


ENGAGING WITH OPSS.MUNI 1101: HIGHLIGHTS AND EXPEREINCES

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OAPC – 2021 ATS

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GOLDER

PRESENTATION OUTLINE

- Introduction
  - Performance Graded Asphalt Cement (PGAC)
  - Asphalt cement specification OPSS.MUNI 1101 before 2016
  - Premature pavement cracking
- OPSS.MUNI 1101 Nov 2016 asphalt cement specification
- Advanced testing
- Asphalt pavement performance
- Current nomenclature
- Summary

INTRODUCTION

- More extreme weather conditions
  - Hot summers

  - Cold winters

INTRODUCTION

PG Grading System

PG 58 -28

Performance Grade

HIGH TEMP RATING
DSR; T=58 ^{O}C at:
G*/sin δ >= 1.00 kPa (tank)
- or -
G*/sin δ >= 2.20 kPa (RTFO)

LOW TEMP RATING
BBR; T=-18 ^{O}C at:
S(60) <= 300 MPa
- or -
m(60) >= 0.30

AAT

PGAC ZONES IN ONTARIO

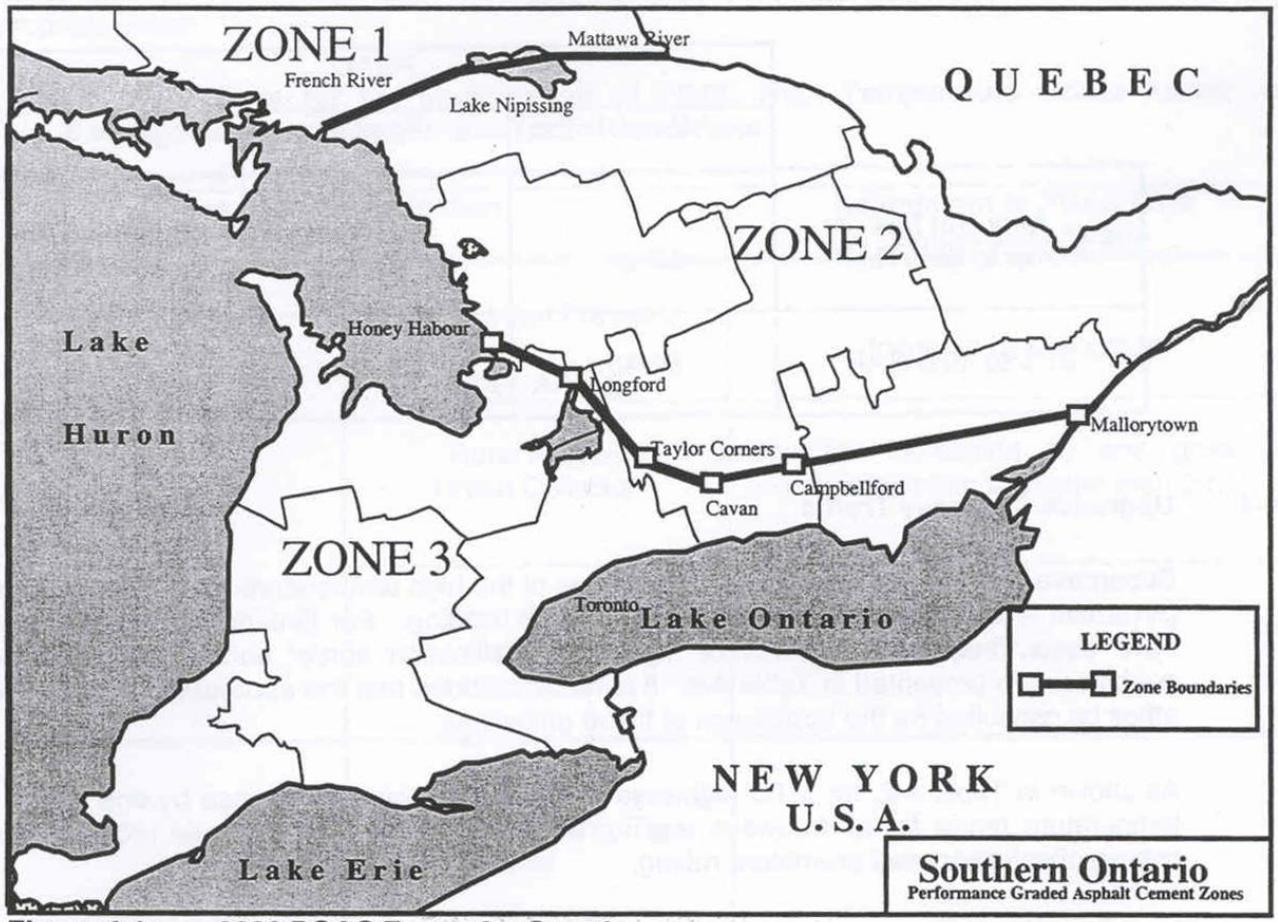
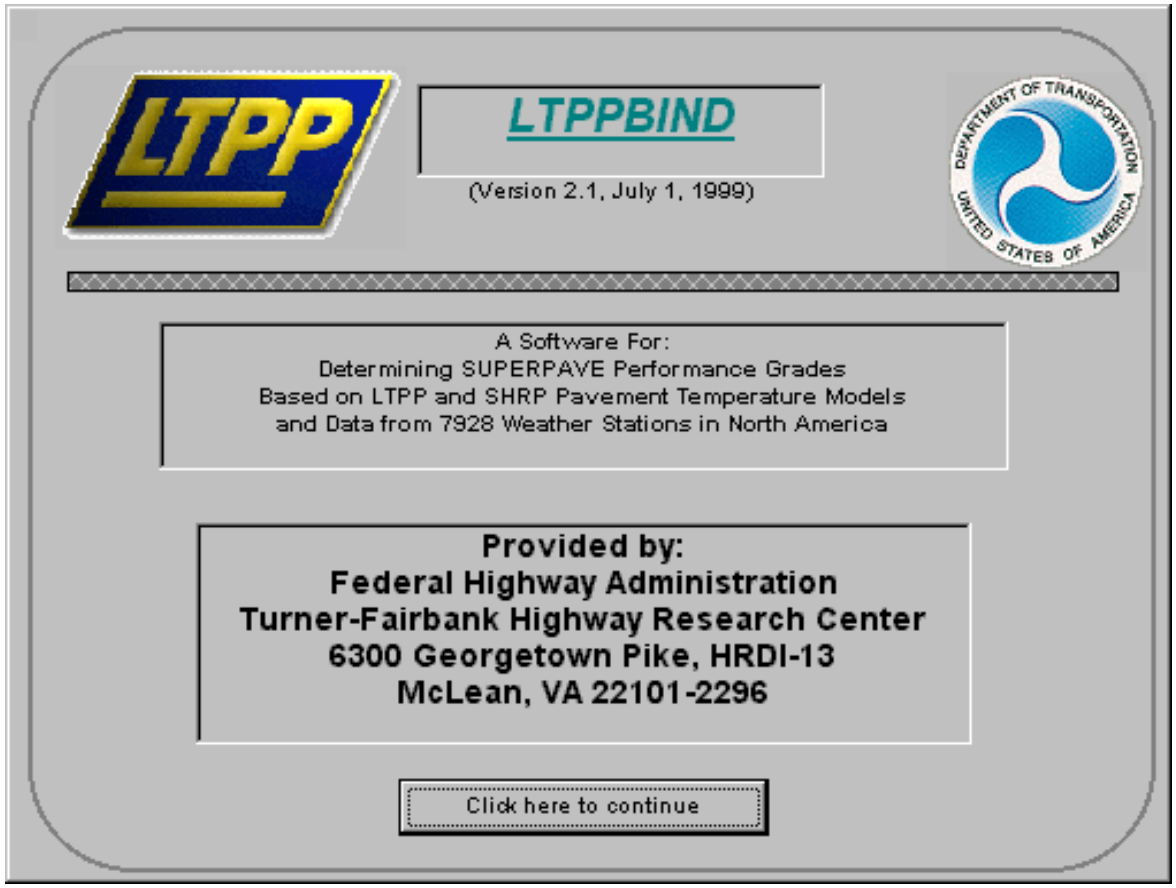
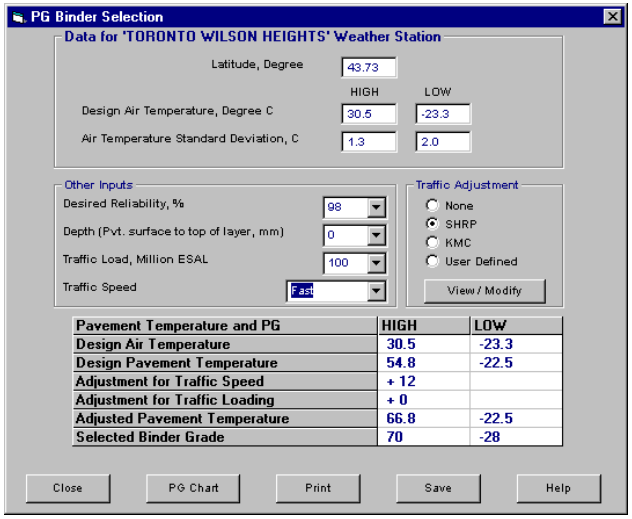
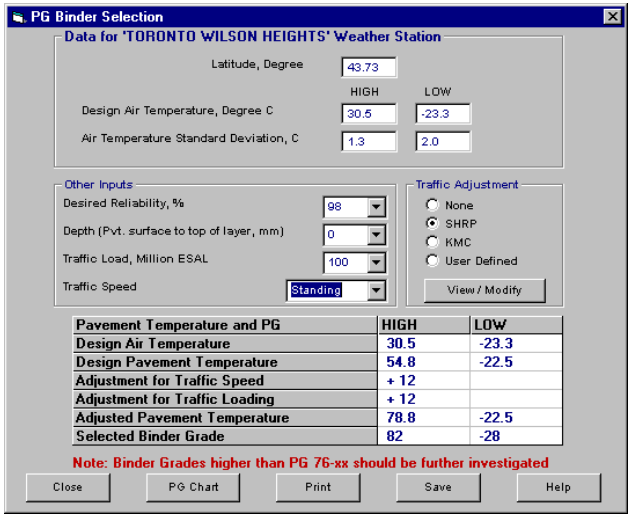


