Rev.0

Recovered Asphalt versus Non-Recovered Asphalt Testing for Acceptance: An Ontario Industry Study

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ONTARIO ASPHALT PAVEMENT COUNCIL

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1 INTRODUCTION

In Ontario, paving-grade asphalts were once specified based on their properties in an original state following a specification such as the Performance Graded (PG) Binder Specification. However, with the increase observations of premature cracking in asphalt pavements, and the increased use of reclaimed asphalt pavement (RAP), many user agencies are also looking for ways to evaluate the properties of the in-place asphalt to ensure the final product will provide the expected performance.

One option is to conduct mixture performance testing. Although this option allows us to measure engineering properties that predict performance, a survey conducted by the National Center for Asphalt Technology (NCAT) shows that agencies have concerns with the validity, availability, and cost of current performance tests.

Another option, often selected by users because of its relative simplicity, is to conduct solvent extraction-recovery testing on the asphalt and determine the physical properties of the recovered binder in accordance with a standard specification, which is usually the same specification by which the asphalt was originally verified. Although intuitive and relatively simple, using recovered asphalt properties, particularly in a specification, is not without some potential concerns. Previous research has shown that:

a) The choice of procedure and solvent can have an impact on the resulting physical properties of the recovered asphalt binder

b) Physical properties test results of recovered binders have much higher variability compared to unrecovered binders.

c) The effect of solvent extraction on polymer modified binders and impact on physical properties is not well understood and still being investigated.

The Ontario Asphalt Pavement Council (OAPC) partnered with the University of Waterloo's Center for Pavement and Transportation Technology (CPATT) to conduct a study to compare the variability in physical properties between original asphalt and recovered asphalt from a plant produced asphalt mix. The study includes test methods that have not been included in past recovered asphalt studies such as: Extended Bending Beam Rheometer (ExBBR), and Double Notched Edge Tension (DENT) tests. The data collected was also compared to current specifications for illustration.

2 MATERIALS AND METHODOLOGY

2.1 Materials

The materials collected for this study are shown in Table 1:

Table 1: List of Asphalt Binders and Asphalt Mixes included in the study

Identification	Asphalt Mix Class	PGAC Grade	RAP Content
1-0708	HL1	70-28	0
2-0809	12.5FC2	70-28	15
3-0915	12.5	58-34	15
4-1003	12.5	58-34	0
6-1006	12.5	58-28	0
7-1010	12.5FC2	64-28	0
8-1031	12.5FC1	58-34	0

2.2 Methodology

Five industry labs in Ontario and one lab in the United States participated in the mini-laboratory study (ILS). Each lab received seven sets of asphalt materials sampled from the asphalt plant (tank asphalt), and its equivalent plant produced asphalt mix sampled from the paving site (Figure 1). When the asphalt mix contained RAP, RAP material was also collected.

Labs were instructed to follow the Ministry of Transportation Ontario (MTO) laboratory standards for testing both tank and recovered asphalt, with the exception that the solvent used for extraction was limited to reagent grade trichloroethylene (TCE). In addition to determining the true grade of the samples by AASHTO R29, the following tests were included which have not been part of past ILS's:

- MTO LS-227: Ash content.
- AASHTO T350: Multiple Stress Creep Recovery (MSCR) Test
- MTO LS-299: Double Edge Notch Tension (DENT) Test
- MTO LS-308: Extended Bending Beam Rheometer (ExBBR) Test

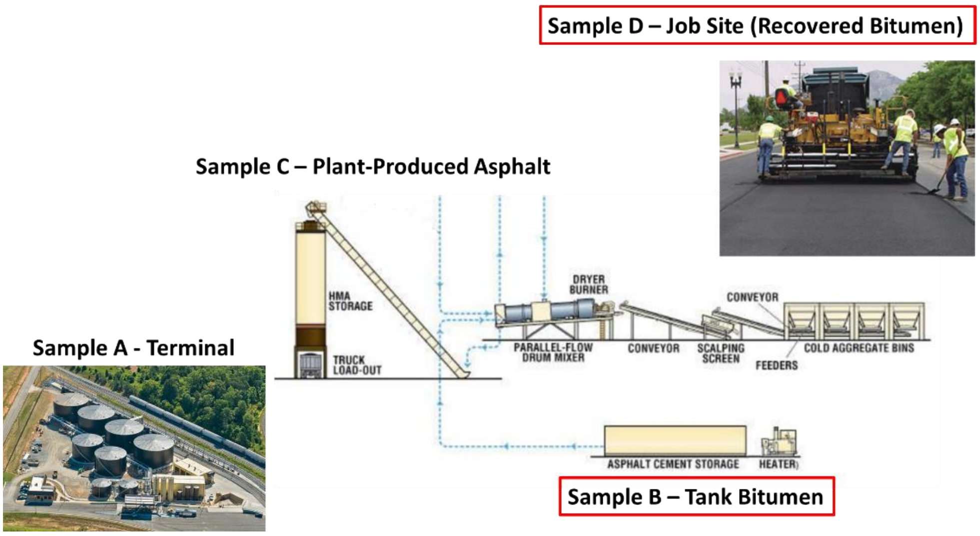

Figure 1: Schematic of Sampling Locations of Bitumen and Asphalt Mix

3 RESULTS AND DISCUSSION

The tank and recovered asphalt material properties results presented in this section are organized in tables for each bitumen grade. The tables show the average values and standard deviations of the measured parameters for each sample as an evaluation of the ILS. Asphalt mixes that contained RAP are separated from virgin (0% RAP) mixes.

