Ontario's Quest for Improved Asphalt Cement Specifications

Extended BBR

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Ontario Ministry of Transportation
ETG Binder Meeting

April 10, 2015

MTO MERO
Materials Engineering and Research Office

Improved MTO Laboratory Standards

1. Double-Edge-Notched Tension (DENT)

- *First published in 2006*
- *Used for acceptance of all modified AC on MTO contracts since 2012*
- *Passed AASHTO SOM ballot in January 2015*

2. Extended Bending Beam Rheometer (EBBR)

- *First published in 2006*
- *Used for acceptance on selected contracts since 2009*

3. Modified Pressure Aging Vessel (PAV)

- *First published in 2012*

Premature Pavement Cracking

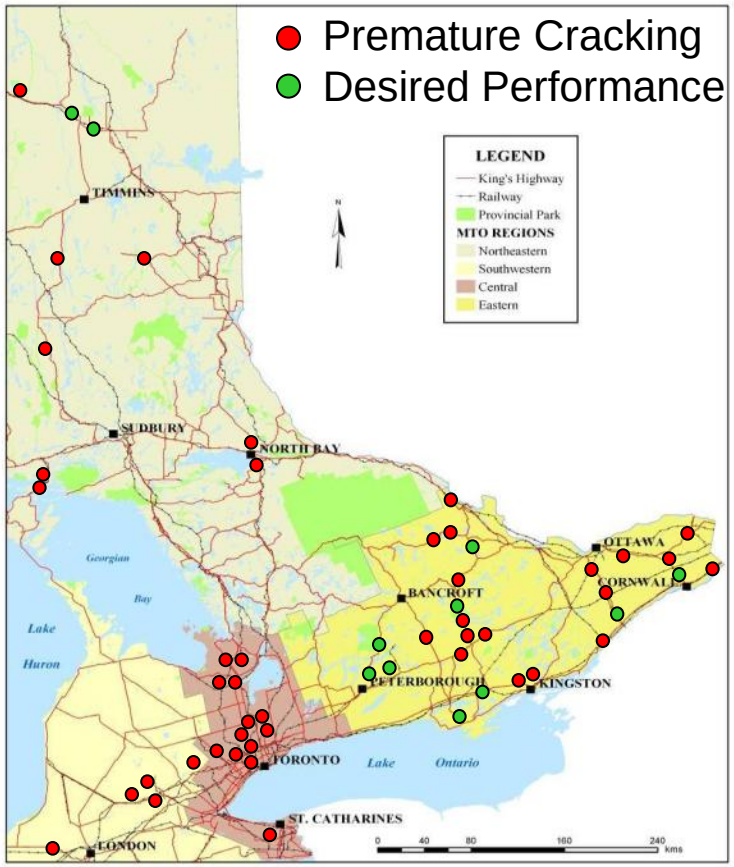
Ontario research has shown that AC with identical grades can provide wide performance variation.

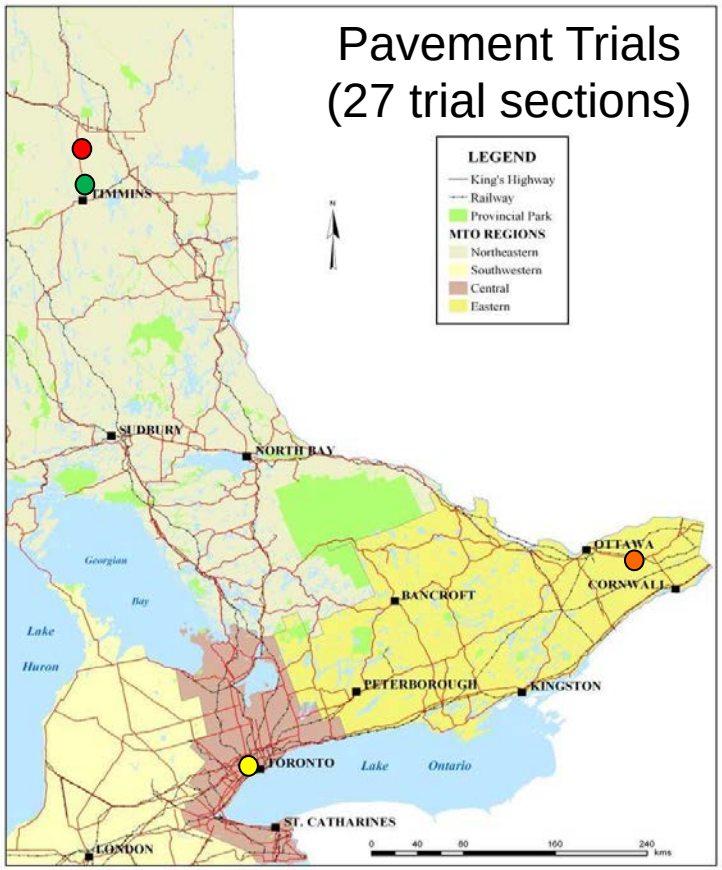
Hwy 41 North of Kaladar (1999)

Hwy 11 West of Cochrane (1999)

