Monitoring Oxidation Signals of Asphalt Pavement Surfaces by Portable Infrared Spectroscopy: in-situ testing of % RAP in HMA

Delmar Salomon
Iliya Yut
Pavement Preservation Systems, LLC

WASHTO
2016 Construction and Materials Subcommittee Meeting
April-3-6, 2016
Salt Lake City, Utah

Acknowledgements

Pavement Preservation, LLC thanks the Idaho Transportation Department for sponsoring this project, and Agilent Technologies for the loan of the portable hand-held infrared spectrometer.

Outline

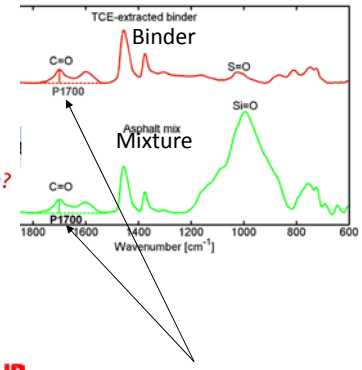
- Oxidation as major factor of HMA pavement deterioration → Need for quick field indicator of oxidation level of an HMA
- Laboratory studies of oxidation of asphalt by FT-IR Well known → SHRP 2 advances in field applications of portable FT_IR
- Nondestructive testing of oxidation levels in HMA by FT-IR
- Proposed AASHTO Standard Practice on measuring oxidation in HMA by FT-IR → Use of Portable Infrared Spectroscopy for : in-situ testing of RAP
- Potential of incorporating in-situ pavement oxidation index into PMS

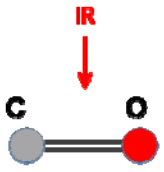
Infrared Spectroscopic Methods

Fourier-**T**ransform **I**nfra-**R**ed **(FTIR)** Spectroscopy

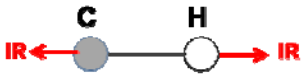
What is there ?

How much of it in there?





Bending vibration



Stretching vibration

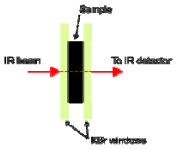
"Oxidation Signal"
From binder and mixture

Evolution of FT-IR Sampling Modes in Asphalt Studies

Transmission (since 1960s and SHRP – 1980s)

Destructive

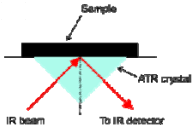
1. Dissolve sample
2. Prepare KBr pellets
3. Place sample into a cell

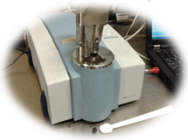


Attenuated Total Reflection (ATR) (1990s and SHRP2 2009-2014)

Non-invasive for binders
Mildly invasive for mixtures

1. Sieve or drill
2. Bring sample to instrument

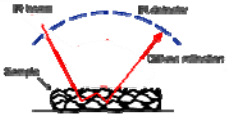




Hand-Held Diffuse Reflection (DR) – This study (Idaho 2015)
(a.k.a. Portable Infrared Spectrometer, or PIRS)

Non -destructive (point-and-shoot)

1. Bring instrument to sample



First Demonstration Study - Idaho

Monitoring the consistency of HMA/RAP samples and in-place Pavement using a Portable Infrared Spectroscopy Device (PIRS)

Objectives:

1. Evaluate PIRS capability of estimating %RAP.
2. Provide recommendations for use of PIRS on future paving projects.

Select projects	Collect materials	Mix calibration samples	Measure oxidation in mixes	Analyze data
Low RAP Medium RAP High RAP	Virgin binder Virgin agg. RAP	Vary %RAP (0-**15**-30-100) (0-25-**50**-100)	Lab (calibration) Plant, pavement (validation)	Variability Agreement between lab, plant, and pavement Influencing factors

Compare with Field results and Develop Recommendations

First Demonstration Study - Idaho

3 Projects and Materials – Mix Designs

Mix Design	Project 1	Project 2	Project 3
Project ID	"Karcher"	"Fruitland"	"Lewiston"
Location	Nampa, ID	Nampa, ID	Lewiston, ID
Traffic Level [ESAL]	1 - 10 mln	1 – 10 mln	10 – 30 mln
NMAS	12.5 mm	12.5 mm	12.5 mm
Target PG	70-28	70-28	76-28
RAP [by agg.]	17%	54%	45% (40% mill + 5% pit)
Adjusted virgin PG	70-28	52-34	70-34
Target P_b	5.3	5.3	5.6
RAP P_b	5.3	5.2	**6.0**
RAP PG (est.)	Unknown	PG 88-XX	PG 76(82)-XX (mill)
Antistrip	0.5%	0.5%	0.75%