Figure 4-1: 2000 PGAC Zones for Ontario

INTRODUCTION



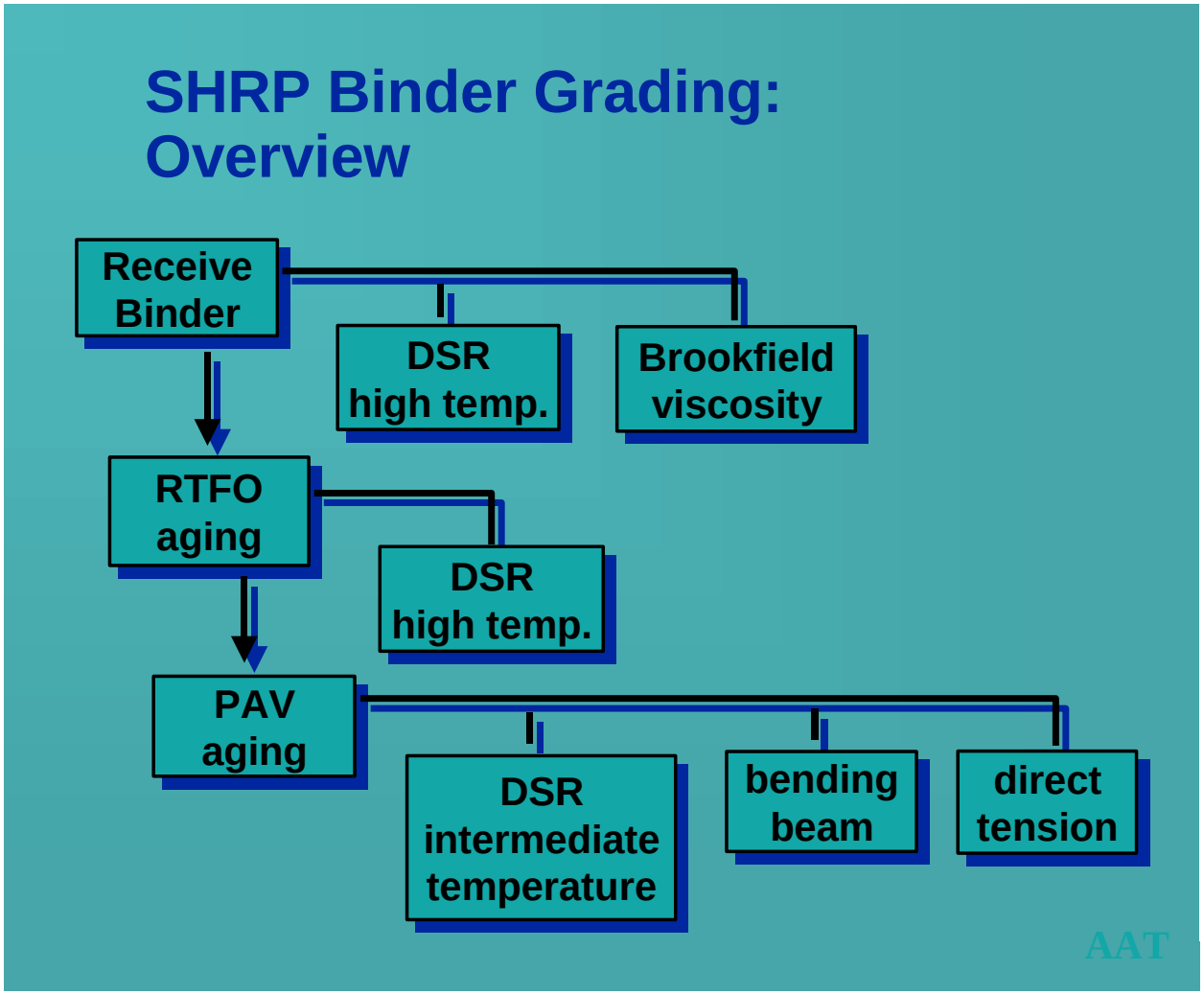




BEFORE 2016 AC SPECIFICATION

- Rotational Viscometer (Brookfield)
  - Is this material pumpable?
- Dynamic Shear Rheometer (DSR)
  - Strength properties at high temperatures
- Rolling Thin Film Oven (RTFO)
  - Simulates short term aging
- Pressure Aging Vessel (PAV)
  - Simulates long term aging
- Bending Beam Rheometer (BBR)
  - Flexibility properties at low temperatures
- Direct Tension Testing (DTT) (optional)

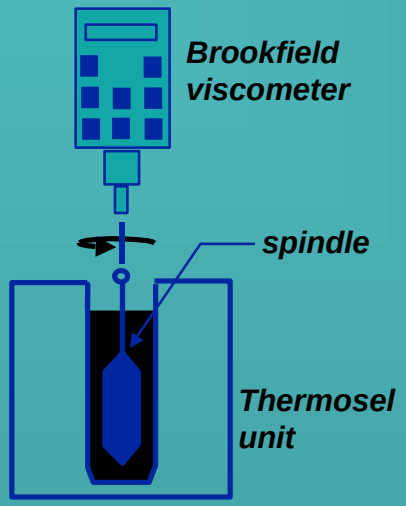
SUPERPAVE TESTING



Source: OHMPA

ROTATIONAL VISCOSITY

Rotational Viscosity



shear stress:

$$\tau = T / 2\pi R_s^2 L$$

shear strain rate:

$$\dot{\gamma} = \frac{2 R_c^2 \omega}{R_c^2 - R_b^2}$$

viscosity:

$$\eta = \tau / \dot{\gamma}$$

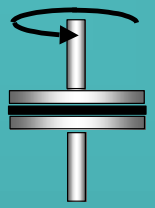
Source: OHMPA

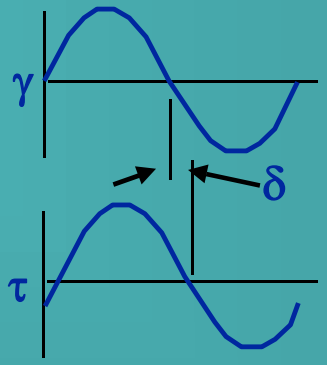
DYNAMIC SHEAR RHEOMETER (DSR)

- Measures strength properties of the asphalt cement at selected temperature
- High Temperature Testing
  - Tests performed on Tank and RTFO aged asphalt cement
  - Tests performed at pavements high temperature
  - Results from both tests must meet minimum specifications
  - Determines rutting resistance

DYNAMIC SHEAR RHEOMETER (DSR)

Dynamic Shear Rheometer (DSR)





complex modulus:

$G^* = \tau_{max} / \gamma_{max}$

loss modulus:

$G'' = G^* \sin \delta$

storage modulus:

$G' = G^* \cos \delta$

AAT

Source: OHMPA

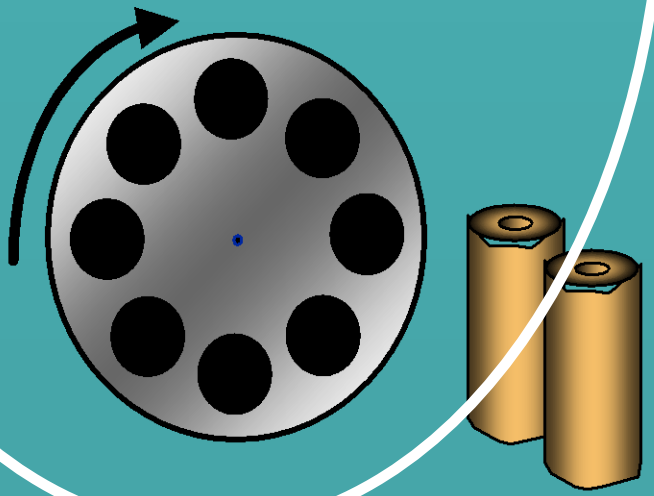
Binder Aging Methods

hot-mix plant

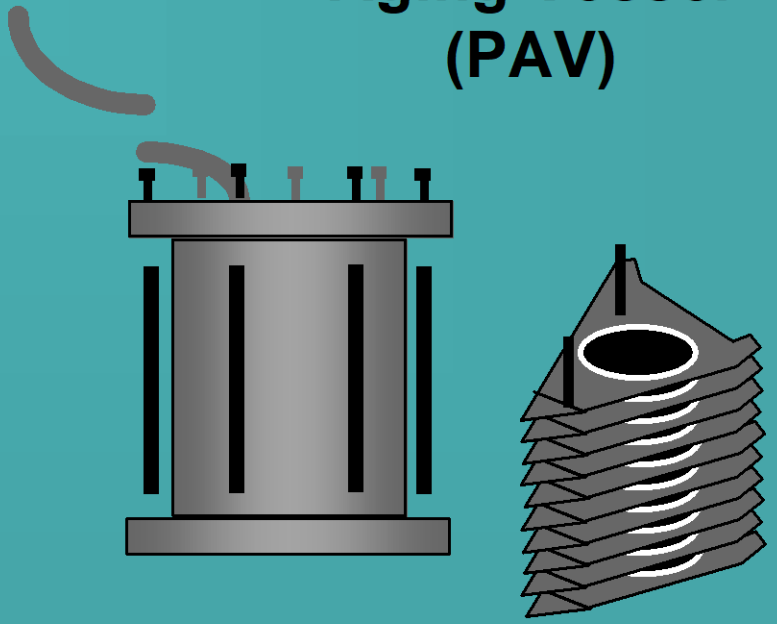
3 to 6 months

2 to 5 years ?

Rolling Thin Film Oven (RTFO)



Pressure Aging Vessel (PAV)



Source: OHMPA

ROLLING THIN FILM OVEN (RTFO)

- Simulates the aging of the asphalt cement as it travels through the asphalt plant, mixed with aggregate and placed
- Determines the stability of the asphalt cement when subjected to hot air
  - Asphalt cement is placed in glass bottles
  - Bottles are rotated @15 RPM, AC is spread thin
  - Hot air @ 163 C is blown into bottles
  - Mass loss is determined after 85 minutes in oven
  - Maximum allowable change in mass is +/- 1%

ROLLING THIN FILM OVEN (RTFO)

Source: GAL

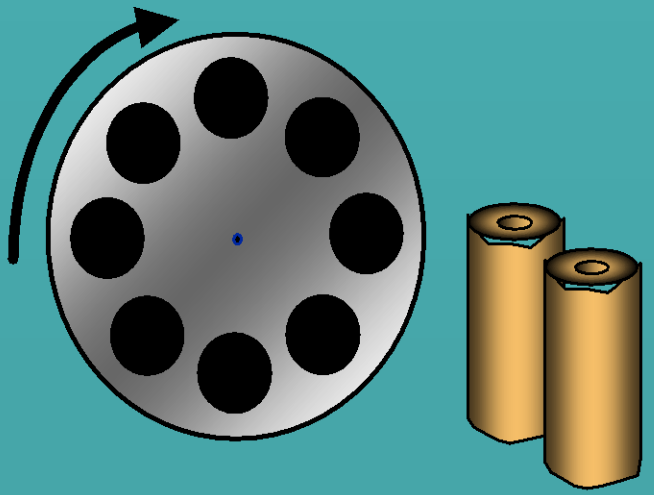
Binder Aging Methods

hot-mix plant

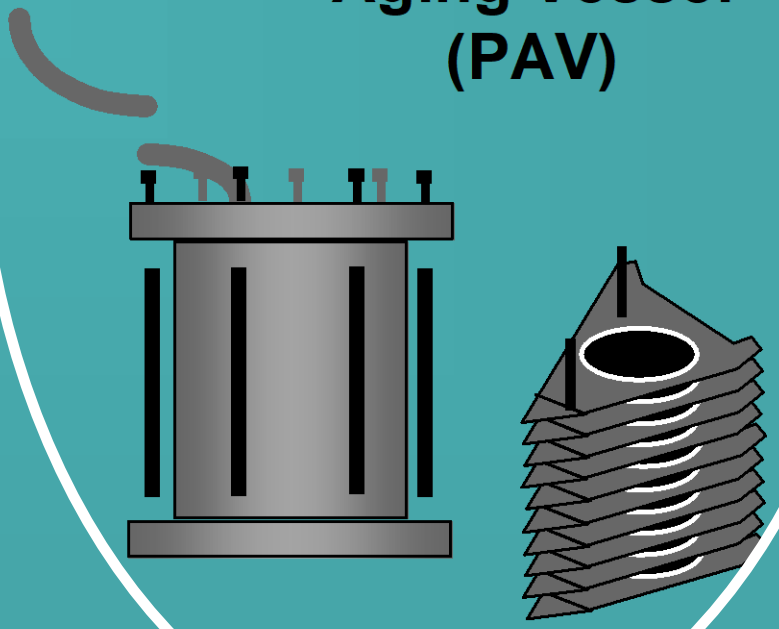
3 to 6 months

2 to 5 years ?

