Innovative Testing of Ontario's Asphalt Materials

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Presentation Outline

- Background
- Ash Content Test
- Double Edge Notched Tension (DENT) Test
- Multiple Stress Creep Recovery (MSCR)
- Extended Bending Beam Rheometer (ExBBR) Test
- X-Ray Fluorescence (XRF)
- Fourier Transform Infrared (FTIR) Spectroscopy
- Highlights of Mixture Testing
- Future Work, Conclusions

Background

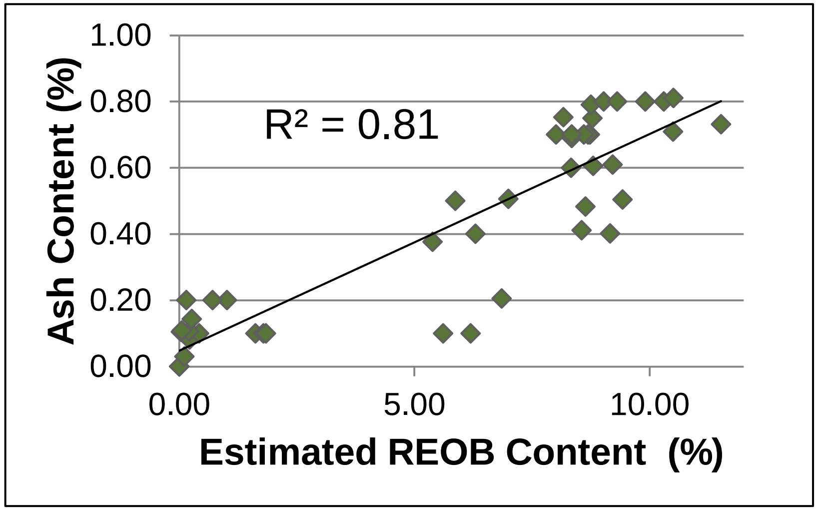
- MTO implemented performance grading grading in 1997 and was only used Superpave mix designs since 2005
- Rutting has all but disappeared
- Cracking is still a concern
- MTO uses a PG plus specification to mitigate cracking concerns and will be refocusing our attention to the properties of the mix

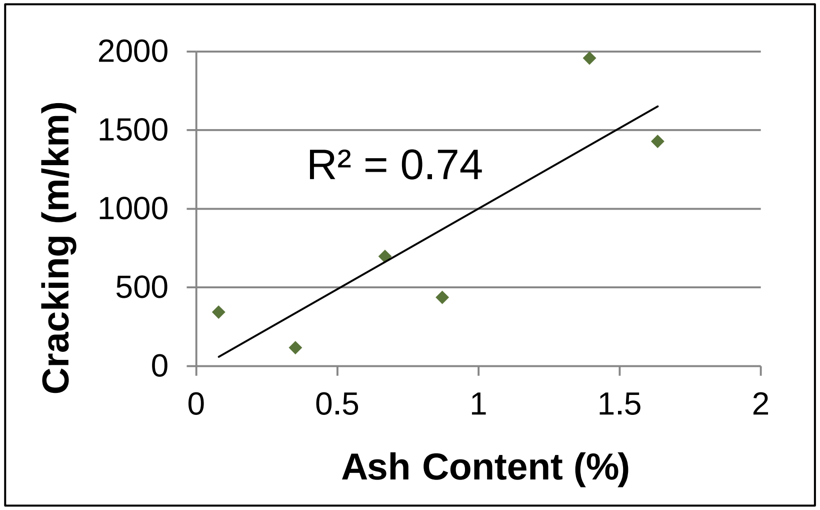
Ash Content Test

- Ash Content test was implemented to prevent over-modification with Re-Refined Engine Oil Bottoms (REOB)

  - Analysis of over 80 samples showed an excellent correlation between ash content and estimated REOB content

  - Limited analysis to date shows excellent correlation between 5 year pavement cracking and ash content