First Demonstration Study - Idaho

Mix Sample Preparation with different % RAP

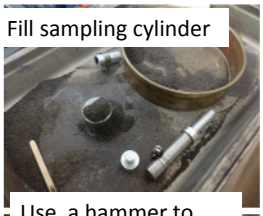
Sample type	Project	JMF RAP	Virgin Binder	Virgin Agg.	RAP	# of samples	Preparation
Laboratory	Karcher	17%	5.6% 4.7% 3.8% 2.9%	94.4% 80.3% 66.1% 52.0%	0% 15% 30% 45%	5 5 5 5	✓ Obtain components from contractor, ✓ Preheat components, ✓ Mix at plant T, ✓ Cool down, ✓ Store in a box
	Fruitland	54%	5.6% 4.1% 2.7% 1.3%	94.4% 70.9% 47.3% 23.7%	0% 25% 50% 75%	5 5 5 5	
	Lewiston	45%	5.7% 3.6% 2.8% 1.9%	94.3% 64.9% 52.2% 39.6%	0% 31% 45% 58%	5 5 5 5	
Source RAP			**Each project**			**5**	**No preparation**
HMA Plant			**Each project**			**5**	**No preparation**
Pavement			**Each project**			**5**	**No preparation**

* All weights =% by total aggregate

First Implementation Study - Idaho

Lab mix sample processing for PIRS scanning

Sieve through No.8-No. 30



Fill sampling cylinder

Use a hammer to compact sample

Plant mix sample processing for PIRS scanning

Example of Sampling cylinder with compacted HMA

D= ½ “ X L= 2 “

Testing in the Field (PIRS pavement monitoring)

First Demonstration Study - Idaho

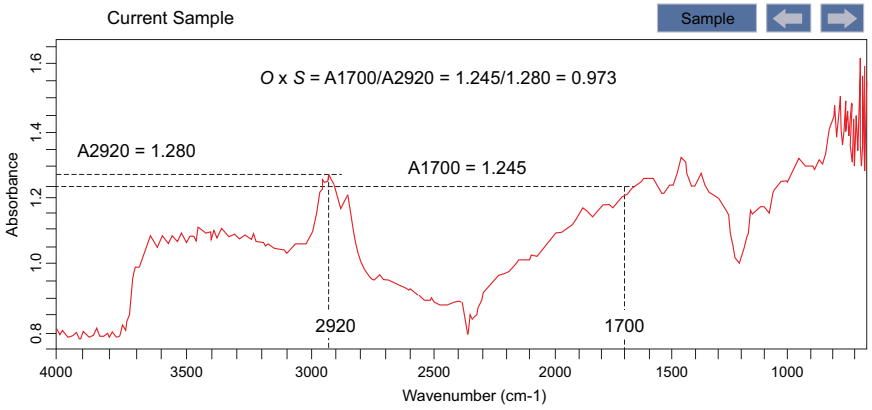
Measuring Oxidation in by PIRS

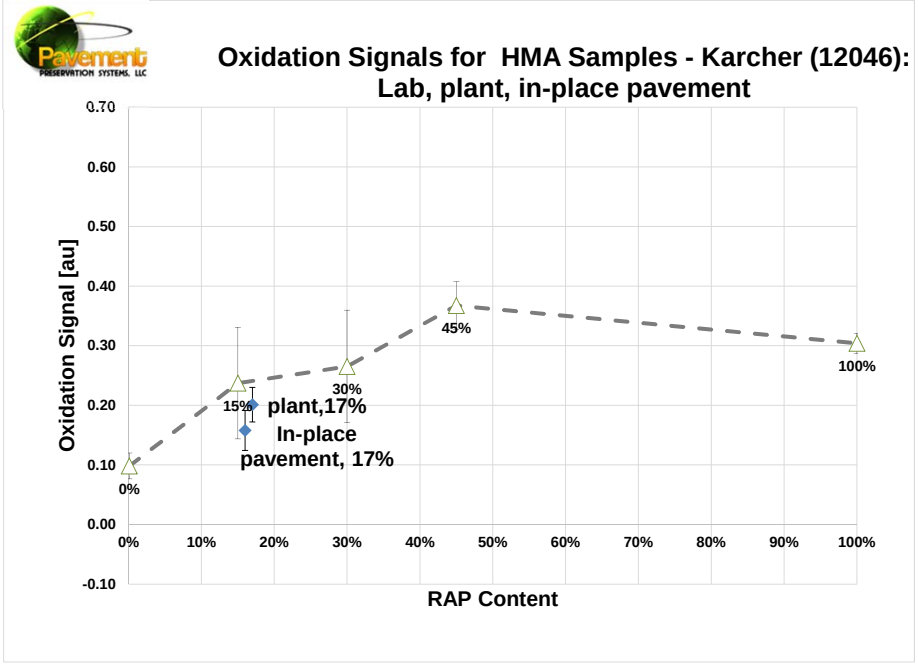
Scanning mode :	**DR on RAP-HMA,**
Scanning IR region:	**4000-400 cm^{-1}**
Signal resolution:	**8 cm^{-1} for RAP-HMA,**
Spectra averaged:	**24**