Hesp et al., *Int. J. Pavement Eng.*, 2009

Pavement Performance



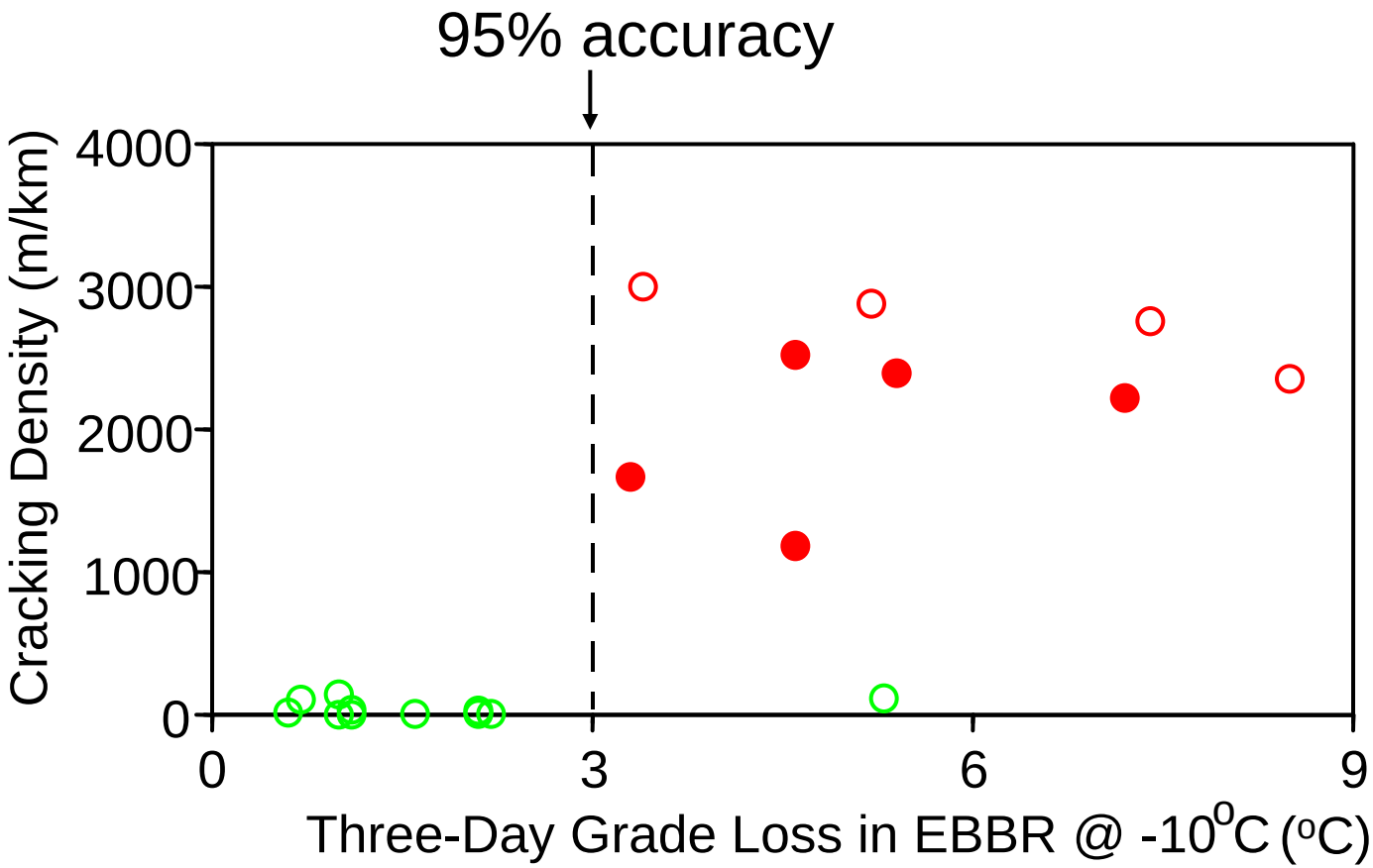


Ontario Trials

- 2003
- 2006
- 2007
- 2008

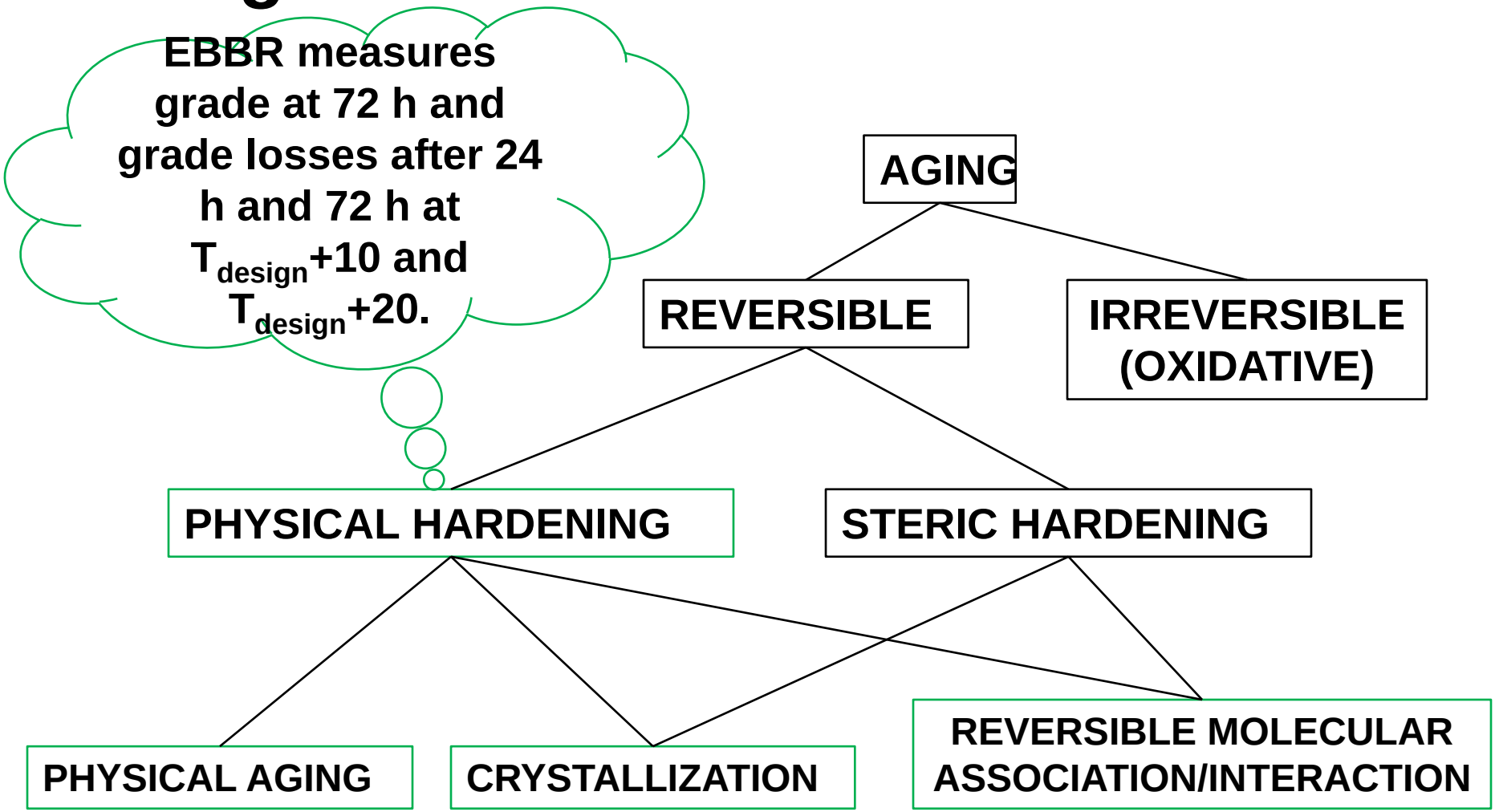
Validation with Real-World Contracts

MTO Regional Pavements (1993-2001)



Hesp et al., *Int. J. Pavement Eng.*, 2009

Background on Extended BBR



Hesp et al., 2007 and Kriz, 2009

Background on Physical Hardening

Traxler and coworkers 1936 & 1937

- Age hardening (viscosity, 25°C).
- Effects from oxidation are small compared to age hardening.
- Gradual isothermal sol-gel transition with magnitude depending on crude source and processing.