Rolling Thin Film Oven (RTFO)



Pressure Aging Vessel (PAV)



Source: OHMPA

PRESURRE AGING VESSEL (PAV)

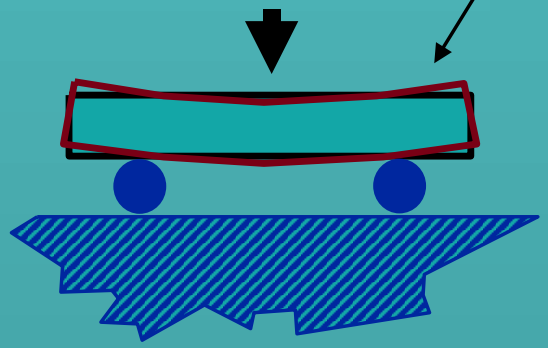
- Simulates the aging of the asphalt cement over many in-service years
  - Asphalt cement is placed in pans
  - Test chamber is set to:
    - Pressure of 2070 kPa using compressed air
    - Temperature of 90, 100 or 110 C
  - Test is run for 20 hours
  - Entrapped voids may effect BBR test results

PRESURRE AGING VESSEL (PAV)

Source: GAL

BENDING BEAM RHEOMETER (BBR)

Bending Beam Rheometer (BBR)



load, P,
and deflection δ

beam of thickness, t,
width w, and length l

creep stiffness, S(t):

$$S(t) = \frac{Pl^3}{4wt^3\delta(t)}$$

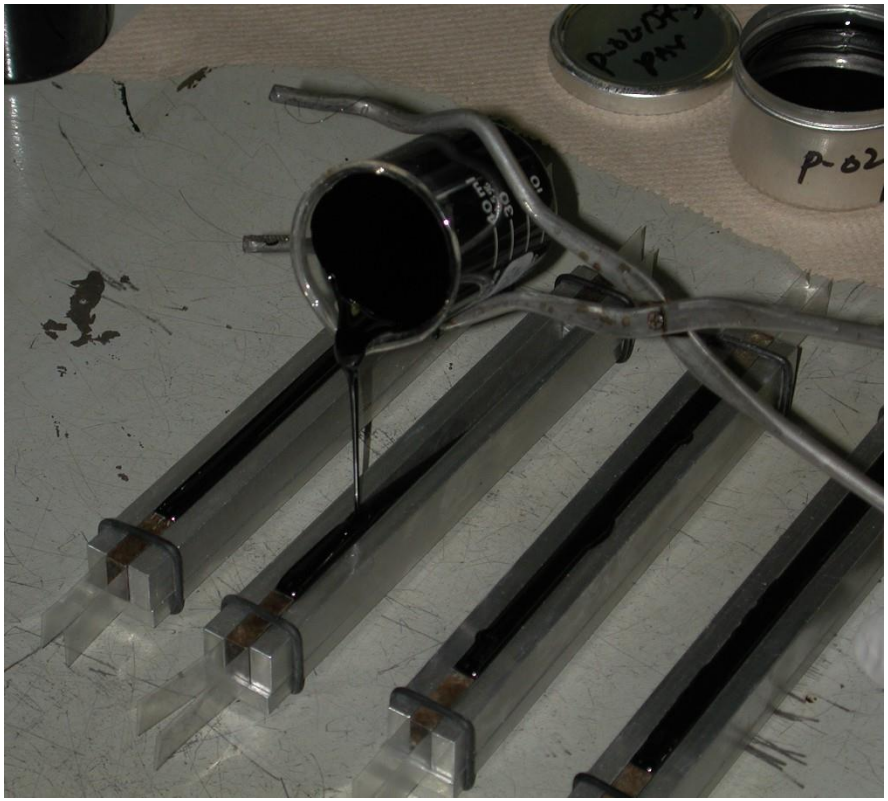
m-value:

$$m(t) = d\,S(t) / d\,t$$

AAT

Source: OHMPA

BENDING BEAM RHEOMETER (BBR)



Source: GAL

BEFORE 2016 AC SPECIFICATION

- **PGAC shall be according to AASHTO M 320 for the performance grade specified in Contract Documents**