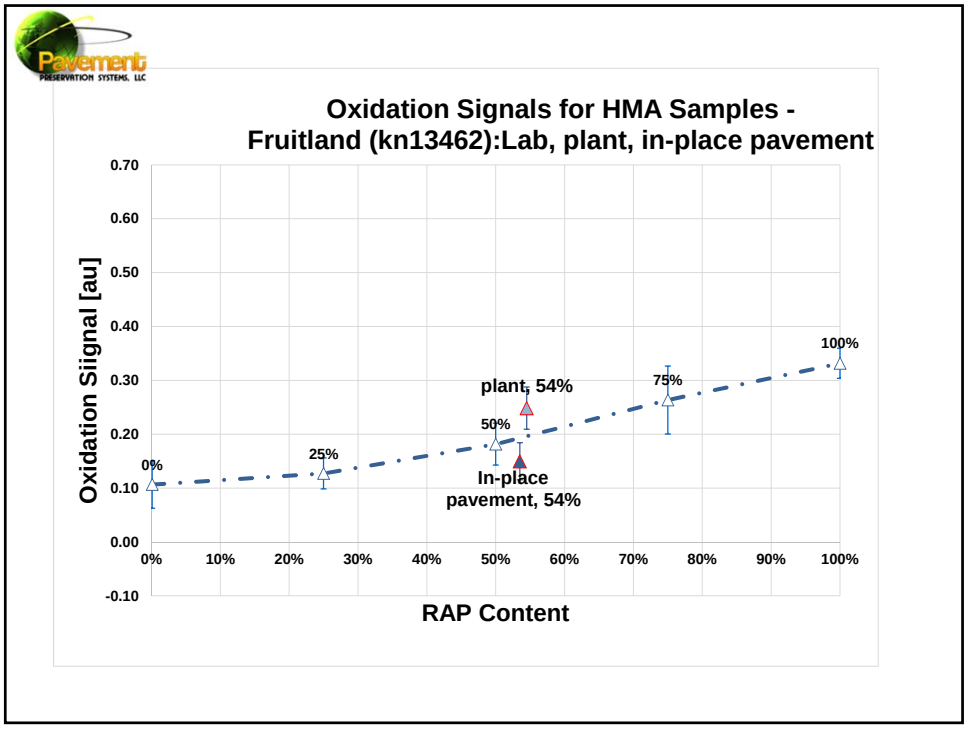
Oxidation Signal OxS = normalized peak at 1700 cm^{-1}

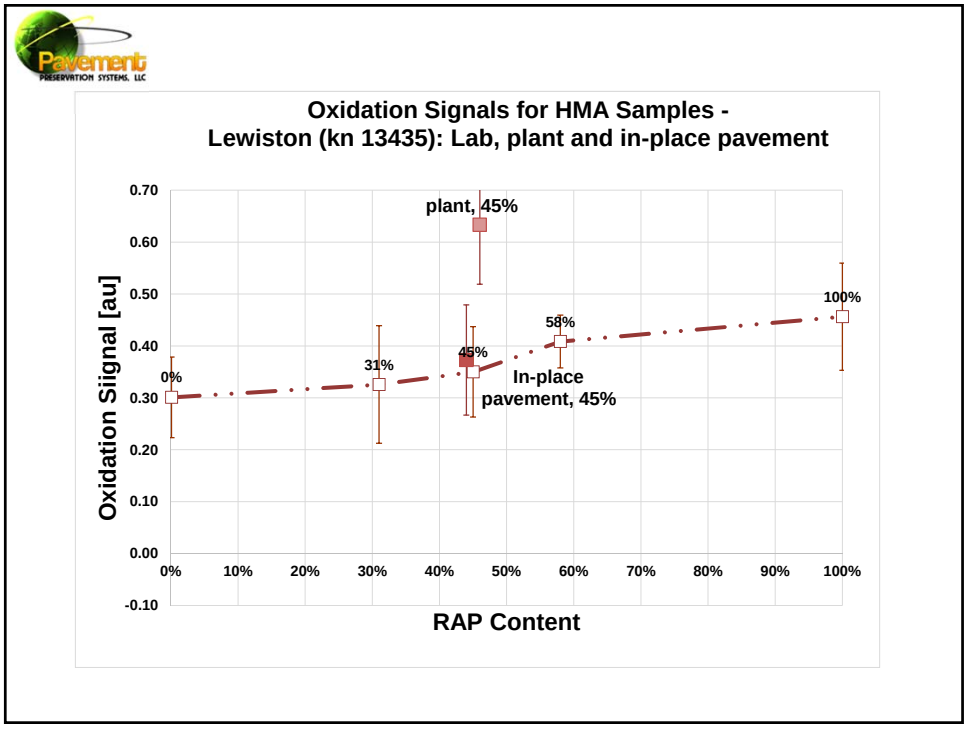
IR scans and oxidation signals

Calculation of Oxidation Signal from an absorbance spectrum of an asphalt mix sample.