Notes for all tables and charts:

- PG High = Performance Graded High Temperature
- PG Low = Performance Graded Low Temperature

- MSCR Jnr = Multiple Stress Creep Recovery Non-Recoverable Creep Compliance
- LTLG = Low Temperature Limiting Grade
- CTOD = Crack Tip Opening Displacement.
- StDev = Standard Deviation
- COV = Coefficient of Variance

3.1 PGAC 58-28: Variability in Testing of Material Properties of Tank and Recovered Asphalt

Table 2: PGAC 58-28 Tank Bitumen Properties

Material Property	Ash (%)	PG High (°C)	PG Low (°C)	MSCR Jnr (3.2kPa-1)	Grade Loss (°C)	LTLG (°C)	CTOD (15°C, mm)
Average	0.1	59.8	-34.3	2.2	2.7	-30.2	13.8
Min	0.05	58.9	-35.4	2.0	2.2	-31.2	9.7
Max	0.11	60.6	-33.0	2.4	4.0	-28.9	17.9
StDev	0.0	1.2	1.2	0.1	0.9	1.0	3.5
COV	0.0	2.0	3.5	4.5	33.3	3.2	25.4
Sample Size	4	2	3	4	4	4	4

Table 3: PGAC 58-28 Recovered Bitumen Properties (No RAP)

Material Property	Ash (%)	PG High (°C)	PG Low (°C)	MSCR Jnr (3.2kPa-1)	Grade Loss (°C)	LTLG (°C)	CTOD (15°C, mm)
Average	2.6	58.2	-35.5	4.8	5.3	-29.1	8.6
Min	1.32	51.5	-37.8	1.3	3.5	-30.0	1.5
Max	4.11	64.8	-34.1	8.7	8.2	-27.5	14.7
StDev	1.2	9.4	2.0	3.7	2.1	1.4	6.6
COV	44.7	16.2	5.6	77.5	40.6	4.9	76.8
Sample Size	4	2	3	4	4	3	4

Table 4: PGAC 58-28 Comparing Variability in Results for Tank and Recovered Bitumen

Material Property	Ash (%)	PG High (°C)	PG Low (°C)	MSCR Jnr (3.2kPa-1)	Grade Loss (°C)	LTLG (°C)	CTOD (15°C, mm)
StDev (Tank Bitumen)	0	1.2	1.2	0.1	0.9	1.0	3.5
StDev (Rec Bitumen)	1.2	9.4	2	3.7	2.1	1.4	6.6
% Change StDev	100	87	40	97	57	29	47

Table 4 shows that for PG 58-28, depending on the parameter being measured, the variability in test results increased between 29% to 100% for recovered asphalt samples versus the tank asphalt samples.

3.2 PGAC 64-28: Variability in Testing of Material Properties of Tank and Recovered Asphalt

Table 5: PGAC 64-28 Tank Asphalt Properties

Material Property	Ash (%)	PG High (°C)	PG Low (°C)	MSCR Jnr (3.2kPa-1)	Grade Loss (°C)	LTLG (°C)	CTOD (15°C, mm)
Average	0.1	65.4	-35.3	0.3	3.5	-30.4	14.0
Min	0.04	64.9	-37.1	0.2	3.1	-31.4	6.4
Max	0.1	65.9	-33.3	0.4	3.9	-29.2	21.2
StDev	0.0	0.7	1.9	0.1	0.4	0.9	6.1
COV	45.2	1.1	5.4	25.7	11.1	3.0	43.8
Sample Size	4	2	3	4	4	4	4

Table 6: PGAC 64-28 Recovered Asphalt Properties (No RAP)

Material Property	Ash (%)	PG High (°C)	PG Low (oC)	MSCR Jnr (3.2kPa-1)	Grade Loss (°C)	LTLG (°C)	CTOD (15°C, mm)
Average	5.0	76.3	-31.6	0.4	5.5	-25.1	6.7
Min	1.68	69.9	-32.2	0.1	3.9	-28.7	4.9
Max	7.8	82.6	-31.2	0.8	9.7	-20.5	8.9
StDev	2.7	9.0	0.5	0.3	2.8	3.4	1.9
COV	54.7	11.8	1.6	80.9	50.5	13.6	28.0
Sample Size	4	2	3	4	4	4	4

Table 7: PGAC 64-28 Comparing Variability in Results for Tank and Recovered Asphalt

Material Property	Ash (%)	PG High (°C)	PG Low (°C)	MSCR Jnr (3.2kPa-1)	Grade Loss (°C)	LTLG (°C)	CTOD (15°C, mm)
StDev (Tank Bitumen)	0	0.7	1.9	0.1	0.4	0.9	6.1
StDev (Rec Bitumen)	2.7	9	0.5	0.3	2.8	3.4	1.9
% Change StDev	100	92	-280	67	86	74	-221

Table 7 shows that for PG 64-28, apart from the PG Low temperature and CTOD parameters, the standard deviation increased approximately 67% to 100% for the recovered asphalt samples depending on the measured parameter. Although the standard deviation decreases for CTOD of recovered asphalt, it is also important to note the difference in the average result of CTOD: 14.0mm and 6.7mm for tank and recovered asphalt respectively. The impact of this difference becomes evident in the next section when the results are compared to the acceptance criteria.

3.3 PGAC 58-34: Variability in Testing of Material Properties of Tank and Recovered Asphalt

Table 8: PGAC 58-34 Tank Asphalt Properties

Material Property	Ash (%)	PG High (°C)	PG Low (oC)	MSCR Jnr (3.2kPa-1)	Grade Loss (°C)	LTLG (°C)	CTOD (15°C, mm)
Average	0.2	62.8	-37.4	0.6	3.3	-33.1	25.5
Min	0.07	61.6	-39.9	0.4	1.5	-36.8	15.8
Max	0.65	65.0	-35.4	1.0	4.7	-27.8	37.4
StDev	0.2	1.1	1.6	0.2	1.1	2.5	6.7
COV	86.8	1.8	4.2	30.4	31.7	7.7	26.3
Sample Size	12	8	10	12	12	12	12

Table 9: PGAC 58-34 Recovered Asphalt Properties (No RAP)

Material Property	Ash (%)	PG High (°C)	PG Low (oC)	MSCR Jnr (3.2kPa-1)	Grade Loss (°C)	LTLG (°C)	CTOD (15°C, mm)
Average	3.0	67.4	-37.6	0.7	4.9	-32.2	12.1
Min	1.10	66.9	-39.1	0.2	2.7	-34.9	7.0
Max	6.70	68.5	-36.0	1.9	6.4	-28.1	20.8
StDev	1.8	0.8	1.3	0.6	1.2	2.3	4.2
COV	59.6	1.1	3.4	82.9	24.3	7.1	35.0
Sample Size	8	4	6	7	8	8	8

Table 10: PGAC 58-34 Recovered Asphalt Properties (15% RAP)

Material Property	Ash (%)	PG High (°C)	PG Low (oC)	MSCR Jnr (3.2kPa-1)	Grade Loss (°C)	LTLG (°C)	CTOD (15°C, mm)
Average	2.4	70.9	-33.5	0.6	6.6	-23.4	4.5
Min	1.68	68.0	-36.4	0.2	4.6	-28.1	-0.1
Max	3.0	75.5	-29.7	1.3	8.0	-18.0	8.2
StDev	0.6	3.5	3.5	0.5	1.4	4.4	3.7
COV	23.4	4.9	10.3	77.7	21.7	18.7	83.1
Sample Size	4	4	3	4	4	4	4