TS-2b

M 320-4

Table 1—Performance-Graded Asphalt Binder Specification

Performance Grade	PG 46			PG 52							PG 58					PG 64					
	34	40	46	10	16	22	28	34	40	46	16	22	28	34	40	10	16	22	28	34	40
Average 7-day max pavement design temp, °C[a]	<46			<52							<58					<64					
Min pavement design temperature, °C[a]	>–34	>–40	>–46	>–10	>–16	>–22	>–28	>–34	>–40	>–46	>–16	>–22	>–28	>–34	>–40	>–10	>–16	>–22	>–28	>–34	>–40
Original Binder																					
Flash point temp, T 48, min °C	230																				
Viscosity, T 316:[b] max 3 Pa•s, test temp, °C	135																				
Dynamic shear, T 315:[c] G*/sinδ,[d] min 1.00 kPa test temp @ 10 rad/s, °C	46			52							58					64					
Rolling Thin-Film Oven Residue (T 240)																					
Mass change,[e] max, percent	1.00																				
Dynamic shear, T 315: G*/sinδ,[d] min 2.20 kPa test temp @ 10 rad/s, °C	46			52							58					64					
Pressurized Aging Vessel Residue (R 28)																					
PAV aging temperature, °C[f]	90			90							100					100					
Dynamic shear, T 315: G* sinδ,[d] max 5000 kPa test temp @ 10 rad/s, °C	10	7	4	25	22	19	16	13	10	7	25	22	19	16	13	31	28	25	22	19	16
Creep stiffness, T 313:[g] S, max 300 MPa *m*-value, min 0.300 test temp @ 60 s, °C	–24	–30	–36	0	–6	–12	–18	–24	–30	–36	–6	–12	–18	–24	–30	0	–6	–12	–18	–24	–30
Direct tension, T 314:[g] Failure strain, min 1.0% test temp @ 1.0 mm/min, °C	–24	–30	–36	0	–6	–12	–18	–24	–30	–36	–6	–12	–18	–24	–30	0	–6	–12	–18	–24	–30

[a] Pavement temperatures are estimated from air temperatures using an algorithm contained in the LTPP Bind program, may be provided by the specifying agency, or by following the procedures as outlined in M 323 and R 35.

[b] This requirement may be waived at the discretion of the specifying agency if the supplier warrants that the asphalt binder can be adequately pumped and mixed at temperatures that meet all applicable safety standards.

[c] For quality control of unmodified asphalt binder production, measurement of the viscosity of the original asphalt binder may be used to supplement dynamic shear measurements of G*/sinδ at test temperatures where the asphalt is a Newtonian fluid.

[d] G*/sinδ = high temperature stiffness and G* sinδ = intermediate temperature stiffness.

[e] The mass change shall be less than 1.00 percent for either a positive (mass gain) or a negative (mass loss) change.

[f] The PAV aging temperature is based on simulated climatic conditions and is one of three temperatures, 90°C, 100°C, or 110°C. Normally the PAV aging temperature is 100°C for PG 58-xx and above. However, in desert climates, the PAV aging temperature for PG 70-xx and above may be specified as 110°C.

[g] If the creep stiffness is below 300 MPa, the direct tension test is not required. If the creep stiffness is between 300 and 600 MPa, the direct tension failure strain requirement can be used in lieu of the creep stiffness requirement. The m-value requirement must be satisfied in both cases.

Continued on next page.

PREMATURE PAVEMENT CRACKING

Pavement in 2015 and 2018

FAILURE INVESTIGATION

- Extensive premature cracking of municipal, airport and industrial pavements
- Quality Control/Quality Assurance results review
  - All pavements met project specification requirements
- Laboratory testing
  - Superpave (Region No.1) and Marshall (Region No. 2) mixes – volumetric requirements met
  - Focus on asphalt cement testing
    - Conventional PGAC testing required in project specification

ASPHALT PAVEMENT QUALITY

OHMPA 2015/2016 AP Quality Task Force

- Suppliers, contractors, MTO, municipalities, academia, consultants
- Four bulletins
  - Asphalt pavement issues, additional AC testing, increase AC content, responsible use of RAP

- Research
  - Professor Simon Hesp
  - MTO
  - Industry - suppliers

2016 AC SPECIFICATION

- OPSS.MUNI 1101, Nov 2016

ONTARIO
PROVINCIAL
STANDARD
SPECIFICATION

METRIC
OPSS.MUNI 1101
NOVEMBER 2016

MATERIAL SPECIFICATION FOR
PERFORMANCE GRADED ASPHALT CEMENT

TABLE OF CONTENTS

1101.01 SCOPE

This specification covers the requirements for the properties and use of performance graded asphalt cements.

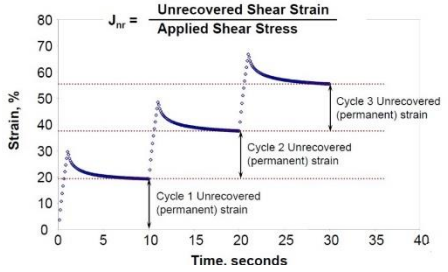
1101.01.01 Specification Significance and Use

This specification is written as a municipal-oriented specification. Municipal-oriented specifications are developed to reflect the administration, testing, and payment policies, procedures, and practices of many municipalities in Ontario.