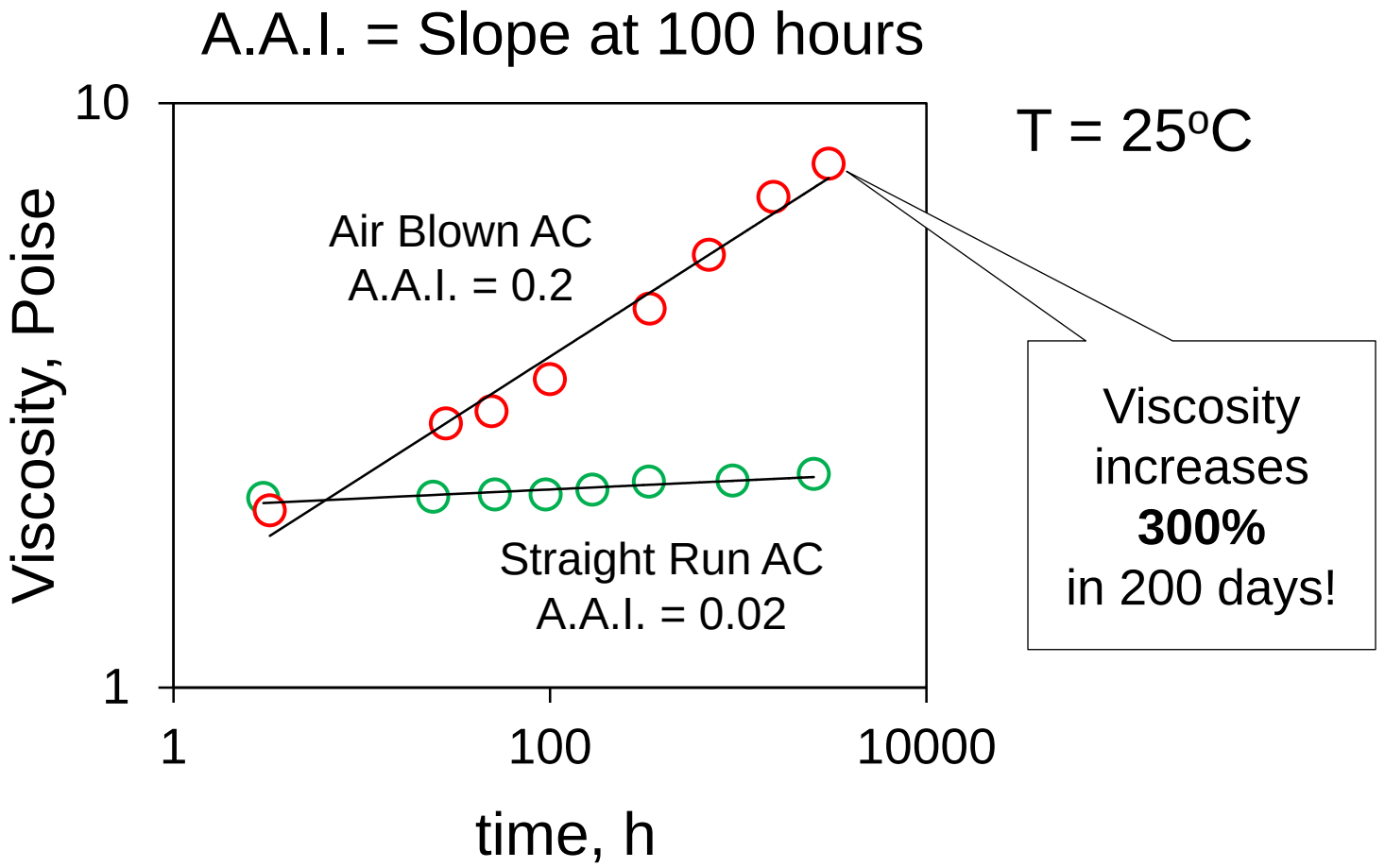
Blokker & Van Hoorn 1959

- Coined the "physical hardening" term to describe (1) wax precipitation (fast) and (2) asphaltene/resins structuring (slow).

Struik 1978

- Physical aging (creep, stiffness, strength, time, temperature, etc).
- "It is of little use to measure creep if one ignores the aging effect."

Traxler's Asphalt Aging Index (1936)



Isothermal Physical Hardening

Pechenyi and Kuznetsov 1990

- Avrami equation for isothermal crystallization (phase transformation).
- Hardening is due to an imperfect ordering process.

Crystallized fraction (CF)

$$C_t = 1 - \exp(-Zt^n)$$

Avrami exponent

Crystallization rate constant

Time

$$1 - C_t = \frac{V_t - V_\infty}{V_0 - V_\infty}$$

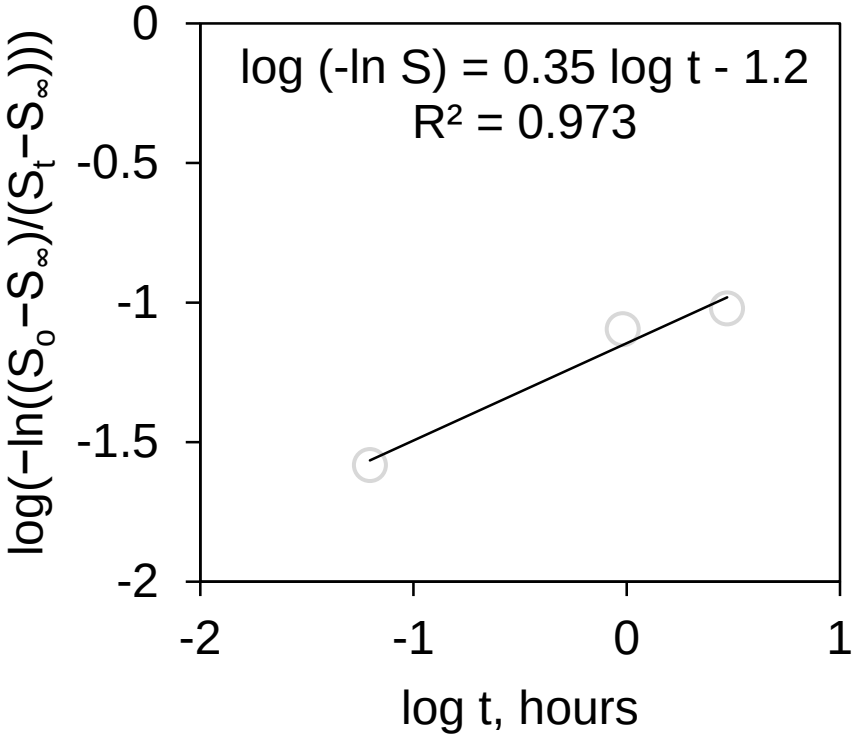
Crystallized fraction (CF)