Table 11: PGAC 58-34 Comparing Variability in Results for Tank and Recovered Asphalt

Material Property	Ash (%)	PG High (°C)	PG Low (°C)	MSCR Jnr (3.2kPa-1)	Grade Loss (°C)	LTLG (°C)	CTOD (15°C, mm)
StDev (Tank Bitumen)	0.2	1.1	1.6	0.2	1.1	2.5	6.7
StDev (Rec Bitumen – No RAP)	1.8	0.8	1.3	0.6	1.2	2.3	4.2
StDev (Rec Bitumen – 15% RAP)	0.6	3.5	3.5	0.5	1.4	4.4	3.7
% Change StDev (No RAP)	89	-38	-23	67	8	-9	-60
% Change StDev (15% RAP)	67	69	54	60	21	43	-81

It is understood that one of the motivations for owners to test recovered asphalt is to control the use of RAP in asphalt mixes. The improper use of RAP can result in less durable mixes that are prone to cracking, which significantly reduces the service life of the asphalt pavement. However, if the testing protocols used for acceptance are not both accurate and precise as demonstrated in Figure 2, owners will have a challenge distinguishing between good and poor performing materials, where the reference value is the actual physical property value. Table 11 and Table 15 show the variability in testing recovered asphalt from a virgin and 15% RAP asphalt mix, produced with the same tank asphalt.

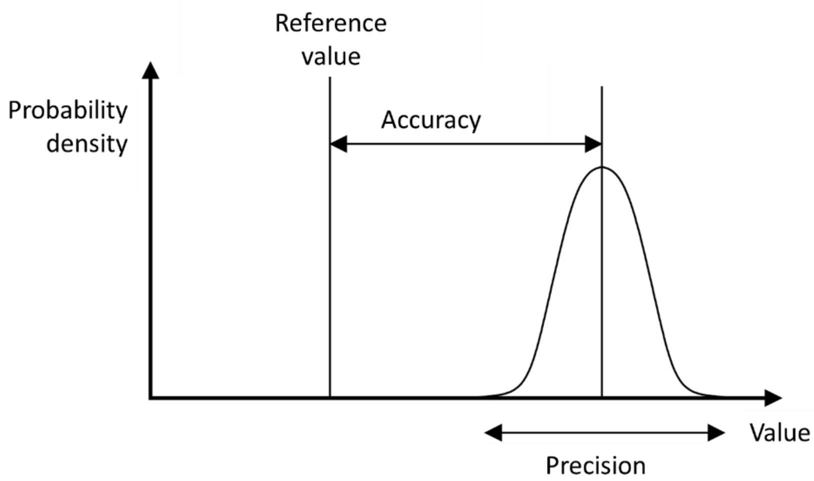

Figure 2: Illustration of Precision and Accuracy

Table 11 shows that for PG 58-34 recovered from a virgin mix, the variability increased for some of the parameters and decreased for others compared to the tank asphalt. When the recovered asphalt included 15% RAP, the variability increased by 21% to 69% for the different measured properties. Also note the difference in the CTOD average values for tank asphalt, 0% RAP recovered asphalt, and 15% RAP recovered asphalt: 25.5mm, 12.1mm, and 4.5mm respectively.

Similarly, these final set of tables show the results for PG 70-28, which is a polymer modified. Table 15 shows that when the recovered asphalt included 15% RAP, the variability in test results were higher by 68% to 100% compared to tank asphalt properties.

This variability presents a challenge for owners to not only accept poor performing material, but equally for rejecting a good performing material.

3.4 PGAC 70-28: Variability in Testing of Material Properties of Tank and Recovered Asphalt

Table 12: PGAC 70-28 Tank Asphalt Properties

Material Property	Ash (%)	PG High (°C)	PG Low (oC)	MSCR Jnr (3.2kPa-1)	Grade Loss (°C)	LTLG (°C)	CTOD (15°C, mm)
Average	0.1	72.4	-35.5	0.1	4.1	-29.7	12.5
Min	0.0	70.3	-36.7	0.0	2.4	-32.8	4.7
Max	0.1	75.7	-34.8	0.1	6.1	-27.9	23.1
StDev	0.0	1.4	0.6	0.0	1.2	1.5	6.6
COV	29.7	2.0	1.6	40.0	29.7	5.1	52.8
Sample Size	8	10	10	10	8	8	8

Table 13: PGAC 70-28 Recovered Bitumen Properties (No RAP)

Material Property	Ash (%)	PG High (°C)	PG Low (oC)	MSCR Jnr (3.2kPa-1)	Grade Loss (°C)	LTLG (°C)	CTOD (15°C, mm)
Average	2.7	75.2	-34.7	0.1	4.0	-28.5	9.3
Min	2.1	72.1	-35.8	0.0	3.5	-29.6	7.1
Max	3.6	77.8	-32.8	0.1	4.8	-27.1	11.0
StDev	0.7	2.3	1.3	0.0	0.6	1.0	1.6
COV	25.2	3.1	3.8	45.4	15.0	3.7	17.5
Sample Size	4	5	4	5	4	4	4

Table 14: PGAC 70-28 Recovered Bitumen (15% RAP)

Material Property	Ash (%)	PG High (°C)	PG Low (oC)	MSCR Jnr (3.2kPa-1)	Grade Loss (°C)	LTLG (°C)	CTOD (15°C, mm)
Average	3.3	82.0	-27.1	0.1	5.5	-21.5	4.0
Min	2.3	77.4	-35.4	0.1	2.3	-25.2	2.5
Max	4.2	93.0	-11.6	0.1	9.7	-16.0	6.1
StDev	0.9	6.3	10.6	0.0	3.8	4.8	1.9
COV	28.2	7.7	39.0	17.1	68.4	22.5	46.1
Sample Size	4	5	4	4	3	3	3

Table 15: PGAC 70-28 Comparing Variability in Results for Tank and Recovered Bitumen