Double Edge Notched Tension (DENT) Test

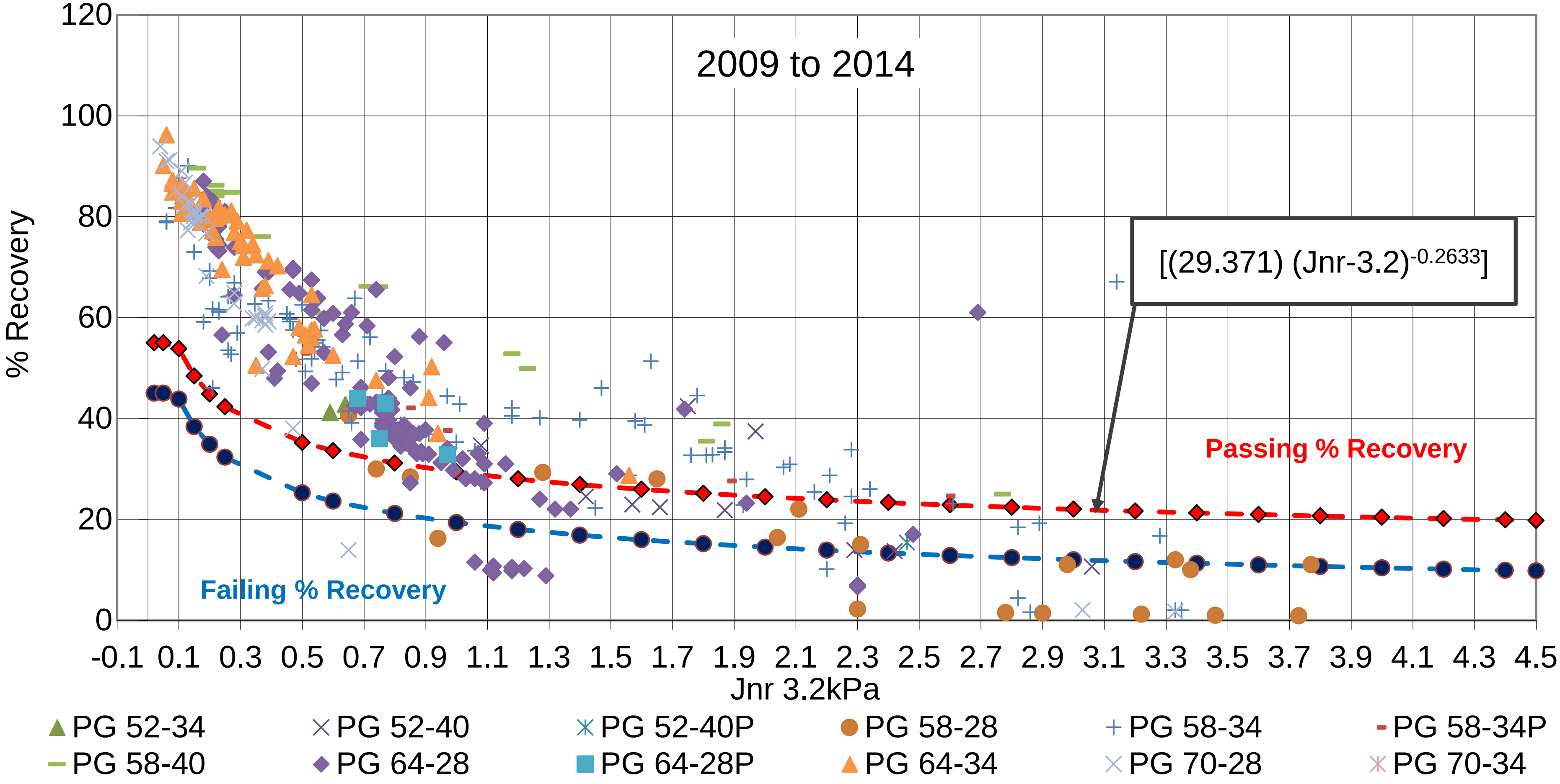
- Used for acceptance as a measure of asphalt cement's:
  - elasticity
  - ability to stretch and
  - resist cracking

- AASHTO TP113 specifies silicone molds with aluminum end pieces and testing at 25^{o}C
- Ontario uses brass molds and tests at:
  - 15^{o}C for PG XX-28 and -34 grades
  - 4^{o}C for PG XX-40 grades

Multiple Stress Creep Recovery (MSCR)

- Ontario's pavement performance concerns have focused on premature cracking and not rutting
- The % recovery portion of the test is used as an indicator of the presence of an elastomeric polymer
- Ontario's asphalt cement (AC) specifications include $J_{nr\text{-}3.2}$ and % recovery for acceptance on modified grades since 2012
- J_{nrdiff} (%) is carried out only for information purposes

MTO Experience with MSCR- Elastic Response



MSCR Specification for High Temperature

- Paving first trial on Hwy 11 near Kapuskasing, ON started in 2016. Uses PG 52H-34 in place of PG 58-34
- Required to meet other MTO AC test requirements

Extended Bending Beam Rheometer (ExBBR) Test

- Determines if AC meets the low temperature performance grade after a physical hardening process that occurs with extended conditioning at cool temperatures
- Test is published as AASHTO TP122-16
- Found best able to predict cracking
- Use for acceptance of all grades
- ExBBR determines low temperature grade over 72 hours vs. 1 hour for standard grading