Pechenyi and Kuznetsov, *Khimiya I Tekhnologiya Topliv I Masel*, 1990

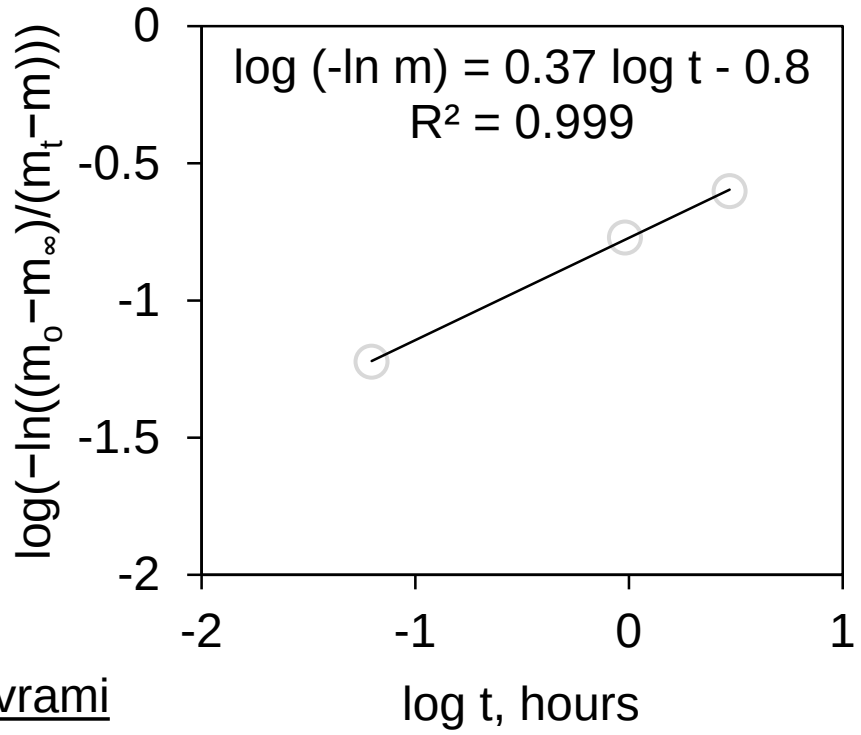
Avrami Analysis of BBR Creep Data

655-1 $PAV_{20\text{-}25}$ @ -24ºC

Creep Stiffness



m-Value



Avrami Constants

n = 0.35 and 0.37

Z = 1.2 and 0.8

Hesp et al., *Unpublished*, 2015

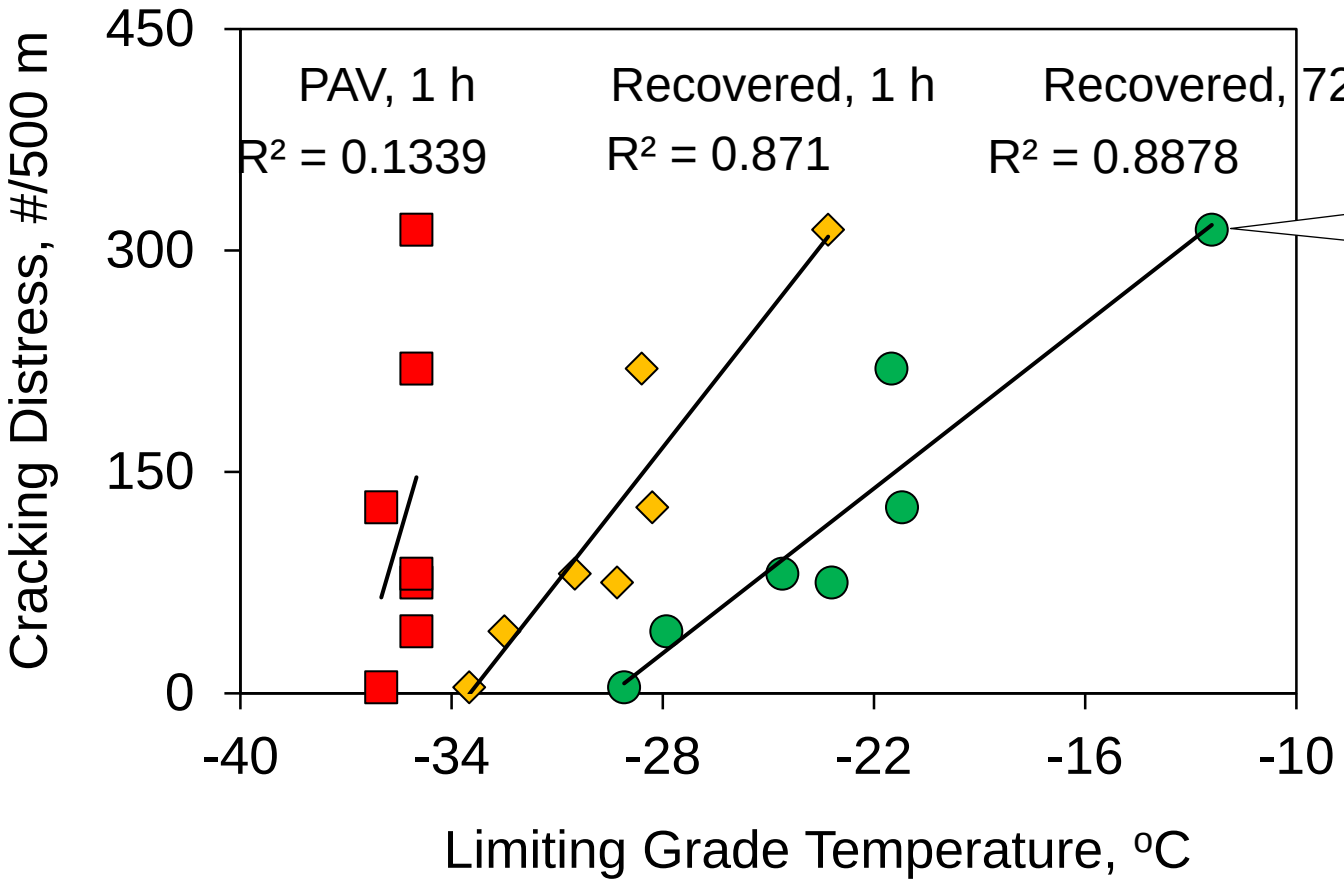
Near-Perfect Prediction of 72 h Grades

Sample	Predicted 72 h Grade Temperature*, °C	EBBR 72 h Grade Temperature, °C
655-1	-34.5	-34.4
655-2	-31.0	-30.4
655-3	-32.6	-32.6
655-4	-31.3	-30.7
655-5	-30.9	-30.9
655-6	-30.2	-30.3
655-7	-29.8	-29.7

* Predicted from 1, 3 and 24 hours measurements, using Avrami theory.

Various BBR Protocols

MTO Trial, Timmins, Ontario

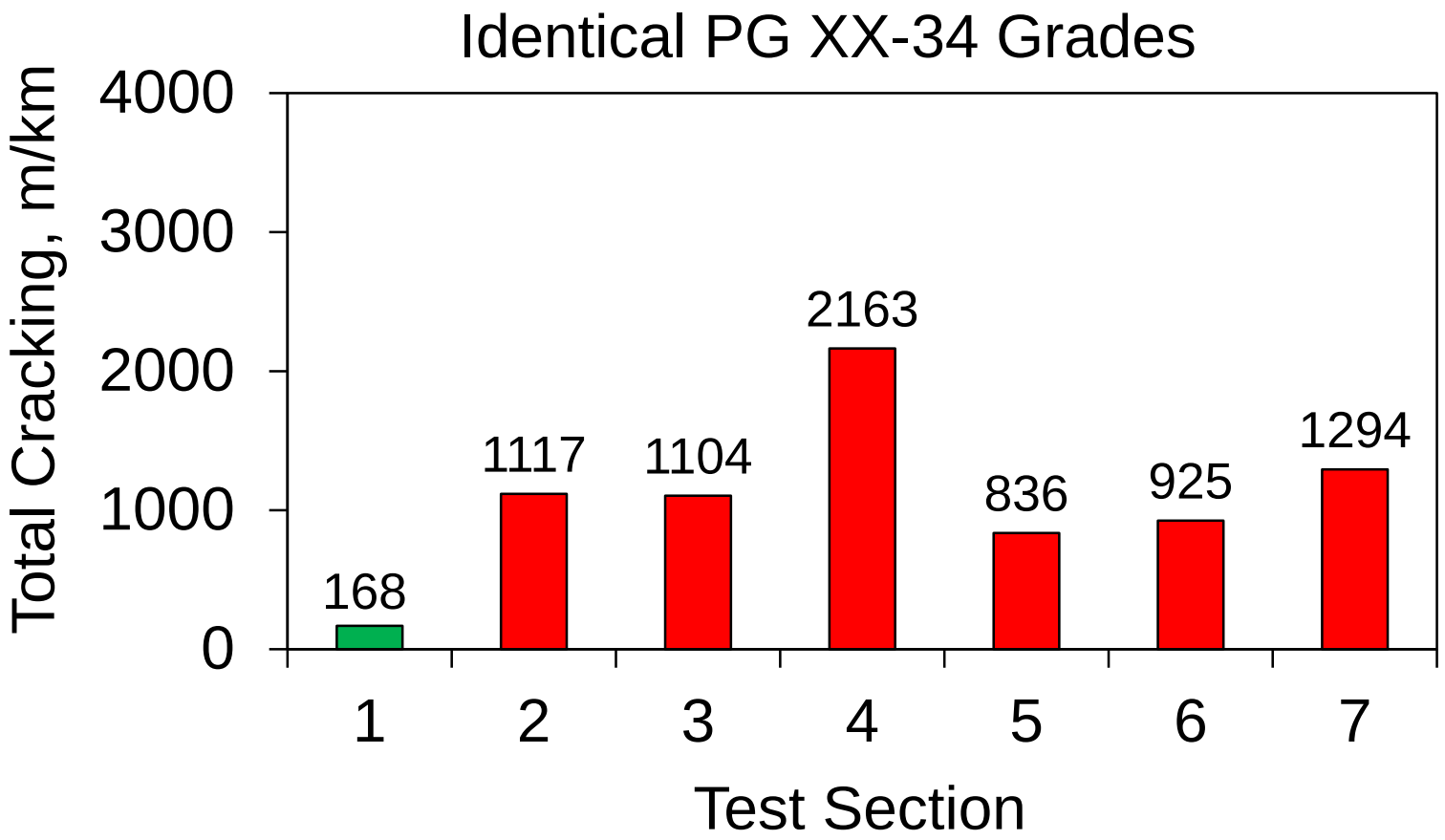


10°C-20°C differences!