Material Property	Ash (%)	PG High (°C)	PG Low (°C)	MSCR Jnr (3.2kPa-1)	Grade Loss (°C)	LTLG (°C)	CTOD (15°C, mm)
StDev (Tank Bitumen)	0.0	1.4	0.6	0.0	1.2	1.5	6.6
StDev (Rec Bitumen – No RAP)	0.7	2.3	1.3	0.0	0.6	1.0	1.6
StDev (Rec Bitumen – 15% RAP)	0.9	6.3	10.6	0.0	3.8	4.8	1.9
% Change StDev (No RAP)	100	39	54	-	-100	59	-313
% Change StDev (15% RAP)	100	78	94	-	68	69	-247

3.5 Graphical Comparison of Tank and Recovered Bitumen Properties to Ontario Bitumen Specification

The tables showed that testing variability is higher for recovered asphalt compared to tank asphalt, however it is also important to illustrate the impact of testing recovered asphalt for acceptance. Most specifications apply the same acceptance criteria and tolerances to recovered asphalt as they do for tank asphalt. The following graphs show the test results of tank asphalt and recovered asphalt properties on the 2019 MTO specification for acceptance of original asphalt. The error bars show the average and standard deviation of the test results submitted by the participating labs.

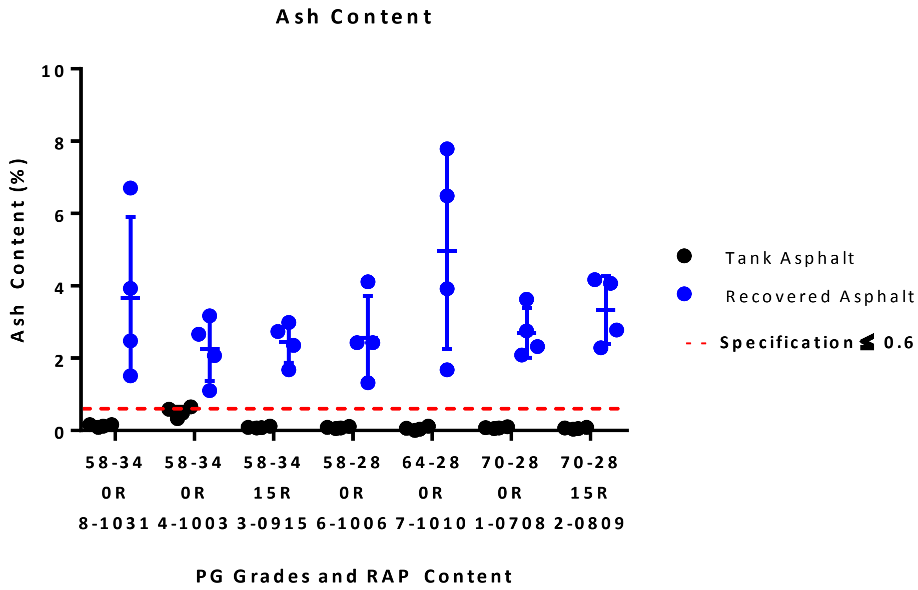

Figure 3: Comparing Tank and Recovered Asphalt Results for Ash Content to MTO Asphalt Specifications

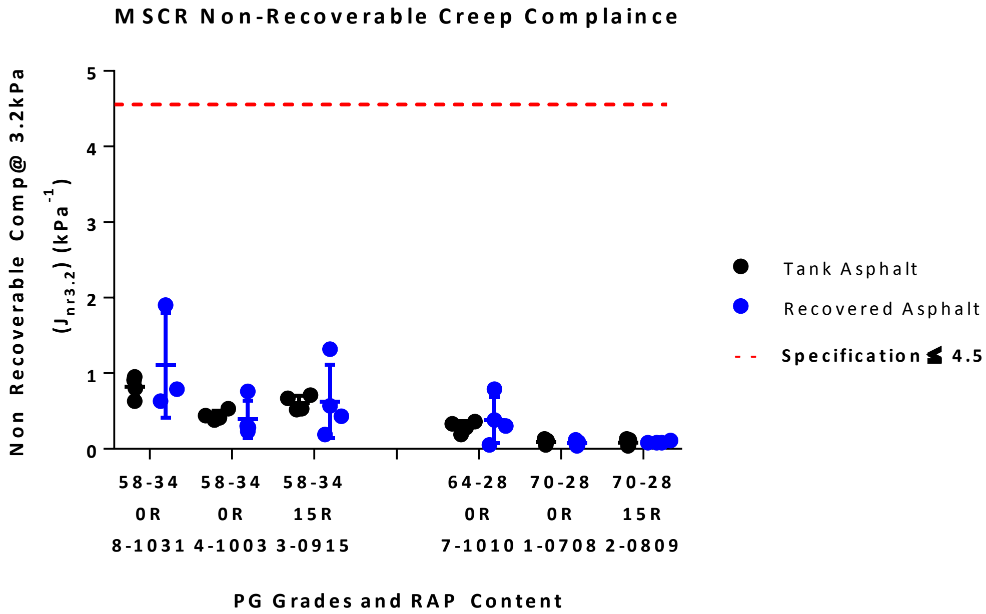

Figure 4: Comparing Tank and Recovered Asphalt Non-Recoverable Creep Compliance Results from Multiple Stress Creep Recovery Test to Ontario Asphalt Specification