Oxidation Signals for HMA Samples -
Fruitland (kn13462):Lab, plant, in-place pavement
Oxidation Siignal [au]
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
0%
25%
50%
75%
100%
plant, 54%
In-place
pavement, 54%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
RAP Content

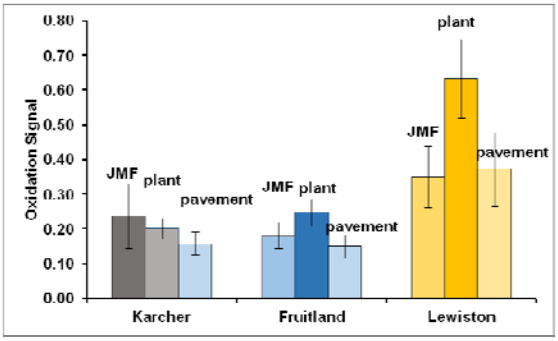

Oxidation Signals for HMA Samples -
Lewiston (kn 13435): Lab, plant and in-place pavement
Oxidation Siignal [au]
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
plant, 45%
0%
31%
45%
58%
100%
In-place
pavement, 45%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
RAP Content

First Demonstration Study - Idaho

Laboratory Calibration Curves for RAP-HMA

Objective of analysis:

2. Detect deviation of plant and pavement samples from the JMF



Results:

✓All pavement measurements remained within 1 st.d. from JMF

✓Plant signals were higher than pavement ones.

✓Lewiston plant sample may be not representative (night time paving)

Standard Method of Test for (proposed Provisional Standard)

Evaluation of Oxidation Level of Asphalt Mixtures by a Portable Infrared Spectrometer

Draft AASHTO Provisional Standard

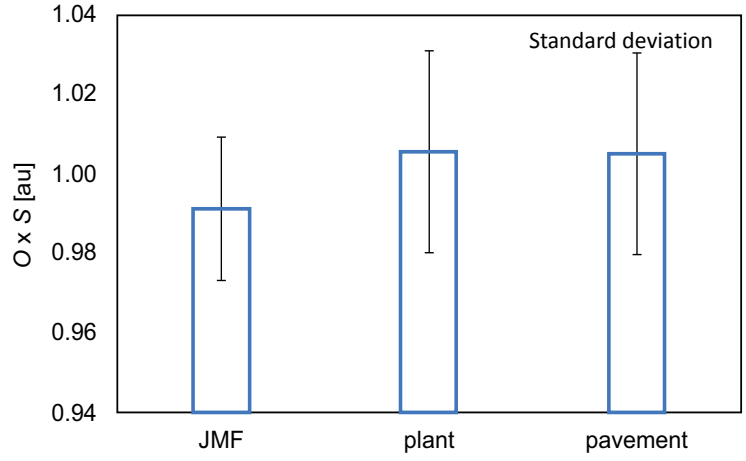
- Was developed by SRHP2 R06B research team for aged asphalts.
- Was modified and submitted to AASHTO TS-2c by PPS, LLC
- **Scope:**
  - ✓ Monitor oxidation levels in HMA (HMA/RAP)
  - ✓ Based on the quantitative analysis of DR infrared spectrum.
  - ✓ Sampling obtained directly from the in-place pavement surface.
  - ✓ Sample may be modified by adding RAP and/or RAS.
  - ✓ Oxidation level in the samples is calculated based on the intensity of the signal associated with carbonyl content.

The oxidation signal from the in-place pavement surface is compared with predetermined signals from JMF and plant samples.

Testing frequency of threshold is established by an agency based on a pilot study.

Example of Comparison of oxidation signals from JMF, HMA plant and in-place pavement

Mean and and standard deviation; the error bars are one standard deviation from the mean of five samples

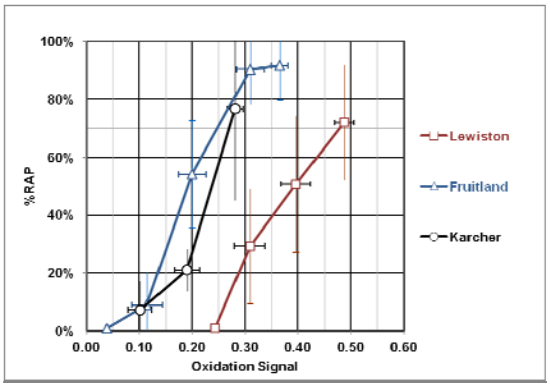


First Demonstration Study - Idaho

What have we learned about RAP-HMA?

✓On average, every 20% RAP to 0.1 unit Ox.Signal with St.d. = 10% RAP

✓%RAP in HMA can be determined with 82% reliability based on no-RAP and 100% RAP measurements