Paliukaite et al., 2015

2014 Automatic Road Analyzer Data

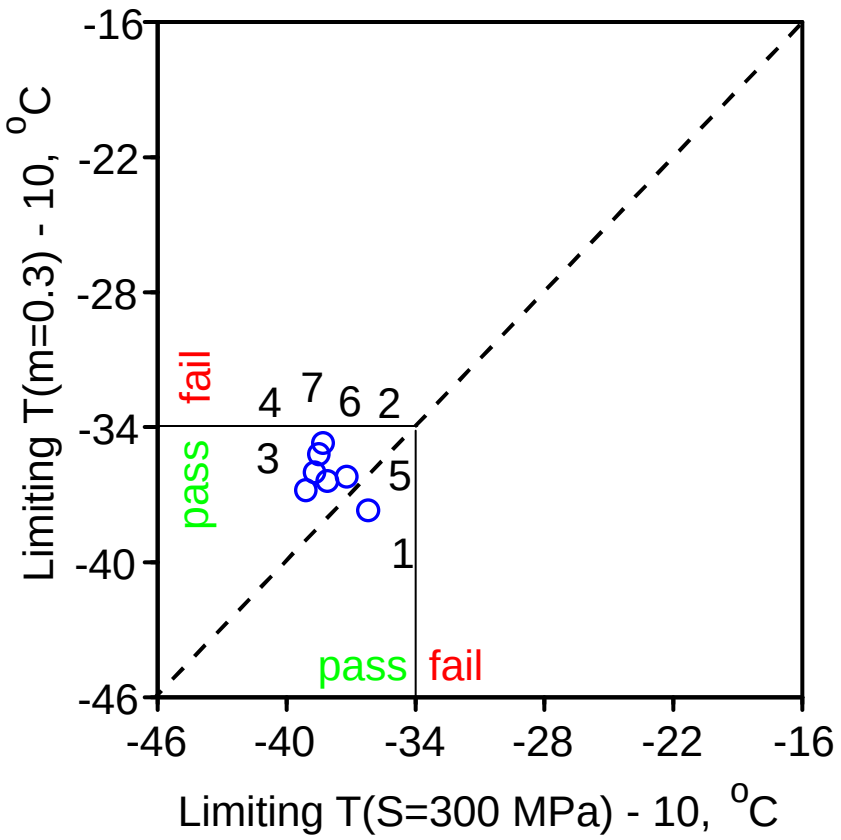
MTO Timmins Trial



BBR versus EBBR PAV Grading

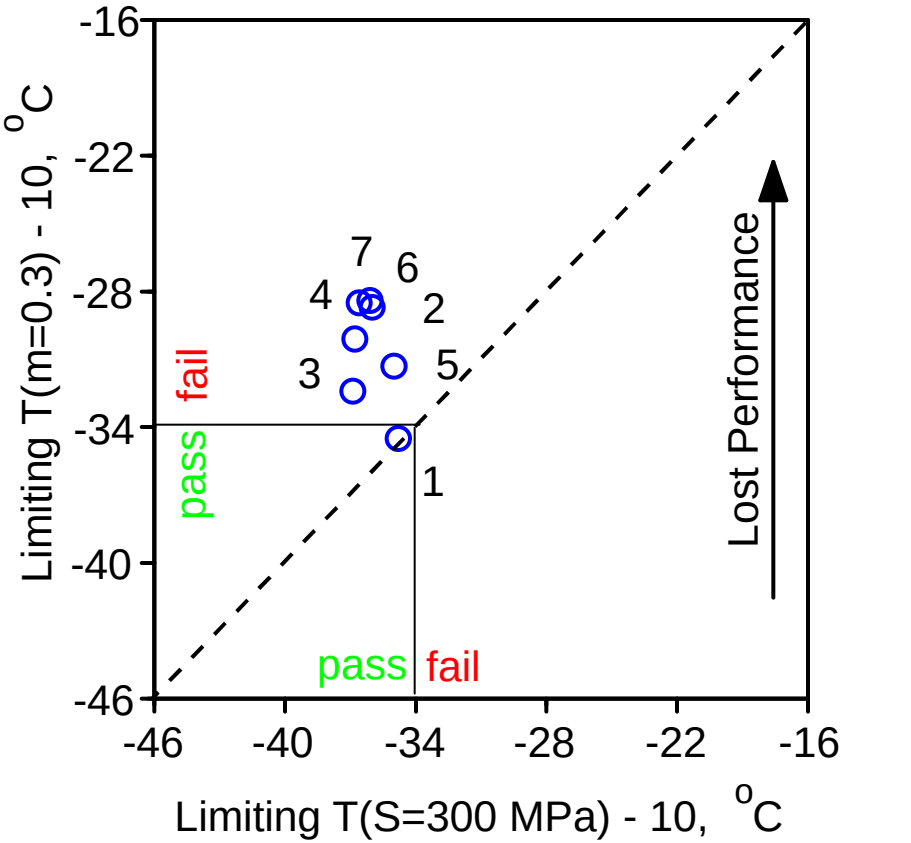
BBR Grading

14 % Overall Accuracy (1 times out of 7)
0 % Accuracy in Predicting Failure (0 times out of 6)



EBBR Grading

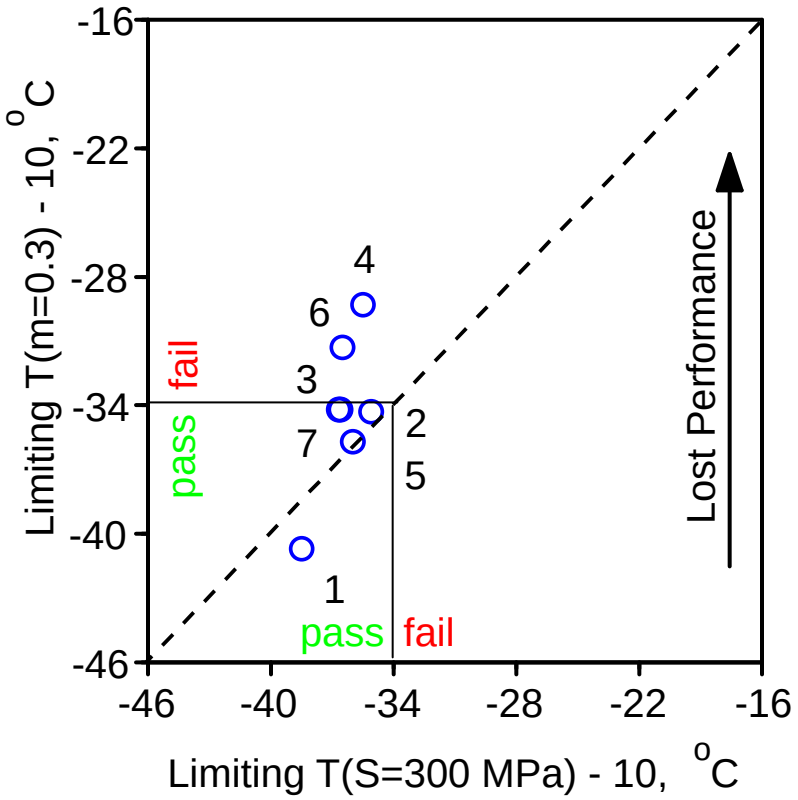
100 % Overall Accuracy (7 times out of 7)
100 % Accuracy in Predicting Failure (6 out of 7 times)