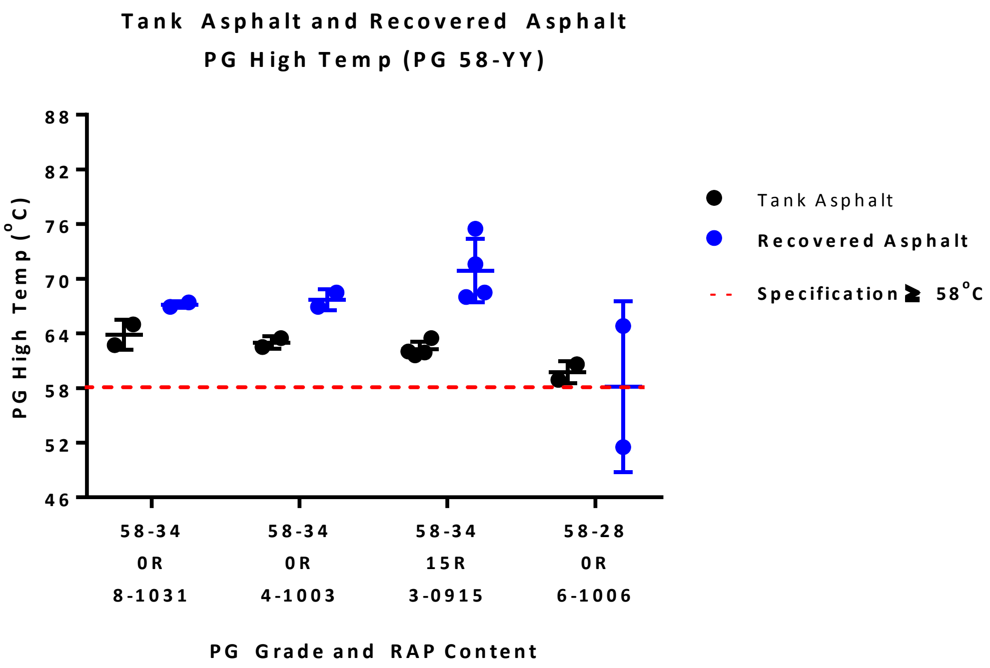

Figure 5 Comparing Tank and Recovered Asphalt Results for Performance Grade (PG) High Temperature for PG 58-YY to Ontario Asphalt Specifications

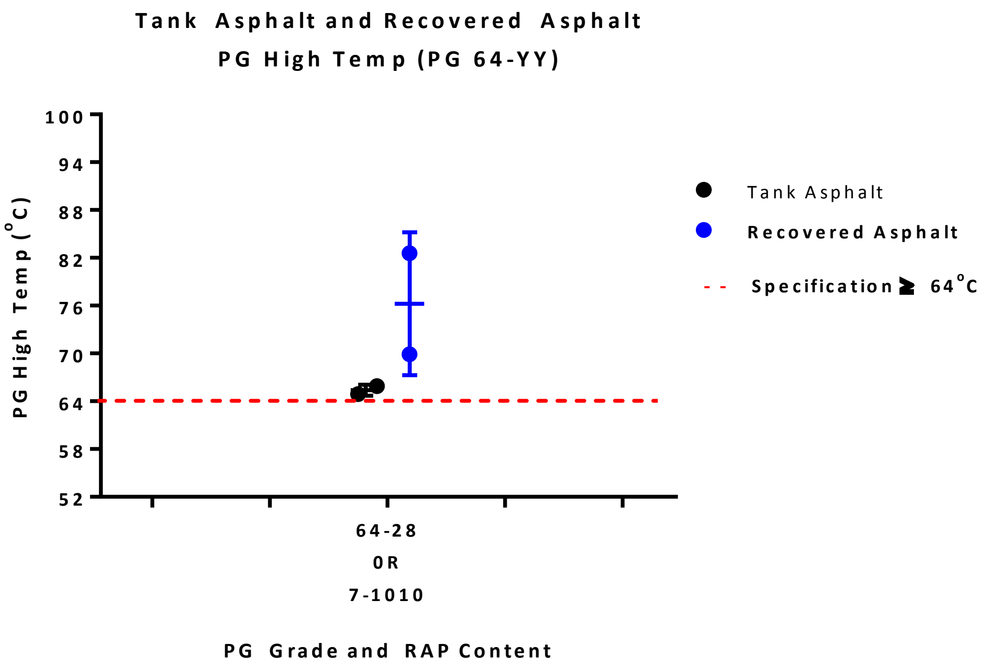

Figure 6: Comparing Tank and Recovered Bitumen Performance Graded (PG) High Temperature Results for (a) PG-64-YY to Ontario Asphalt Specification

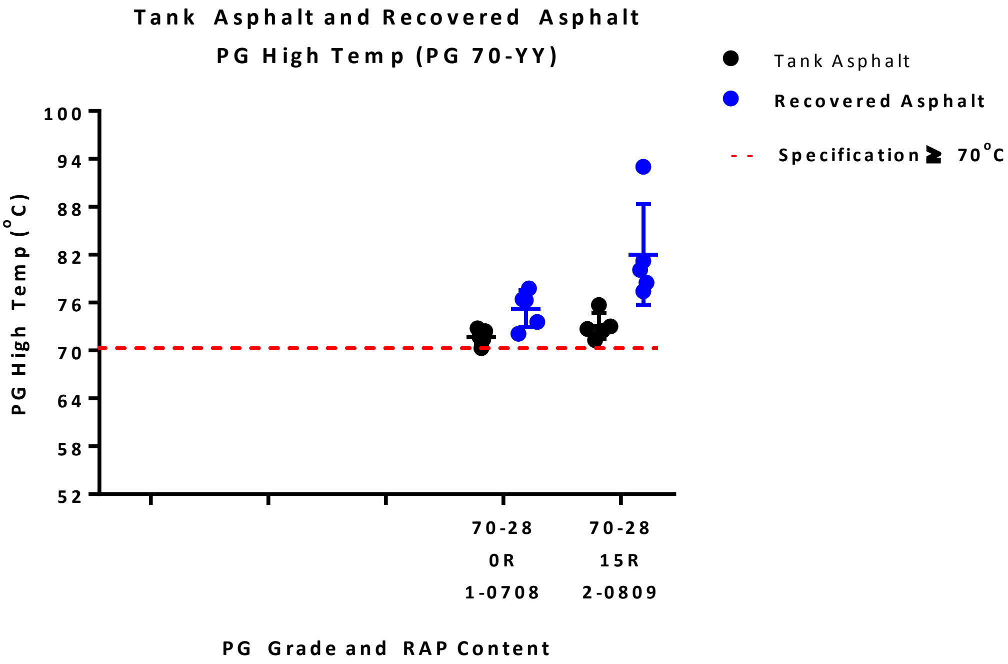

Figure 7: Comparing Tank and Recovered Bitumen Performance Graded (PG) High Temperature Results for PG 70-YY to Ontario Asphalt Specification