Estimation of 72 Hour Stiffness and Creep

- MTO developed multivariable regression formulae to predict the 72 hour ExBBR test based on 1 and 24 hour properties:

m-value at 72 hrs (T_{ht}) = 0.03239*(m-value @ 1 hr) + 0.88952*(m-value @ 24 hr) + 0.01129

m-value at 72 hrs (T_{lt}) = 0.17770*(m-value @ 1 hr) + 0.795125*(m-value @ 24 hr) -0.00869

S at 72 hrs (T_{ht}) = 0.13495*(S @ 1 hr) + 0.94721*(S @ 24 hr) + 3.34123

S at 72 hrs (T_{lt}) = 0.16874*(S @ 1 hr) + 0.93364*(S @ 24 hr) + 0.14202

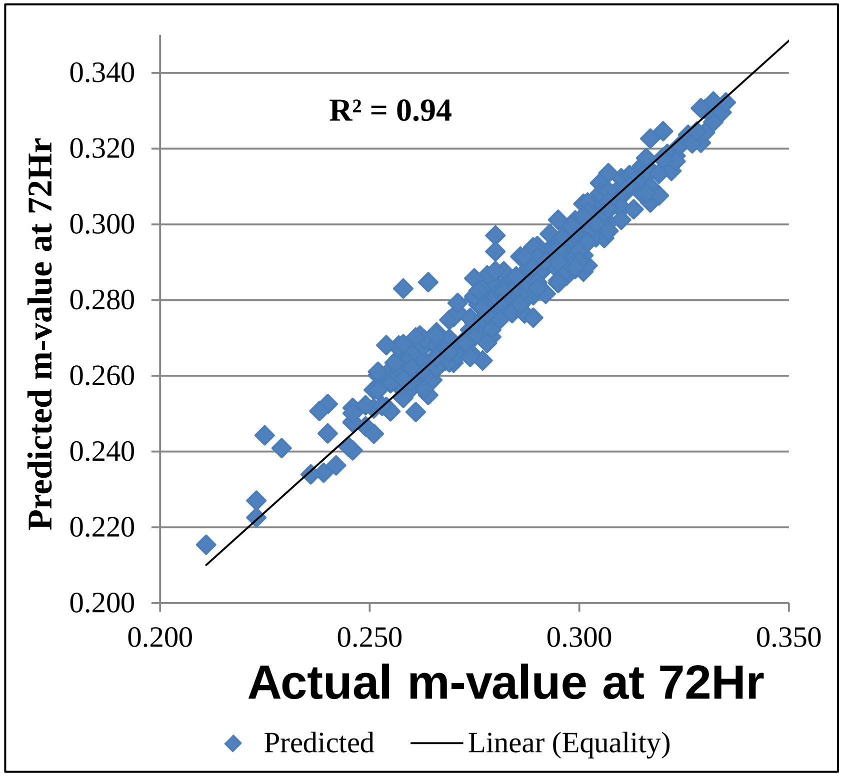
Where:

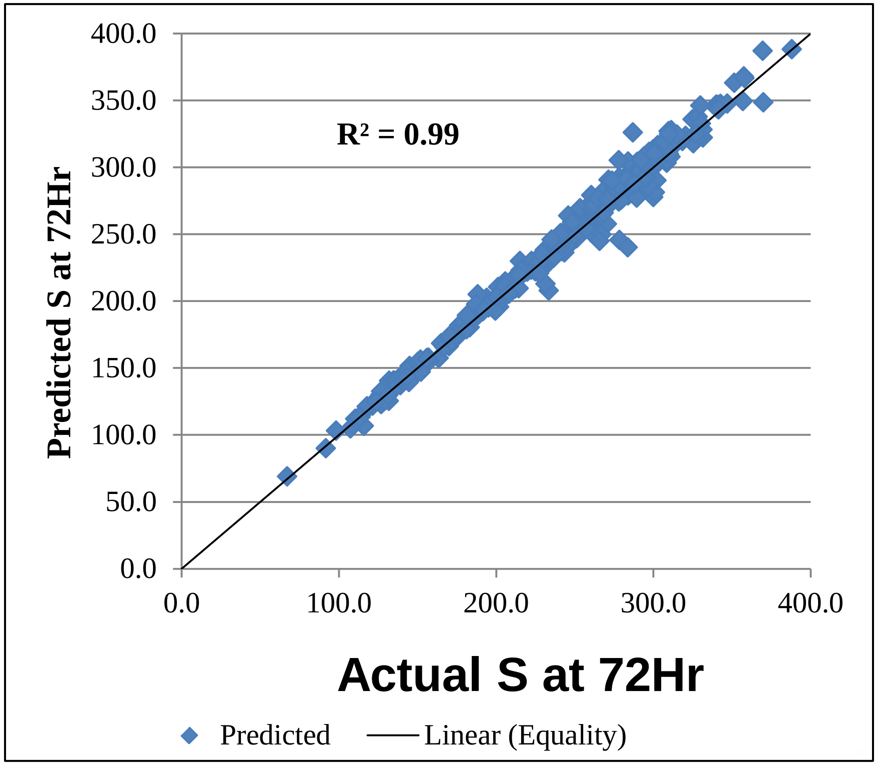
T_{ht} = high test temperature T_{lt} = low test temperature