Recovered Binder
BBR versus EBBR Grading

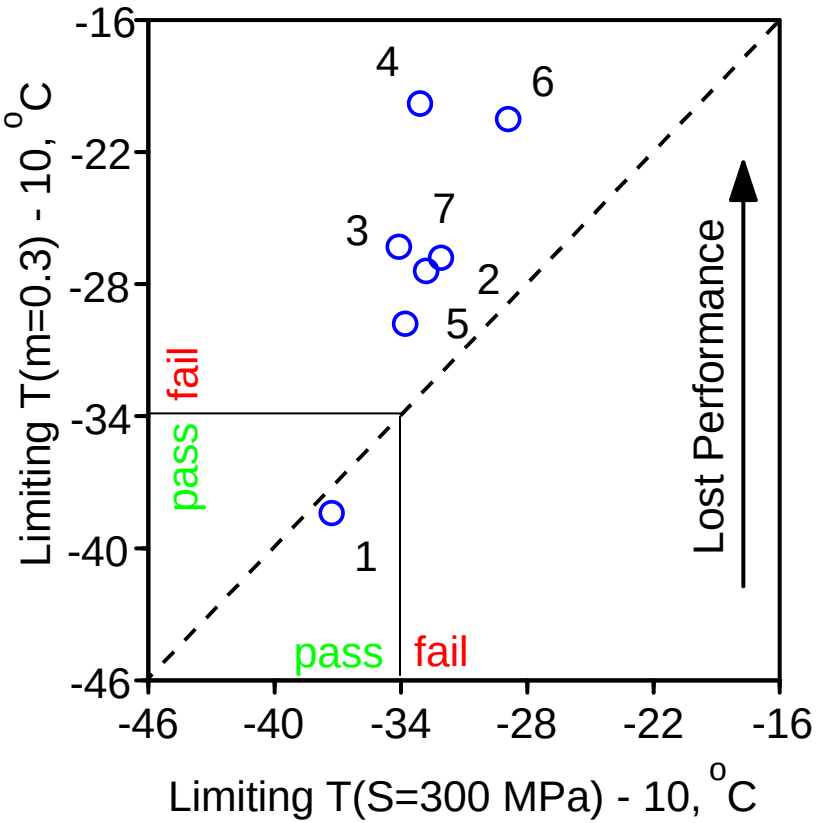
BBR Grading

43 % Overall Accuracy (3 times out of 7)
33 % Accuracy in Predicting Failure (2 times out of 6)



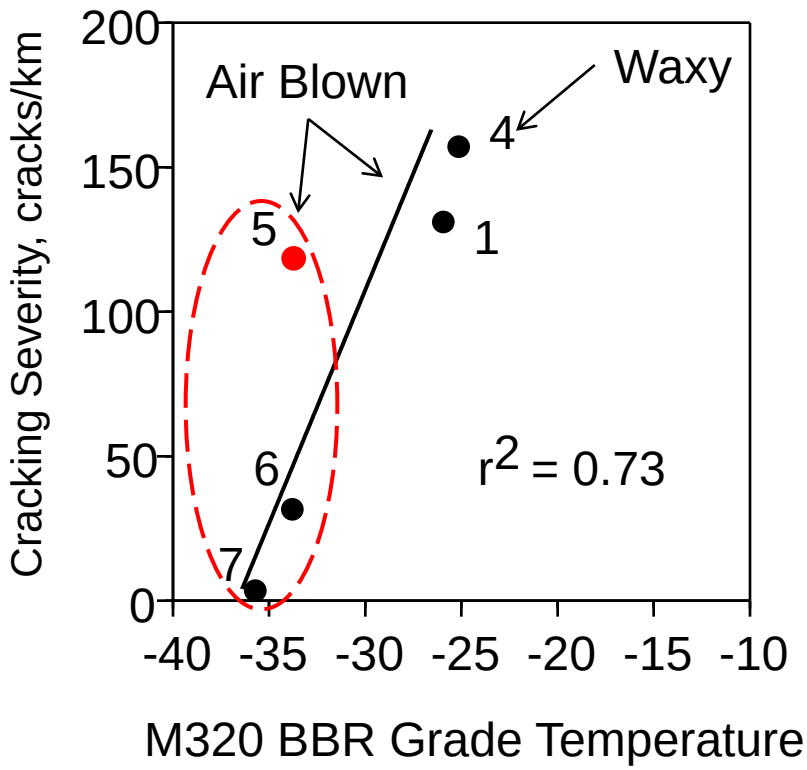
EBBR Grading

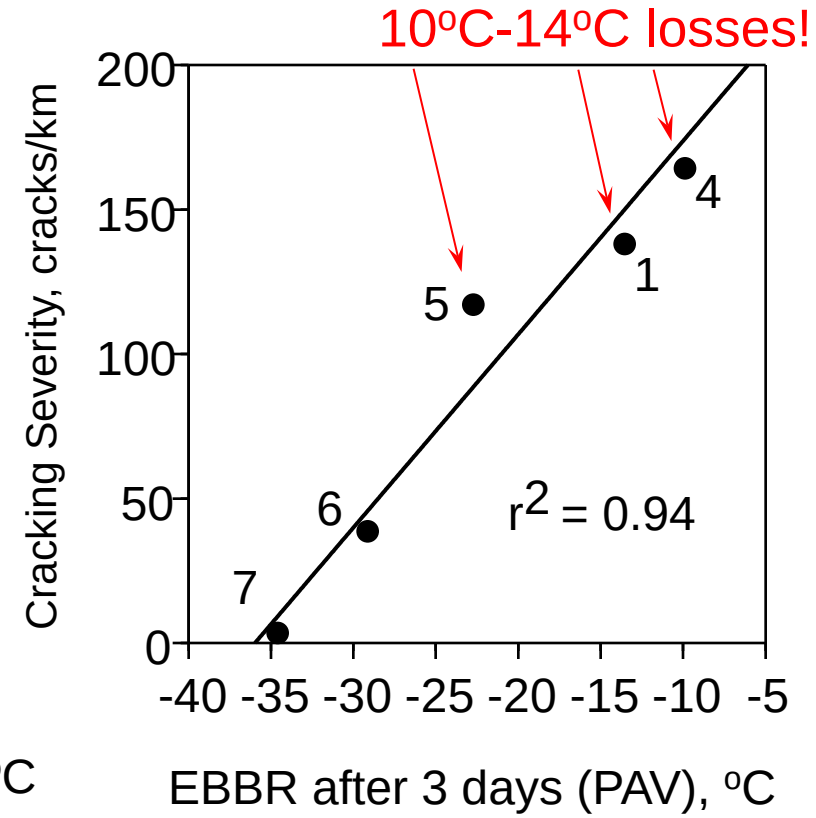
100 % Overall Accuracy (7 times out of 7)
100 % Accuracy in Predicting Failure (6 out of 7 times)