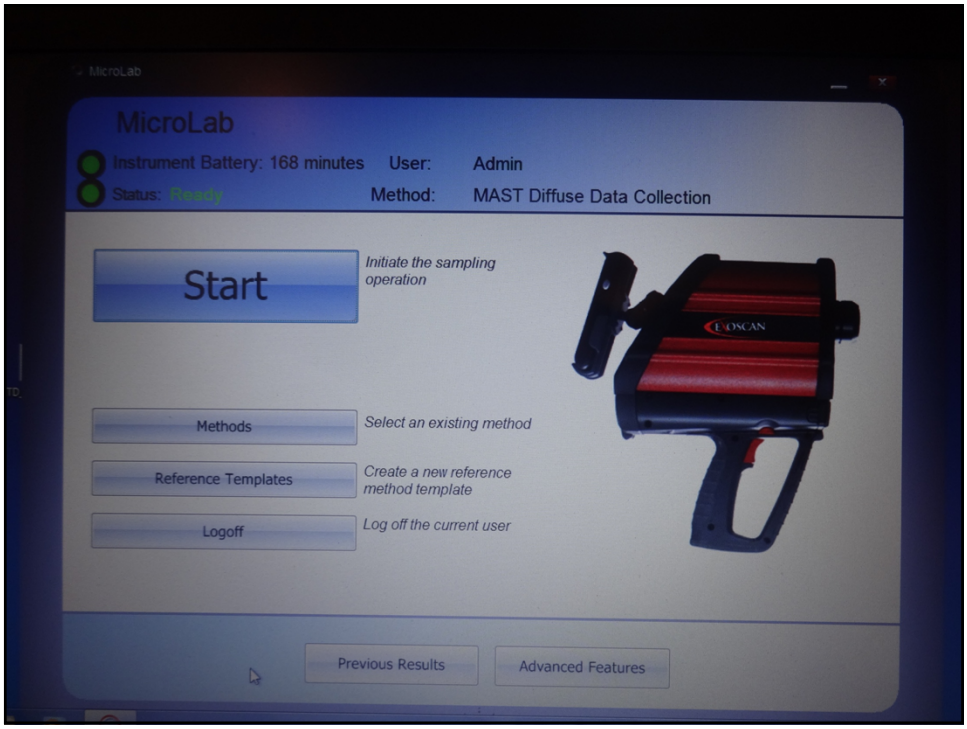


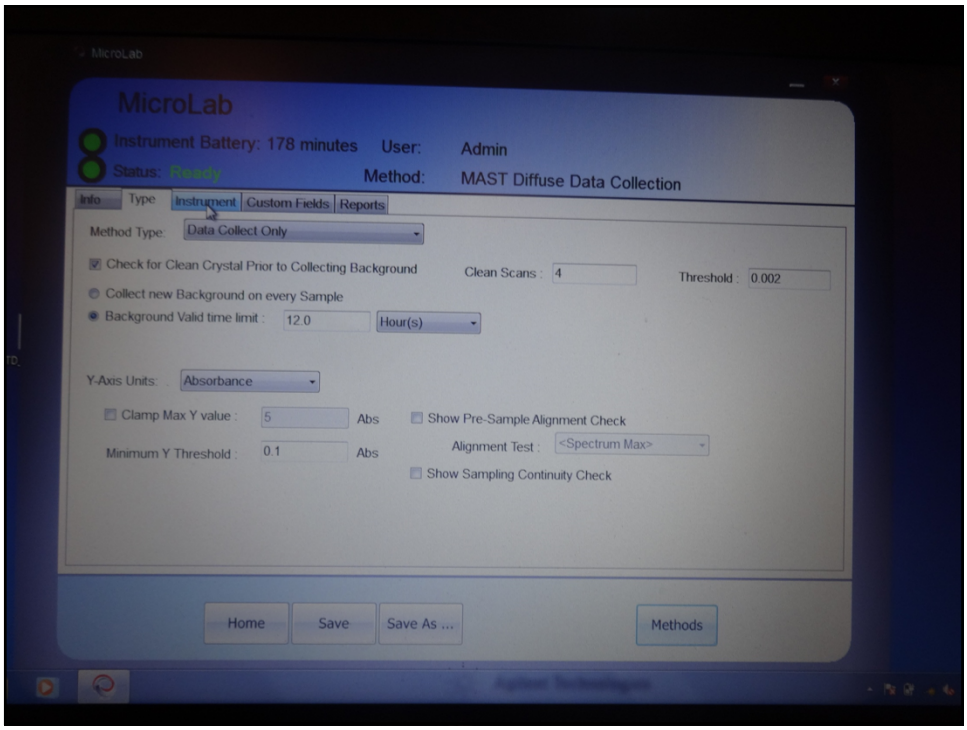
First Demonstration Study - Idaho

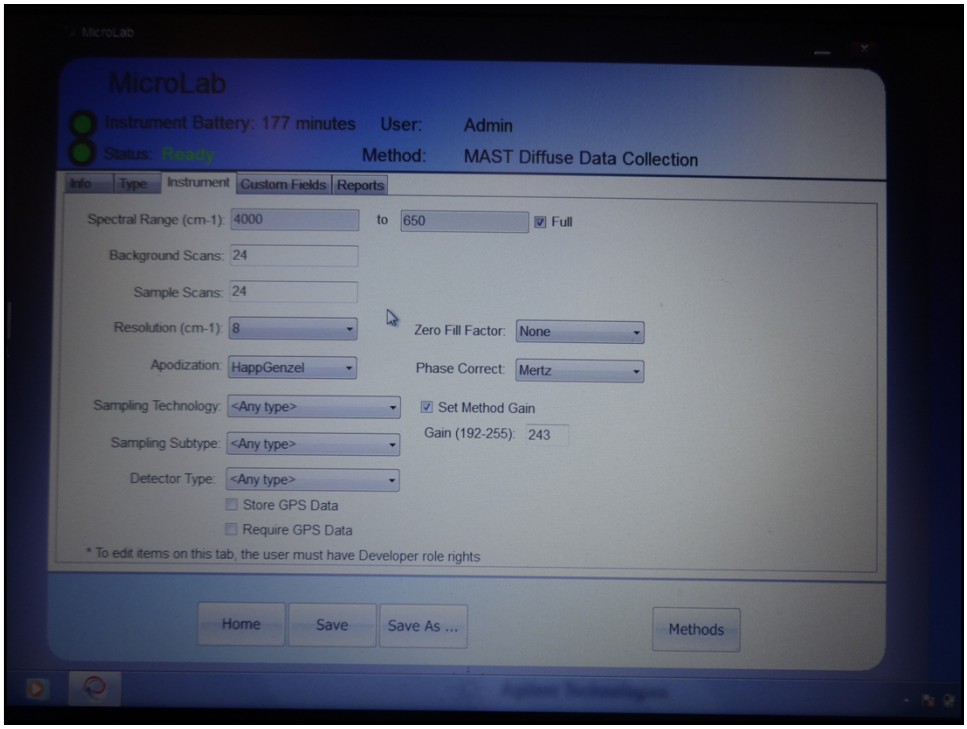
What can be done to improve results?