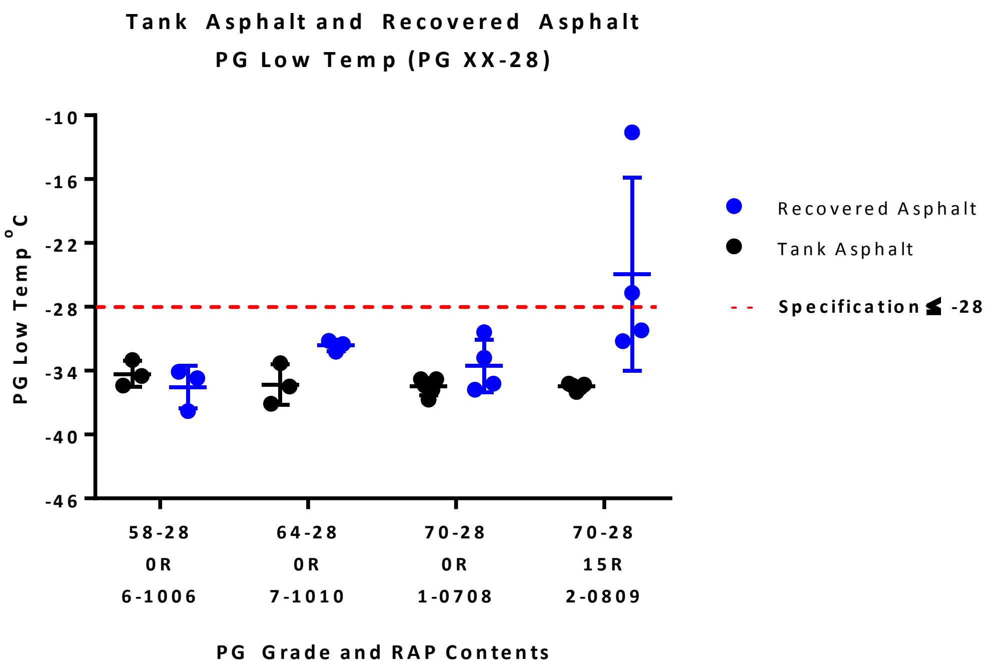

Figure 8: Comparing Tank and Recovered Asphalt Performance Graded (PG) Low Temperature Results for (a) PG XX-28 to Ontario Asphalt Specification

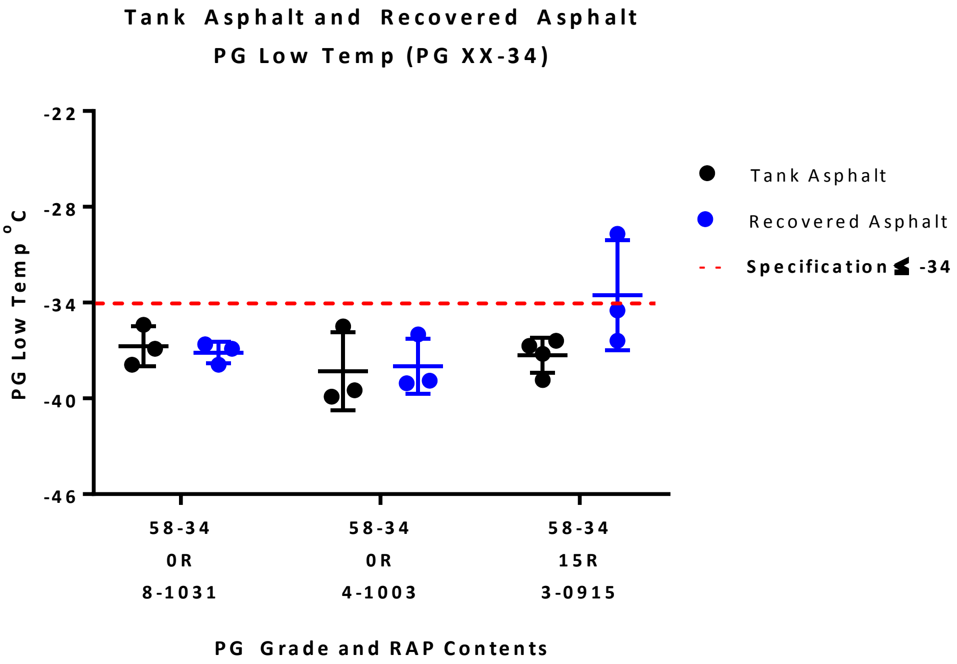

Figure 9: Comparing Tank and Recovered Asphalt Performance Graded (PG) Low Temperature Results for PG XX-34 to Ontario Asphalt Specification

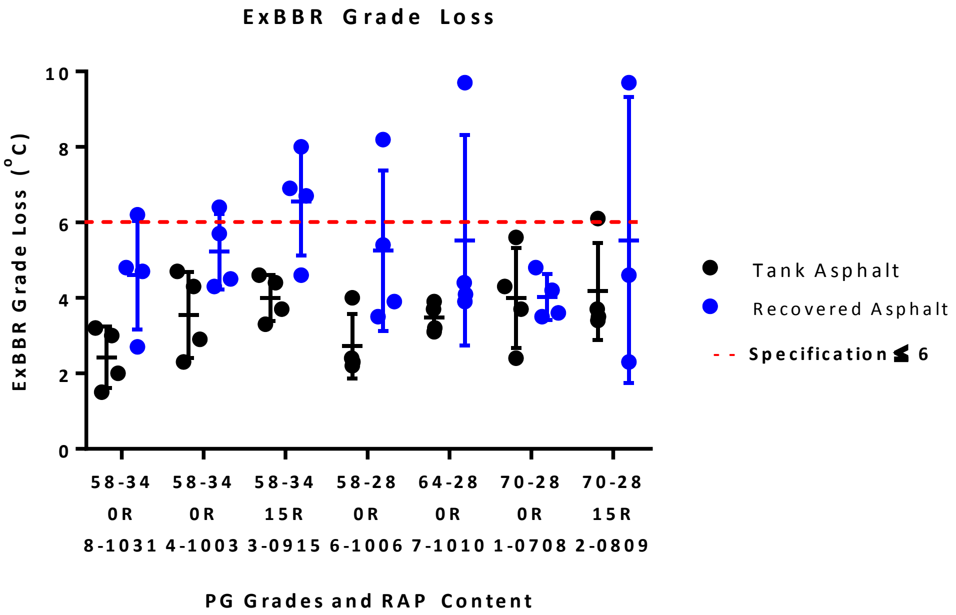

Figure 10: Comparing Tank and Recovered Asphalt Grade Loss from Extended Bending Beam Rheometer to Ontario Asphalt Specification