Extended BBR Validation

Canadian-SHRP Trial, Lamont, Alberta (1992-2003)

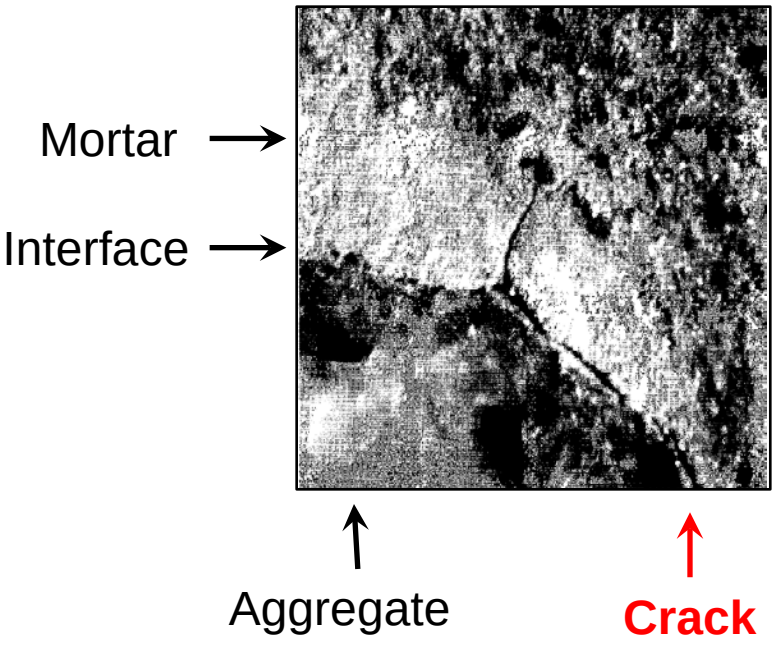


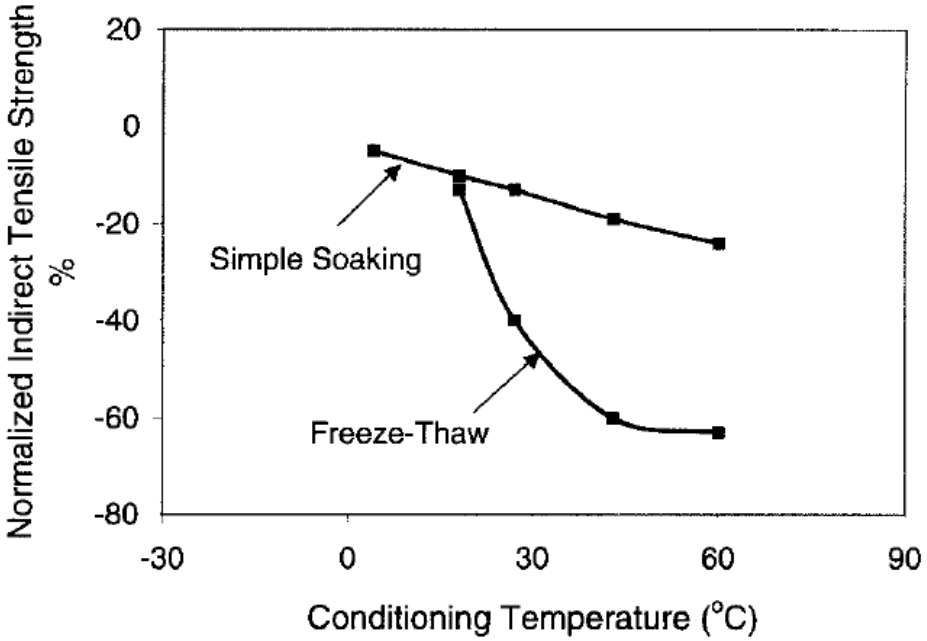


Gavin et al., *Proc. CTAA,* 2003 and Ou Zhao and Hesp, *IJPE*, 2006

Mix Hardening or Softening?

Hairline Cracks Cause Debonding → Severe Moisture Damage





El Hussain, Kim and Ponniah, *J. Mat. Civ. Eng.*, 1998

Identical PG 64-34 Sections,

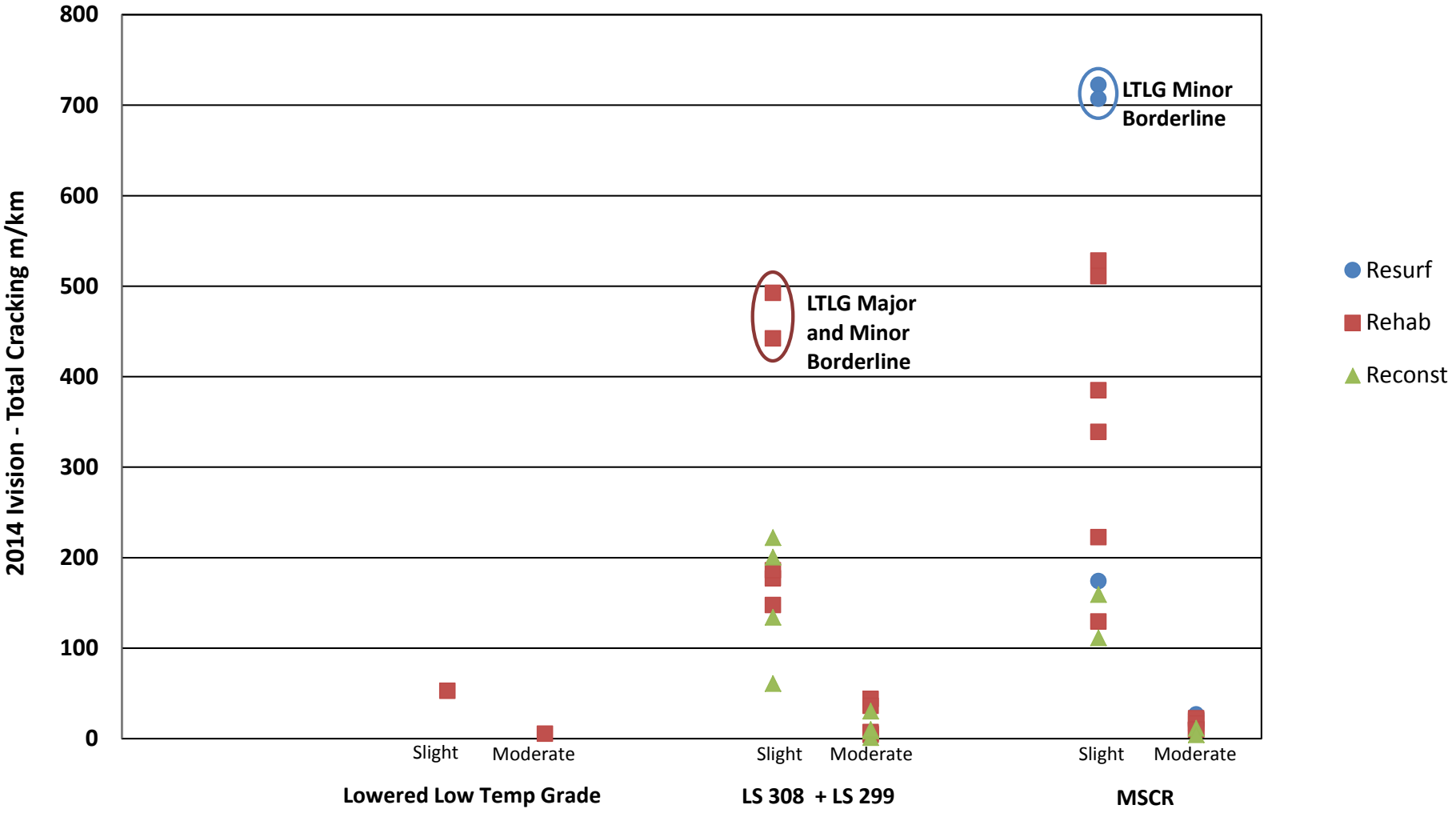
655-1 Sol-type AC: Low physical hardening, PI, R-value, oxidative hardening, S-controlled, and high CTOD. **No cracking or moisture damage.**

