Depth, mm
0
0.2
0.4
0.6
0.8
1
1.2
0
5
10
15
20
Volumetric Parameters
High Temperature Performance
Cracking Performance


LWT Test Results, 50°C
Rut Depth, 20K passes, mm
0.0
4.0
8.0
12.0
16.0
20.0
PG 64-22
PG 70-22 M
PG 76-22 M
PG 82-22rm
Binder Type
19-mm LS

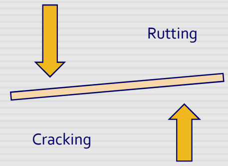

Semi-Circular Bend Test Results, 25°C
Jc, Kj/m2
0.0
0.2
0.4
0.6
0.8
PG 64-22
PG 70-22 M
PG 76-22 M
Binder Type
19-mm LS


Effects of Temperature Segregation on the Quality of Asphalt Pavements
LA 30 PF - WC
Average Jc, kJ/m²
Control
-25
-50
-75
Temperature Categories
Low
Medium
High


Effects of Temperature Segregation on the Quality of Asphalt Pavements
US 165 PF - WC
Average Jc, kJ/m²
Control
-25
-50
-75
Temperature Categories
Low
Medium
High

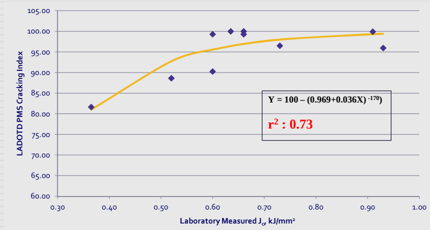
LTRC Research Project 10-4b

- Development of performance-based specification criteria.

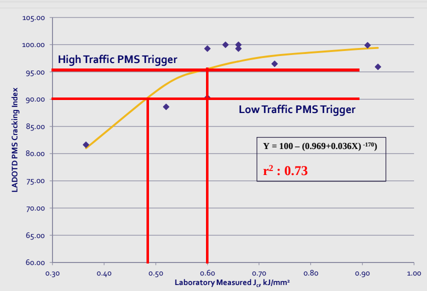


Field Validation: LTRC Project 10-4B

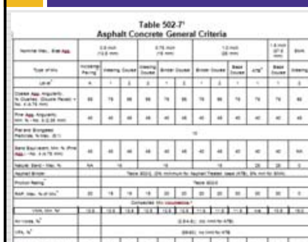
- Laboratory and Field evaluation of 10 projects
  - Projects in service for 3 – 10 years.
  - Does SCB parameter translate to field performance?



Field Validation: LTRC Project 10-4B



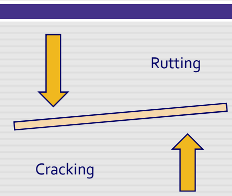
Field Validation: LTRC Project 10-4B



LWT, Rut Depth, 50°C, Wet	Level 1 : 10mm @ 20,000 passes maximum, Level 2 : 6mm @ 20,000 passes maximum.
SCB, min, J_c, kJ/m² @ 25° C, Aged	Level 1 : Jc = 0.5 minimum , Level 2 : Jc = 0.6 minimum.

LADOTD Specification Changes

- LWT required for all mixtures
  - L1: 10mm @20K passes (maximum)
  - L2: 6mm @ 20K passes (maximum)
- SCB required for all mixtures
  - L1: PG 70-22m, 0.5 kJ/m² (minimum)
  - L2: PG 76-22m, 0.6 kJ/m² (minimum)
- Allow for 5% increase in RAP if "fractionated" -split on the 1". (still must meet LWT and SCB for design)

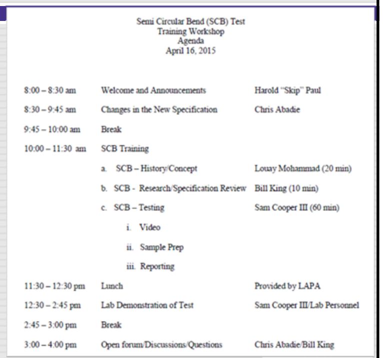


LADOTD Experience – What did we do?

- Developed a system to conduct mechanical property test to determine the anticipated performance of asphalt mixtures
  - LWT and SCB were the most feasible for implementation by state and contractor.
- Incorporate tests into state specification compliance evaluation.

LADOTD Experience – What did we do?

- Semi Circular Bend (SCB) Test Training Workshop
  - April 16, 2015
- Participants
  - Contractors
  - LADOTD
  - Consultants



Semi Circular Bend (SCB) Test
Training Workshop
Agenda
April 16, 2015

8:00 – 8:30 am	Welcome and Announcements	Harold "Skip" Paul
8:30 – 9:45 am	Changes in the New Specification	Chris Abadie
9:45 – 10:00 am	Break	
10:00 – 11:30 am	SCB Training	
	a. SCB – History/Concept	Louay Mohammad (20 min)
	b. SCB - Research/Specification Review	Bill King (10 min)
	c. SCB – Testing	Sam Cooper III (60 min)
	i. Video	
	ii. Sample Prep	
	iii. Reporting	
11:30 – 12:30 pm	Lunch	Provided by LAPA
12:30 – 2:45 pm	Lab Demonstration of Test	Sam Cooper III/Lab Personnel
2:45 – 3:00 pm	Break	
3:00 – 4:00 pm	Open forum/Discussions/Questions	Chris Abadie/Bill King

LADOTD Experience – What did we do?

- Develop a plant lab SCB test protocol.
  - Utilize Marshall Load Frames.
- Contractors in the state have adopted the methodology and are currently evaluating mixtures with success.
  - Reporting low variability of fracture energy
    - <15%
  - Specimen fabrication is a complication
  - Long Term aging protocol – 5 day @ 85°C is a concern.

LADOTD Experience Impacts

- 3 Districts have implemented the 2016 Specification
- LTRC is evaluating "balanced" mixtures designed under the new specifications
  - Increase in Hamburg Rut depth, still meets specification
  - SCB parameter, Jc, is being met
  - Asphalt Cement Increase of **0.2-0.4 %**
  - VFA no longer on the bottom of the range

LADOTD Experience Impacts

- Learning a lot about the relationship between base binders and mixture design.
  - Screens out binder blend compatibility concerns with latex and crumb rubber modification
  - **Binder Quality Matters!**

What's Next?

- Continue collecting a database of mixture LWT and J_c results and compare to field performance.
- Evaluate changes in test parameters from different specimen types
  - Mix Design vs. Plant Produced vs. Field Core
- Develop accelerated aging protocol
- Conduct research regarding the implementation of SCB into QC

Thank You!