- Regression analysis was conducted on over 330 ExBBR tests

Estimation of 72 Hour Stiffness and Creep

- The predicted m-value and S can be used to estimate ExBBR Low Temperature Limiting Grade that could be useful for quality control purposes





ΔT_c From BBR/ExBBR Test

- Another useful outcome from the BBR test is:

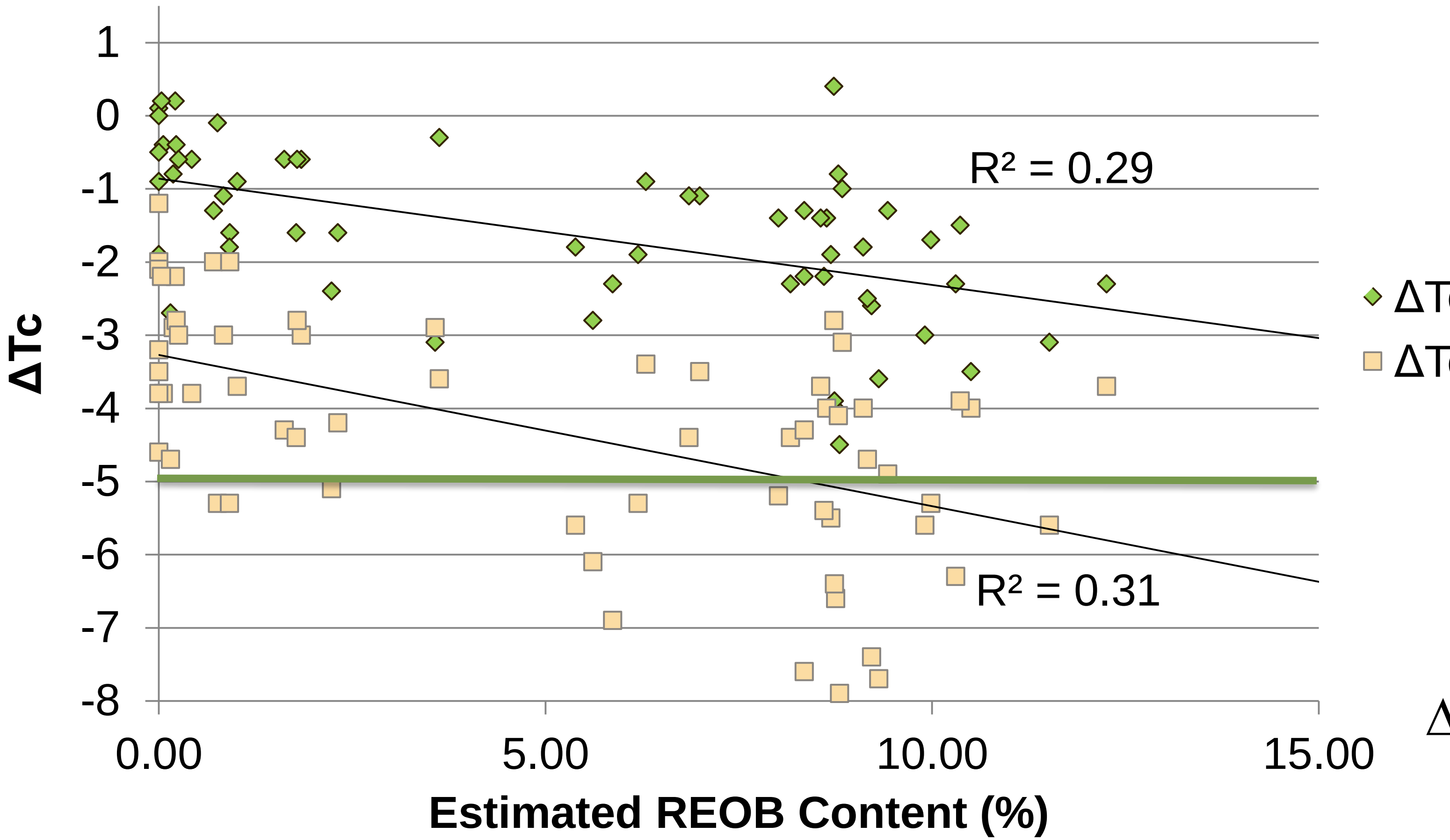
$$\Delta T_c = T_{stiffness} - T_{creep}$$

Where: $T_{stiffness}$ = critical temperature for stiffness (S)