655-4 Gel-type AC: High physical hardening, PI, R-value, oxidative hardening, m-value controlled, and low CTOD. **Major cracking and moisture damage.**

Hesp et al., *Proceedings CTAA,* 2009

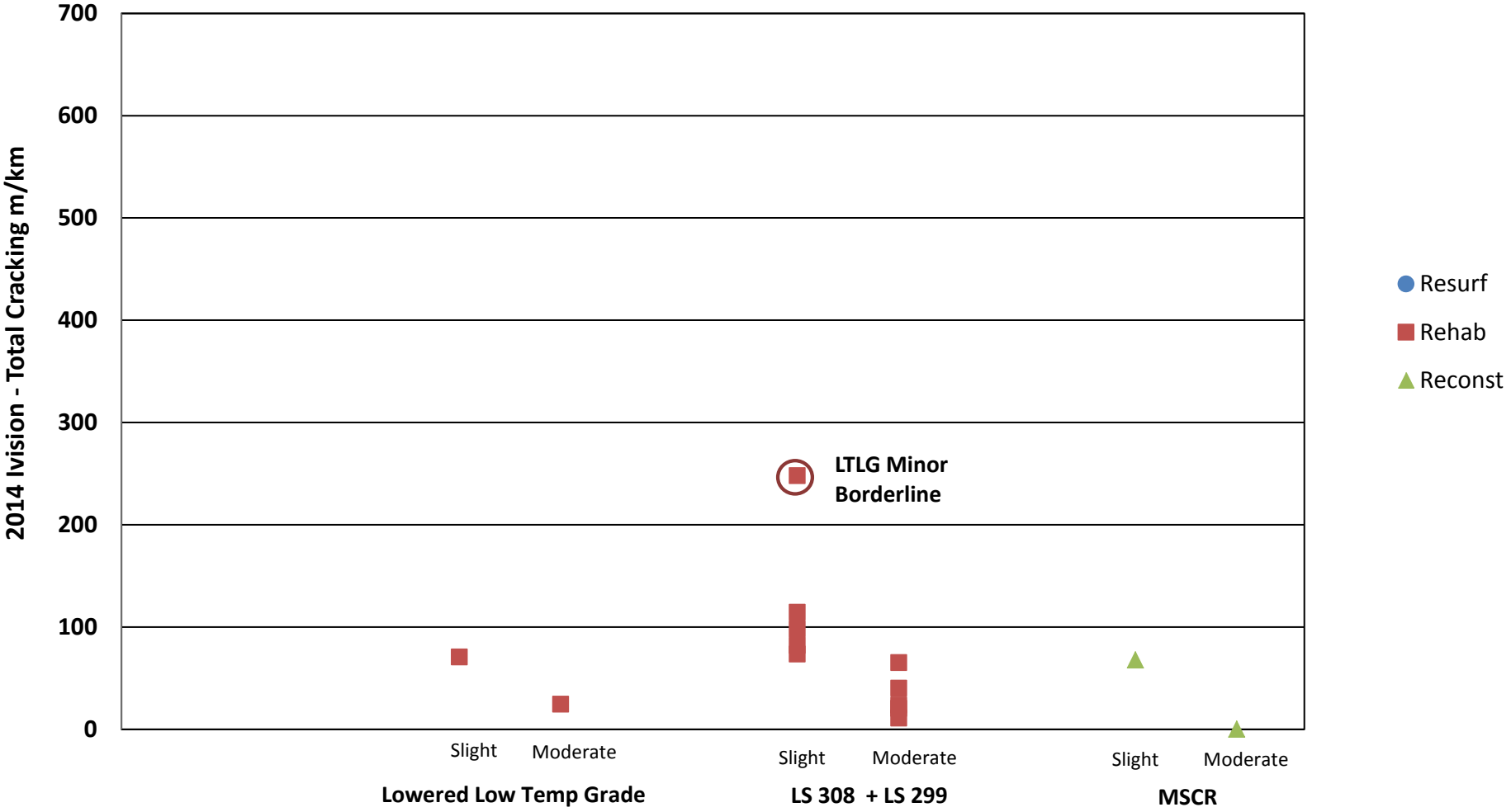
Cracking After 3 Years v.s. AC Initiative

(18 contracts)



Cracking After 2 Years v.s. AC Initiative

(11 Contracts)



Extended BBR Spreadsheet

Exceptional AC

Summary of Extended Bending Beam Rheometer Test Results
MTO Standard Test Method LS-308

OP: SH
LAB ID: SAMPLE A
TEST DATES:
AASHTO M320 GRADE: PG 63-27
SUPPLIER: A

Conditioning Temperature	Conditioning Period	Average m-values		Average Creep Stiffnesses		T_m	T_s	Limiting Temperature at m=0.300 T_m -10(°C)	Limiting Temperature at S=300 T_s -10(°C)	Limiting Grade T_L (°C)	Grade Loss (°C)
		T_{HT} -12	T_{LT} -18	T_{HT} -12	T_{LT} -18						
T +20°C	1 hour	0.404	0.332	133.3	318.7	-20.7	-17.6	-30.7	-27.6	-27.6	-0.4
	24 hours	0.390	0.308	135.0	332.3	-18.6	-17.3	-28.6	-27.3	-27.3	-0.2
-8°C	72 hours	0.380	0.310	144.0	331.3	-18.8	-17.3	-28.8	-27.3	-27.3	-0.1
T +10°C	1 hour	0.403	0.331	130.7	343.3	-20.6	-17.2	-30.6	-27.2	**-27.2**	0.0
	24 hours	0.382	0.290	153.0	332.7	-17.3	-17.2	-27.3	-27.2	-27.2	0.0
-18°C	72 hours	0.381	0.281	152.3	348.7	-16.9	-16.9	-26.9	-26.9	**-26.9**	**0.3**

	10, 11, 12
	4, 5, 6
	7, 8, 9
	1, 2, 3

PG XX-YY:

T + 20 = -8
T + 10 = -18

Note: The conditioning temperatures were kept constant at -8C and -18. All stiffnesses and m-values are averages of three replicates.

Extended BBR Implementation

Climatic Zone	EBBR Grade, ºC	Grade Loss, ºC
-28	< -28	< 6.0
-34	< -34	< 6.0
-40	< -40	< 6.0

Lab Correlation Results for 2014

	All	QA & Ref
Laboratories Participating	13 -17	4-5
Average EBBR LTLG Stdev (ºC)	0.9	0.9
Average Grade Loss (ºC)	0.75	0.4

Questions?

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