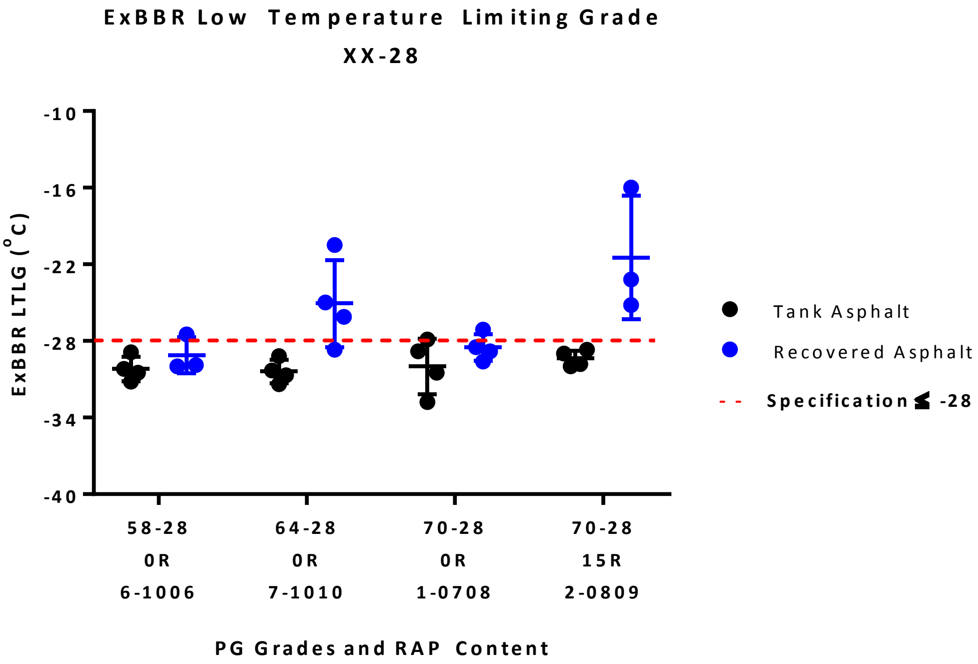

Figure 11: Comparing Tank and Recovered Asphalt Low Temperature Limiting Grade (LTLG) Results for PG XX-28 from Extended Bending Beam Rheometer to Ontario Asphalt Specification

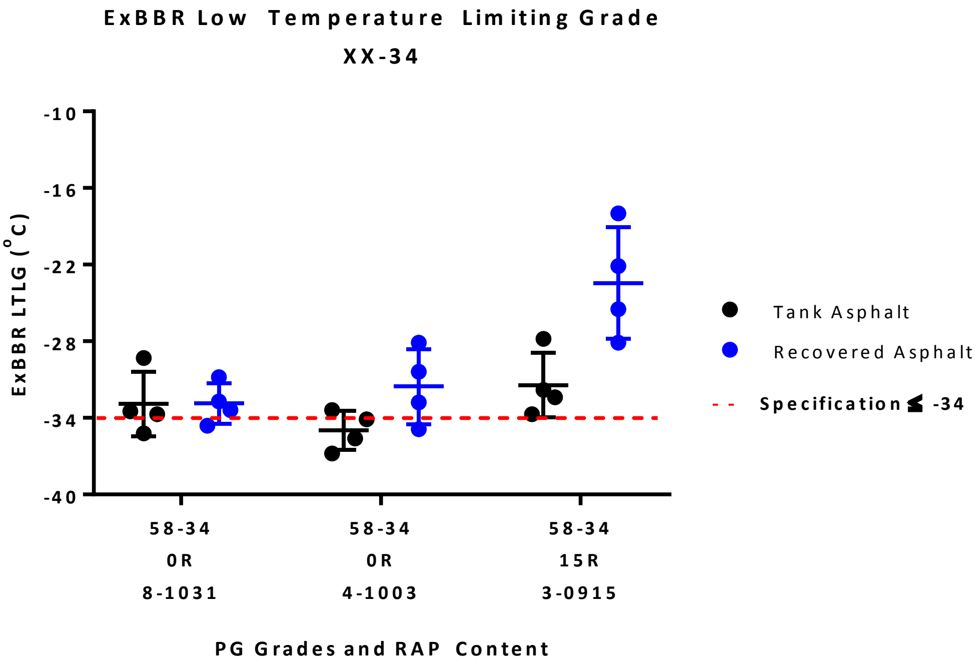

Figure 12: Comparing Tank and Recovered Asphalt Low Temperature Limiting Grade (LTLG) Results for PG XX-34 from Extended Bending Beam Rheometer to Ontario Asphalt Specification

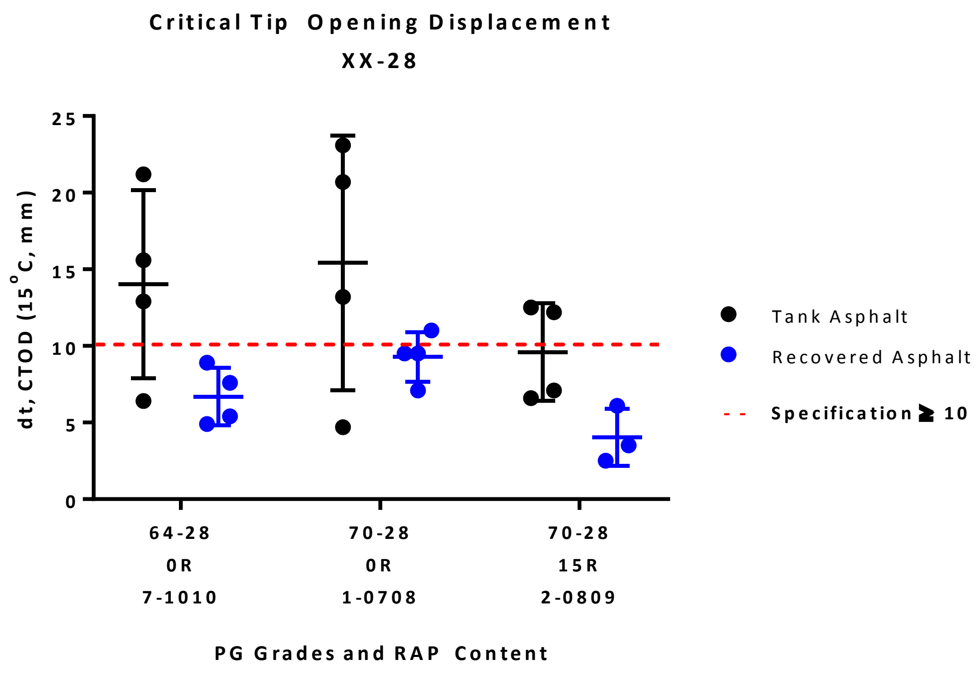

Figure 13: Comparing Tank and Recovered Asphalt Critical Tip Opening Displacement (CTOD) Results from Double Edge Notched Tension Test for XX-28 to Ontario Asphalt Specifications