T_{creep} = critical temperature for creep (m-value)

- For the over 60 samples tested, MTO compared single PAV aged BBR and ExBBR results
- REOB estimates ranged from 0 to 12%

Estimated REOB Content vs. ΔT_c



ΔT_c<-5

ΔT_c From BBR/ExBBR Test

Recovered AC ΔTc (°C)		
% Recycled	BBR	ExBBR
0% RAP + RST	-6.2	-8.3
10% RAP + 1%RST	-6.0	-10.6
	-7.6	-13.3
10% RAP + 0% RST	-8.2	-10.8
0% RAP + 2% RST	-8.3	-8.7
	-4.2	-7.2

AC ΔTc (°C)	
BBR	ExBBR
-4.8	-8.0
-0.5	-6.1
-7.9	-9.0
-1.0	-3.1

X-Ray Fluorescence (XRF)

- XRF detects the elemental content of a sample
- Transportation agencies, including MTO, are looking at XRF to identify over-modification of REOB in asphalt cement
- Elemental intensity peaks obtained are all relative to other elements found, so calibration curves are required for each element in a material to be quantified (in ppm)
- The four key elements and the levels detected in a REOB sample are:

Calcium	10,000 ppm
Zinc	3,000 ppm
Molybdenum	300 ppm
Copper	100 ppm

X-Ray Fluorescence (XRF)

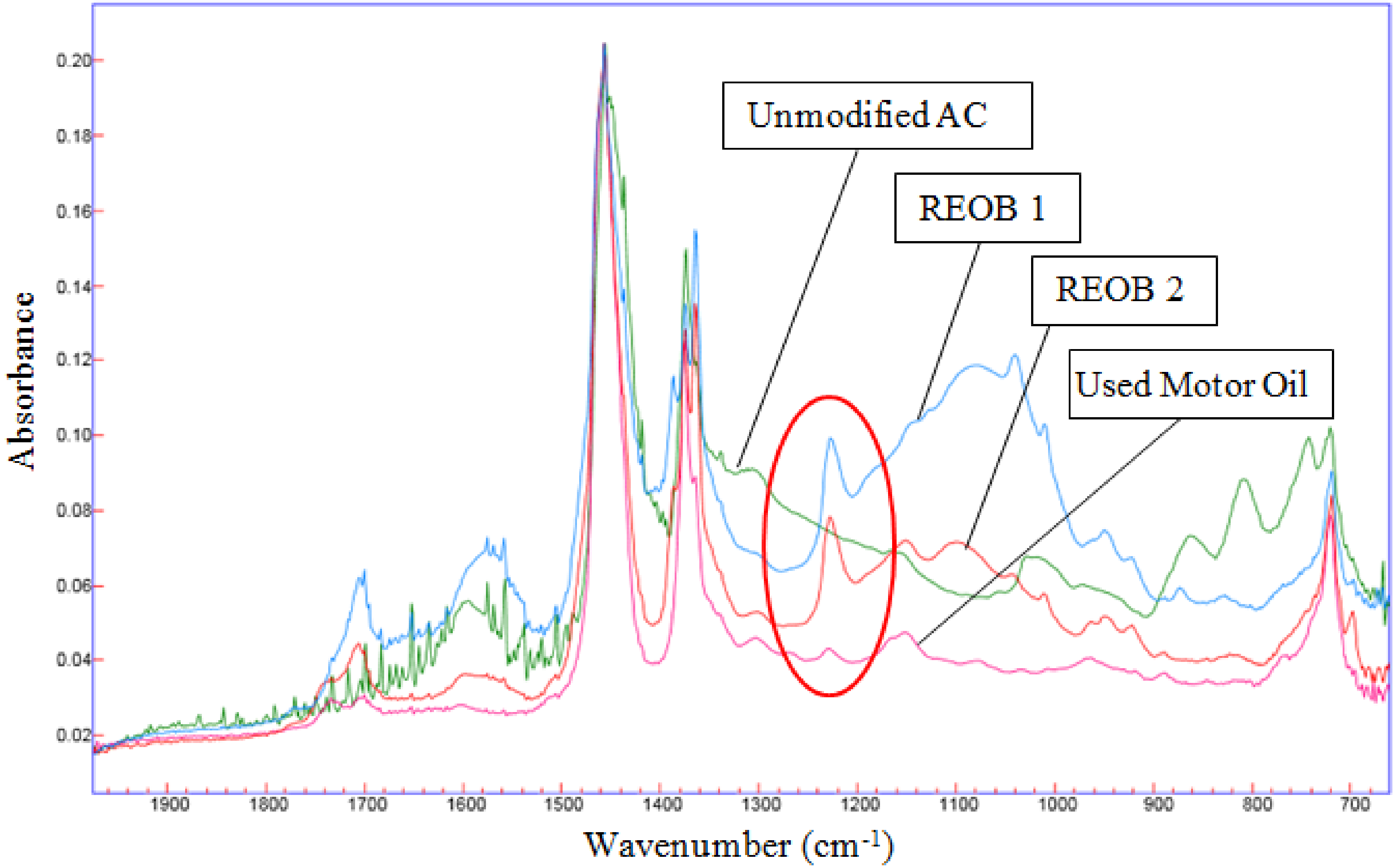
- MTO created calibration curves from base asphalt cement samples with varying percentages of REOB
- A linear regression curve was created for each element
- Equations currently used by MTO for estimating REOB content based on each element follow:

Element	Equation for Estimating REOB Content
Calcium	$REOB\%(Ca) = \frac{XRF(Ca) - 16}{109}$
Zinc	$REOB\%(Zn) = \frac{XRF(Zn) - 14}{48}$
Molybdenum	$REOB\%(Mo) = \frac{XRF(Mo) - 18}{4}$
Copper	$REOB\%(Cu) = \frac{XRF(Cu)}{1.5}$

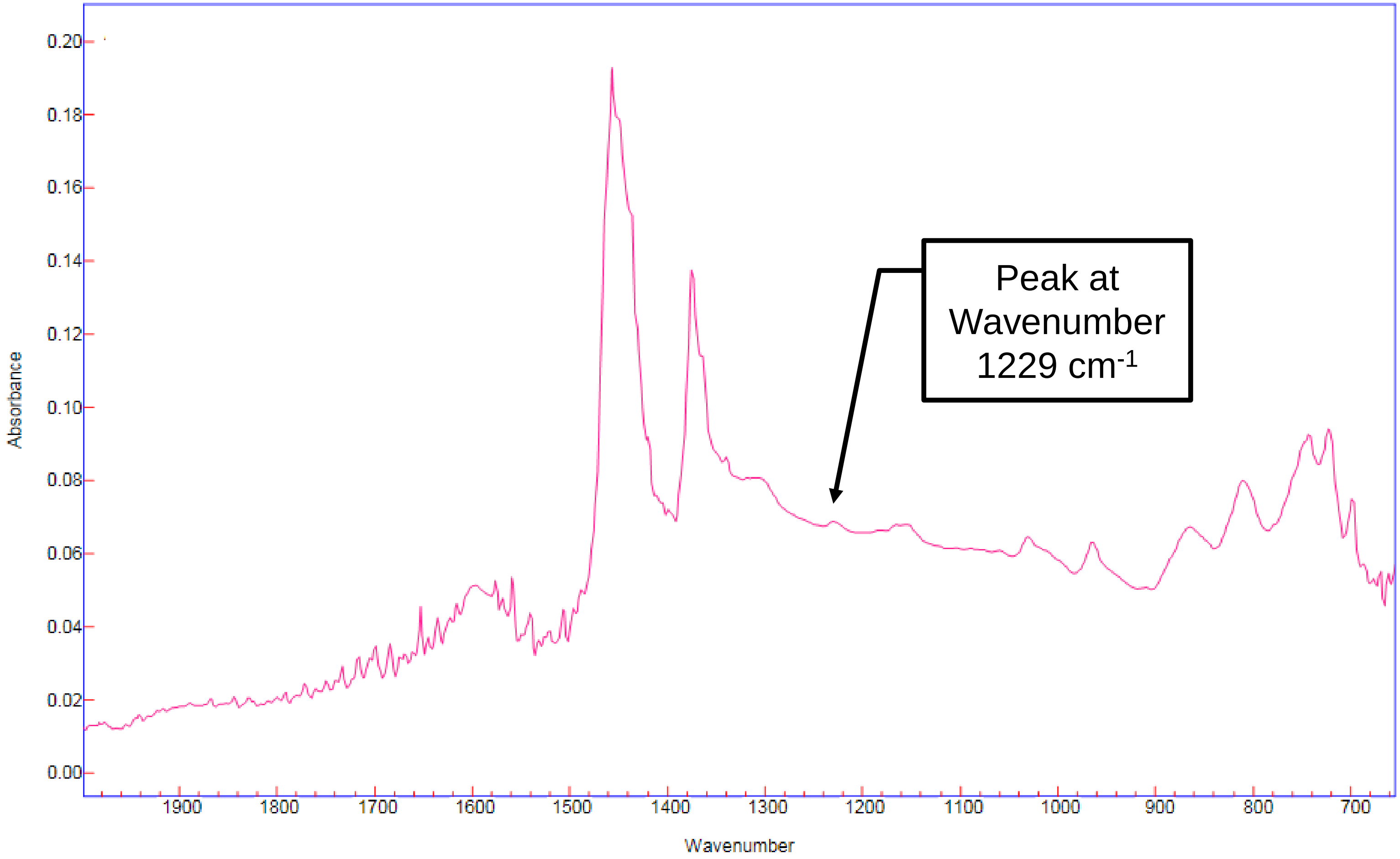
Fourier Transform Infrared (FTIR) Spectroscopy