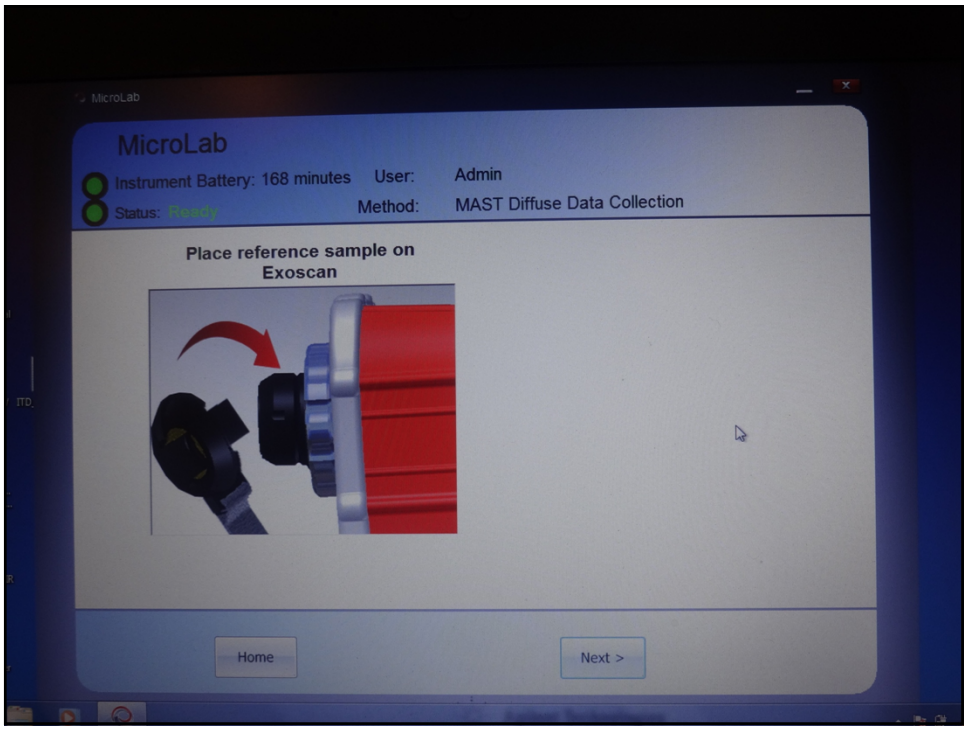
✓Reducing variability:
by controlling sample compaction,
controlling temperature and time of mixing,
and reducing light scattering effect.

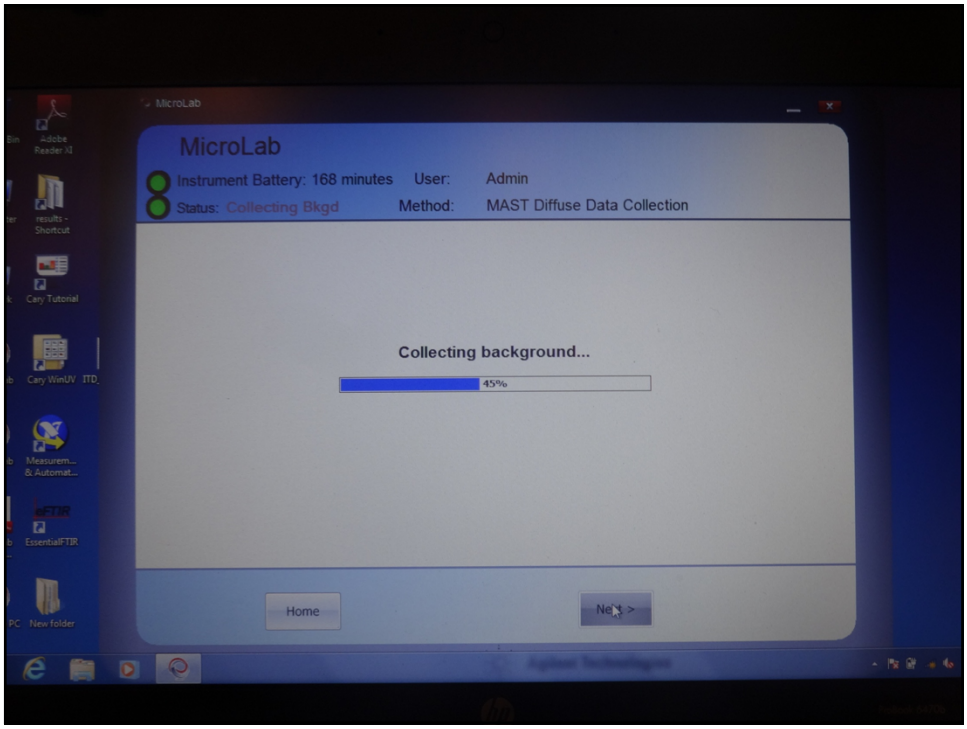
✓Repeating at least 3 projects with the same JMF.