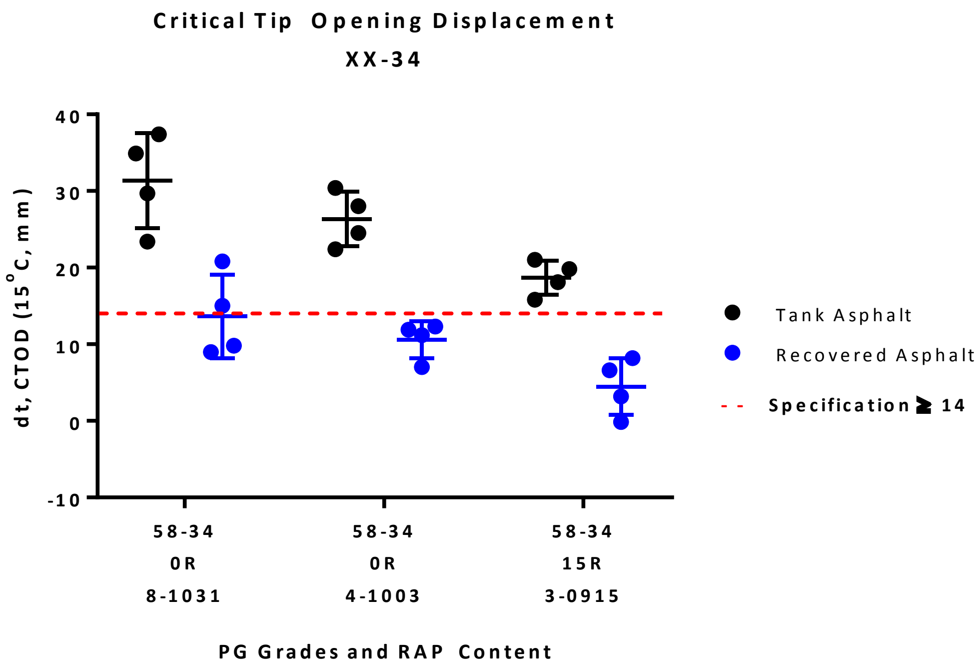

Figure 14: Comparing Tank and Recovered Asphalt Critical Tip Opening Displacement (CTOD) Results from Double Edge Notched Tension Test for XX-34 to Ontario Asphalt Specifications

4 SUMMARY OF FINDINGS

Comparing the variability or standard deviations of material properties of tank asphalt and recovered asphalt revealed the following:

- PG 58-28: the standard deviation for material properties of recovered asphalt increased by 29% to 100%.
- PG 64-28: the standard deviation for material properties of recovered asphalt increased by 67% to 100%, except for the PG Low temperature and CTOD parameters.
- The addition of 15% RAP in the plant produced asphalt mix with PG 58-34 increased the standard deviations of the material properties in the recovered asphalt samples by 21% to 69%.
- The addition of 15% RAP in the plant produced asphalt mix with PG 70-28 increased the standard deviation of the material properties of the recovered asphalt samples by 68% to 100%.

Comparing the test results from the various labs with the 2019 MTO asphalt specification shows the following:

- 100% of tank asphalt samples passed ash content requirement, while 0% of recovered asphalt samples passed.
- In the ExBBR test:
    - 96% of tank asphalt samples passed the grade loss requirement; 70% of recovered asphalt samples passed.
    - 94% of tank asphalt samples passed the XX-28 LTLG requirement; 43% of recovered asphalt samples passed.
    - 33% of tanks asphalt samples passed the XX-34 LTLG requirement; 17% of recovered asphalt samples passed.
- In the DENT test:
    - 67% of tank asphalt samples of PG 64-28 and PG 70-28 passed the CTOD minimum requirement; only 9% of recovered asphalt samples passed.
    - 100% of tanks samples of PG 58-34 passed the minimum CTOD requirement; only 17% of recovered asphalt passed.

5 CONCLUSION

It is well documented that the extraction-recovery procedures and solvents used can have an impact on the recovered asphalt binder properties. As well, the process of mixing an asphalt binder with aggregates and possibly RAP, coupled with the aging that occurs during production can significantly impact the properties of the blended asphalt binder (virgin and recycled).

The physical properties of recovered asphalt, as shown in this study, have much higher variability than would be experienced if performing the same physical property tests on unrecovered (i.e. original) asphalt binder. As such, it is recommended that users should exercise caution when comparing values of recovered asphalt binder to test criteria and variability derived for unrecovered (original) asphalt binder.

6 REFERENCES

Nosler I, Tanghe T, Soenen H. “Evaluation of Binder Recovery Methods and the Influence on the Properties of Polymer Modified Bitumen” Eurasphalt & Eurobitume Congress, Copenhagen, Denmark (2008)

McDaniel RS, Soleymani HR, Anderson RM, Turner PA, Peterson RL. Recommended Use of Reclaimed Asphalt Pavement in the Superpave Mix Design Method, National Cooperative Highway Research Program (NCHRP) Web Document 30, Transportation Research Board, National Research Council, National Academies, Washington, D.C. (2000).

McDaniel RS, Anderson RM. Recommended Use of Reclaimed Asphalt Pavement in the Superpave Mix Design Method: Technician’s Manual, National Cooperative Highway Research Program (NCHRP) Report 452, Transportation Research Board, National Research Council, National Academies, Washington, D.C. (2001).

Reinke G. “Discussion of 2015 ASTM Binder Recovery ILS”, presented at the 2017 Asphalt Institute Summer Meeting, Montreal, QC (August 9, 2017)

Wakefield A, Anderson RM, McKay Z, Tighe SL. “A Review of Solvent Extraction-Recovery Procedures and their Effect on Recovered Asphalt Binder Properties”, Proceedings for 63rd Annual Canadian Technical Asphalt Association Conference, Vol. LXIII, 475-496, Regina, SK (Nov 2018).

West R, Rodezno C, Leiva F, Yin F. Development of a Framework for Balanced Mix Design, National Cooperative Highway Research Program (NCHRP) Final Report, Project NCHRP 20-07/Task 406. (Aug 2018)