- FTIR detects the infrared energy absorbed in a sample
- Comparing FTIR spectra of an unknown sample to a "standard" sample can be used to spot modifications made to an "unknown" sample
- FTIR also provides information on the molecular bond and functional groups of modifications that are made to a material
- We found a unique FTIR absorbance peak corresponding to REOB
- A peak was observed near wavenumber 1229 cm^{-1} - believed to correspond to polyisobutylene, an additive used in engine oil

FTIR Spectra



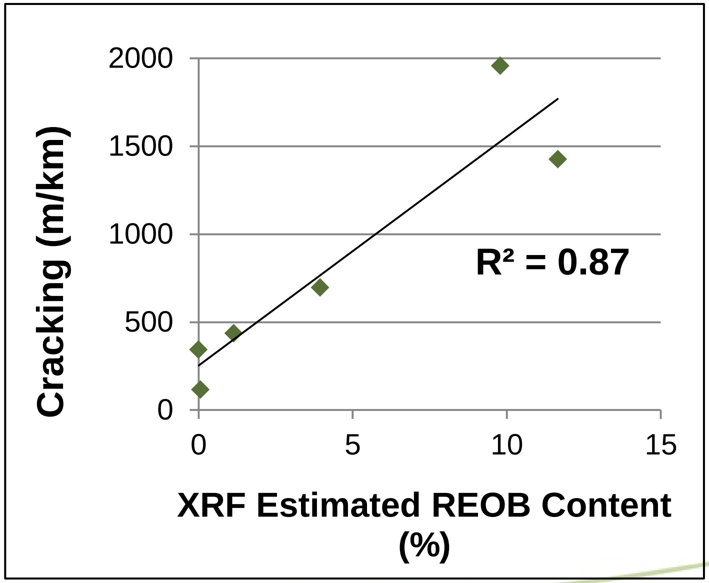
FTIR Spectra for a Contract Sample



REOB Estimation using FTIR and XRF

- FTIR can identify whether REOB is present in the AC
- MTO is currently estimating % REOB in AC with XRF for information purposes
- Results are provided below for:
  - comparison between FTIR peak and XRF estimated REOB content; and
  - five year pavement cracking performance

Sample	FTIR Absorption		XRF Count (ppm)				Average REOB Estimate (%)
	at 1229 cm^{-1}	Peak Present?	Ca	Cu	Zn	Mo	
1	172	**Yes**	937	24	668	79	**13**
2	181	**Yes**	1378	9	331	36	**10**
3	135	**No**	23	0	27	10	**0.1**
4	46	**No**	0	0	11	0	**0**
5	282	**Yes**	945	0	509	29	**5.5**



Highlights of Mixture Testing

- Moisture Sensitivity Tests
- Performance Tests using AMPT
- Performance Tests using DTS-30
- Bitumen Bond Strength Test (BBS)

Stripping by Static Immersion Test

- Determines the stripping susceptibility of the different components of an asphalt mix (MTO LS-285)
- Aggregates are blended with asphalt cement and the blended material is submerged in distilled water at 49°C for 24 hours
- Stripping susceptibility of the asphalt mix is assessed visually based on the percentage of the retained coating on the aggregate

~15% retained coating

~85% retained coating

Stripping by Static Immersion Test

- Use percent coating to determine what aggregate, AC, and anti-stripping treatment combination, provides better moisture resistance

- Minimum satisfactory value for this test is 65% retained coating

Aggregate Type	No Treatment	Hydrated Lime	Alternative AST-AGG
Granite	15%	85%	90%

Tensile Strength Ratio (TSR)

- AASHTO T283 is used during mix design to determine susceptibility of an asphalt mix to moisture damage
- Not used to accept production mix
- In some cases we find this to be insufficient and specify anti-strip to minimize risk of stripping
- Tests uses a 40 hour freeze-thaw cycle

Moisture Induced Stress Tester (MIST)

- An alternative moisture conditioning process to the TSR's freeze/thaw conditioning
- In addition to a conditioning process, MIST can be used to evaluate specimens based on sample swelling
- Air voids are measured and the percent swelling is calculated using

$$Swelling = \frac{(BRD_{before} - BRD_{after})}{BRD_{before}}$$

Where:

BRD_{before} = Bulk Relative Density prior to MIST conditioning

BRD_{after} = Bulk Relative Density after MIST conditioning

Moisture Sensitivity Test Results

- The results of liquid anti-stripping treatments (AST-AC) for the moisture sensitivity are:

Aggregate Type	Static Immersion		TSR		MIST -TSR		MIST-Swelling	
	No AST	AST-AC	No AST	AST-AC	No AST	AST-AC	No AST	AST-AC
Granite	15%	90%	67%	98%	62.0%	74.0%	4.2%	3.1%
Diabase	98%	*	84%	98%	69.0%	85.0%	2.0%	1.1%

* Not tested

- The sample with the lowest retained coating, also has the lowest TSR, MIST-TSR and highest swelling value
- Alternately, the diabase had greatest retained coating without AST, the highest TSR, MIST-TSR and lowest swelling
- More testing required

Hamburg Wheel Tracking Test (HWT)

- MTO uses Hamburg Wheel Tracking Machine to:
  - Evaluate antistripping additives for approved product list
  - Evaluate specialty mixes
  - Investigate premature pavement failure
- Not used to evaluate mixes before or during production

AMPT

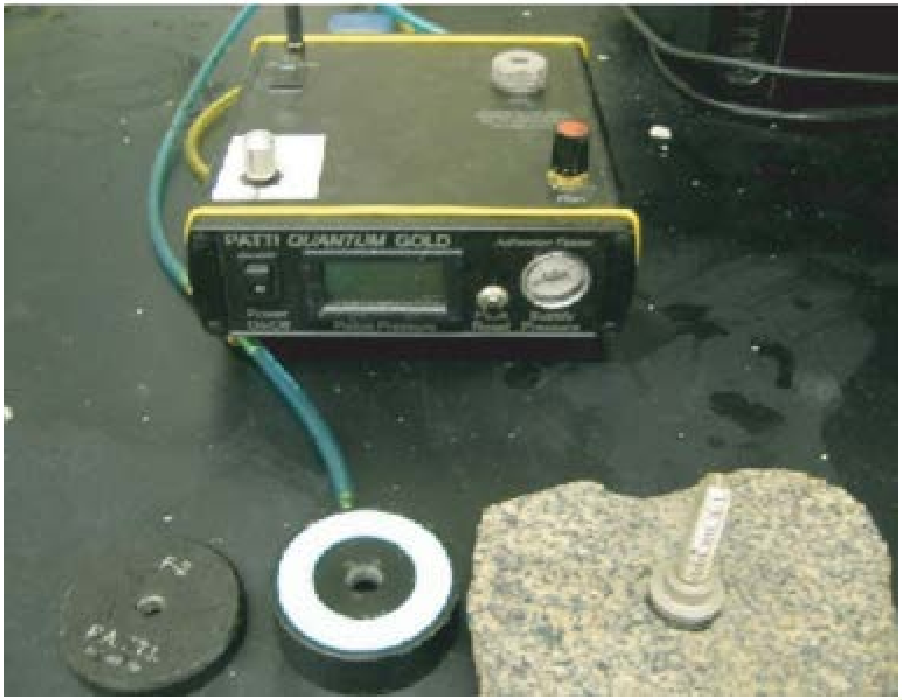
- MTO's AMPT (IPC Global) can run the following tests:
  - Dynamic Modulus
  - Flow Number (WMA)
  - Cyclic Fatigue (SMA)
  - Texas Overlay(Fiber)

Performance Testing using DTS-30

- MTO is purchasing a Dynamic Testing System (Pavement Test) that will allow us to run the following:
  - Dynamic Modulus
  - Flow Number
  - Cyclic Fatigue
  - Texas Overlay
  - Four Point Bending
  - **Semicircular Bend (SCB)**
  - **Disk-Shaped Compact Tension (DCT)**
  - **Indirect Tensile (IDT) Creep Compliance and Strength**
  - Resilient Modulus
  - TSRST (Thermal Stress Restrained Specimen Test)

Bitumen Bond Strength Test (BBS)

- The BBS test is a simple procedure to measure moisture resistance of the asphalt-aggregate interface for different combinations of materials



- "*Pull-Off Strength of Coatings Using Portable Adhesion Testers*". (ASTM D4541)
- Just acquired the device

Future Work

- FRAASS breaking point: measures the brittleness of binders at low temperature
- Refining recovery protocol for characterizing recovered binders from loose mix
- Determine if there is a relationship between double PAV BBR ΔTc and Ontario's pavement performance
- Establish a mix testing program to evaluate best options for predicting cracking of mixes placed

Conclusions

- Strong correlation was found between pavement cracking, estimated REOB and ash content
- Relationship between ΔTc and estimated REOB was found to be poor
- Equations developed to predict ExBBR results after 24 hours, correlated well with actual test data - can be used for QC purposes based on grades current used in Ontario
- Found that FTIR spectroscopy can detect REOB
- Can estimate REOB content in asphalt cement using XRF spectroscopy

Questions?

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