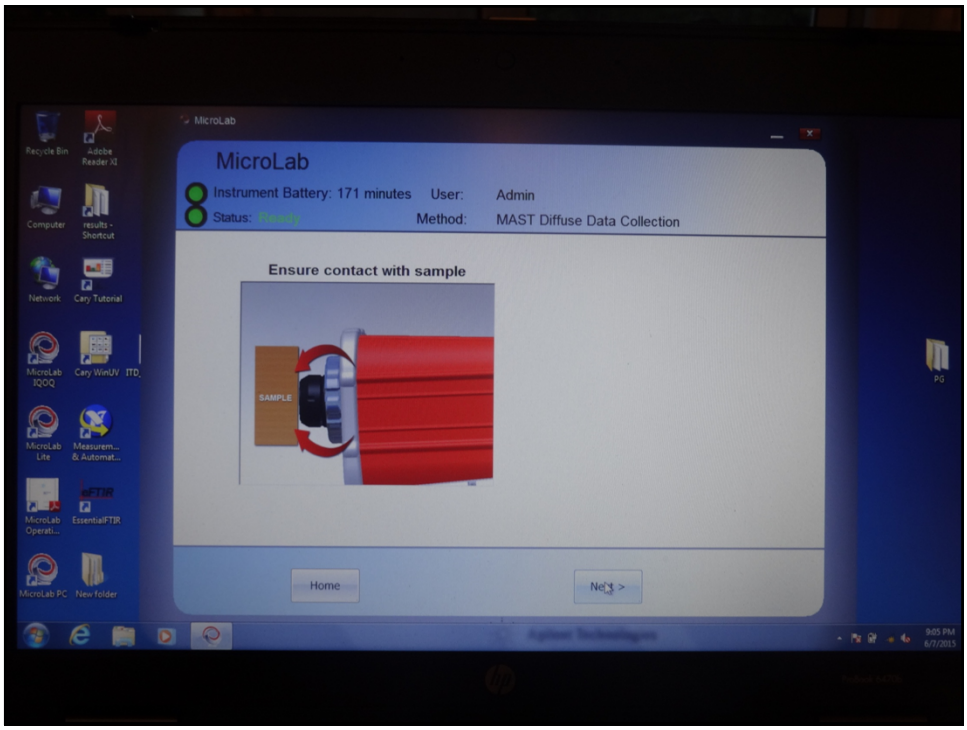

MicroLab
MicroLab
Instrument Battery: 168 minutes
User: Admin
Status: Ready
Method: MAST Diffuse Data Collection
Start
Initiate the sampling operation
Methods
Select an existing method
Reference Templates
Create a new reference method template
Logoff
Log off the current user
Previous Results
Advanced Features

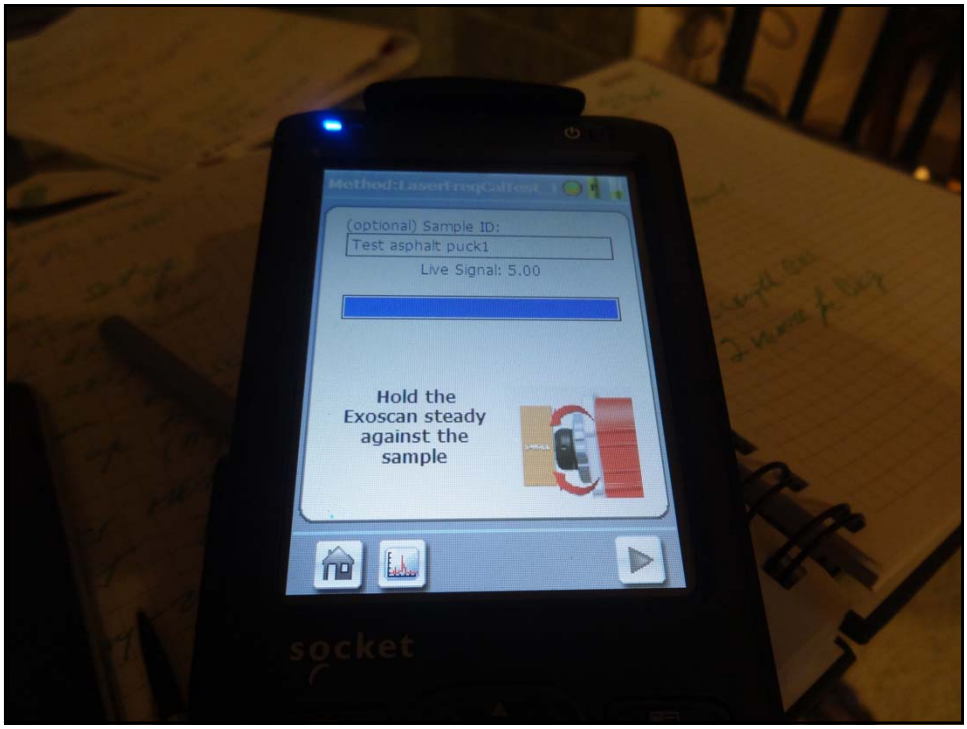

MicroLab
MicroLab
Instrument Battery: 178 minutes
User: Admin
Status: Ready
Method: MAST Diffuse Data Collection
Info
Type
Instrument
Custom Fields
Reports
Method Type:
Data Collect Only
Check for Clean Crystal Prior to Collecting Background
Clean Scans : 4
Threshold : 0.002
Collect new Background on every Sample
Background Valid time limit : 12.0
Hour(s)
Y-Axis Units:
Absorbance
Clamp Max Y value : 5
Abs
Show Pre-Sample Alignment Check
Minimum Y Threshold : 0.1
Abs
Alignment Test :
<Spectrum Max>
Show Sampling Continuity Check
Home
Save
Save As ...
Methods

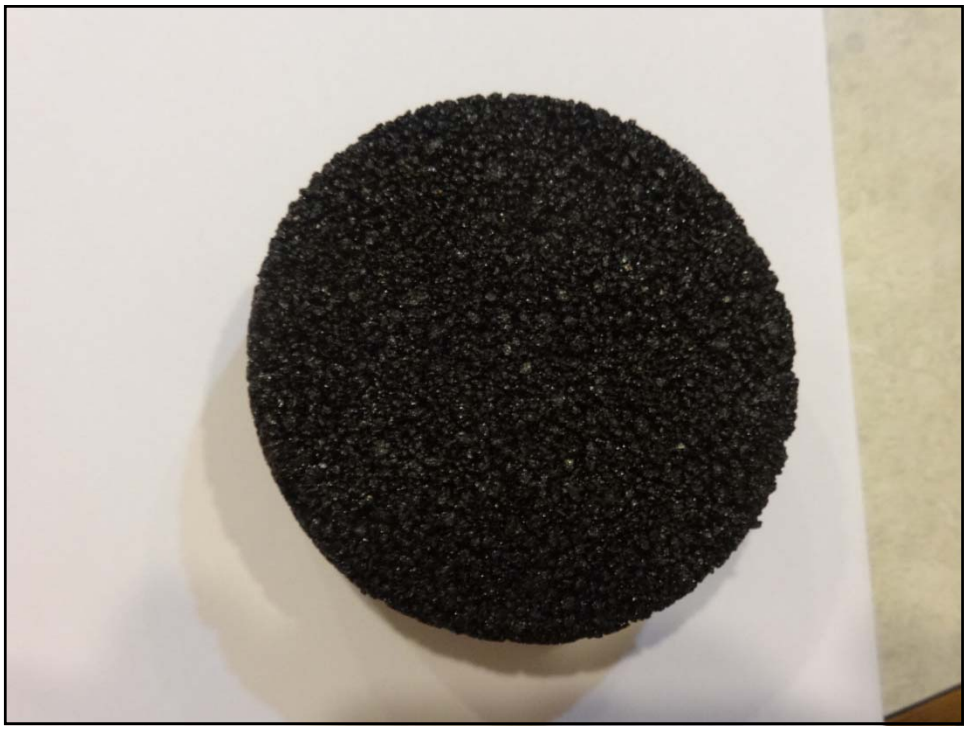

MicroLab
MicroLab
Instrument Battery: 177 minutes
User: Admin
Status: Ready
Method: MAST Diffuse Data Collection
Info
Type
Instrument
Custom Fields
Reports
Spectral Range (cm-1): 4000 to 650 Full
Background Scans: 24
Sample Scans: 24
Resolution (cm-1): 8
Zero Fill Factor: None
Apodization: HappGenzel
Phase Correct: Mertz
Sampling Technology: <Any type>
Set Method Gain
Sampling Subtype: <Any type>
Gain (192-255): 243
Detector Type: <Any type>
Store GPS Data
Require GPS Data
* To edit items on this tab, the user must have Developer role rights
Home
Save
Save As ...
Methods


MicroLab
MicroLab
Instrument Battery: 168 minutes
User: Admin
Status: Ready
Method: MAST Diffuse Data Collection
Place reference sample on Exoscan
Home
Next >


MicroLab
MicroLab
Instrument Battery: 168 minutes
User: Admin
Status: Collecting Bkgd
Method: MAST Diffuse Data Collection
Collecting background...
45%
Home
Next >


MicroLab
MicroLab
Instrument Battery: 171 minutes
User: Admin
Status: Ready
Method: MAST Diffuse Data Collection
Ensure contact with sample
SAMPLE
Home
Next >


(optional) Sample ID:
Test asphalt puck1
Live Signal: 5.00
Hold the Exoscan steady against the sample
socket



Pavement Preservation Systems, LLC

Thank you!