Use of this specification or any other specification shall be according to the Contract Documents.

ADDITIONAL AC TESTING IN ONTARIO

- LS-227 Determination of Ash Content
- LS-299 Determining Asphalt Cement's Resistance to Ductile Failure Using Double Edge Notched Tension (DENT)
- LS-308 Determination of Performance Grade of Physically Aged Asphalt Cement Using Extended Bending Beam Rheometer (BBR) Method
  - Low Temperature Limiting Grade (LTLG)
  - Grade Loss
- Multiple Stress Creep Recovery (MSCR)



2016 AC SPECIFICATION

- OPSS.MUNI 1101, Nov 2016

Table 1
Additional Asphalt Cement Testing Requirements and Acceptance Criteria for All PG Grades

PGAC Grade	Property and Attributes (Unit)		Test Method	Results Reported Rounded to the Nearest	Acceptance Criteria	Rejectable
All PGAC Grades	Ash Content, % by mass of residue (%)	PG XX-28	LS-227	0.1	≤ 0.6	> 0.6
		PG XX-34			≤ 0.6	> 0.6
		PG XX-40			≤ 0.6	> 0.6
All PGAC Grades Except PG 58-28 and PG 52-34	Low temperature limiting grade (LTLG) (°C)		LS-308	0.5	≤ (-YY + 3)	> (-YY + 3)
	Grade Loss (°C)		LS-308	0.5	≤ 6.0	> 6.0
	Non-recoverable creep compliance at 3.2 kPa ($J_{nr-3.2}$) (kPa^{-1})		AASHTO T 350 For testing temperature see Note 1	0.01	≤ 4.5	> 4.5
	Average percent recovery at 3.2 kPa ($R_{3.2}$) (%)			0.1	≥ the lesser of [(29.371) ($J_{nr-3.2}$)$^{-0.2633}$] or 50	< the lesser of [(29.371) ($J_{nr-3.2}$)$^{-0.2633}$ -10] or 50
	CTOD, δ_t (mm)	PG XX-28	LS-299	0.1	≥ 8.0	< 8.0
		PG XX-34			≥ 12.0	< 12.0
		PG XX-40			≥ 16.0	< 16.0

Notes:
1. The testing temperature shall be 52°C for PGAC Zone 1 and 58°C for PGAC Zones 2 and 3.

2016 AC SPECIFICATION

- OPSS.MUNI 1101, Nov 2016

The asphalt cement shall not contain any of the following additives added for PGAC modification: atactic polypropylene; carbon black; polyisobutylene; polyisoprene; natural rubber; alkaline bases; insoluble particulates or fibres; salts of iron, copper, manganese and/or cobalt; silicates; styrene-butadiene rubber (random copolymer latex); synthetic waxes (paraffin waxes, naphthenic waxes); synthetic and saturated oils (including but not limited to the following: vegetable oils or modified vegetable oils; (paraffin oils, polyalphaolefins (PAO), lube oils, and re-refined lube oils.); **waste oils** (including but not limited to the following: cracked residues, re-refined high vacuum distillate oils; tall oils, vacuum tower asphalt extenders; waste cooking oils, **waste engine oils, waste engine oil residues**). Asphalt cement supplier shall declare in writing that they have not added the PGAC additives listed above.

If modifiers or additives other than styrene-butadiene (e.g., SB diblock, SBS triblock, SBS radial, SBS high vinyl, SB tapered, etc.) or epoxy-type (e.g. reactive elastomeric terpolymers) polymers are used for the modification of neat asphalt cement, pre-approval from the Owner is required.

2016 AC SPECIFICATION

- OPSS.MUNI 1101. Nov 2016

Appendix Table A-1
OPSS 1101 - Grade Selection for Ontario

	PGAC Zones		
	Zone 1	**Zone 2**	**Zone 3**
New Hot Mix or up to 15% RAP by Mass	52 - 34	58 - 34	58 - 28

Appendix Table A-2
OPSS 1101 - Guidelines for the Adjustment of PGAC High Temperature Grade Based on Roadway Classification and Traffic Conditions

Highway Type	**Increase from Standard**	**Optional Additional Grade Increase** (Note 1)
Urban Freeway	2 Grades	N/A
Rural Freeway Urban Arterial	1 Grade	1 Grade
Rural Arterial Urban Collector	Consider increasing by 1 grade if heavy truck traffic is greater than 20% of AADT	1 Grade
Rural Collector Rural Local Urban/Suburban Collector	No Change	1 or 2 Grades

Notes:

A. Upgrading of the high temperature grade is recommended for use in both surface and top binder courses, i.e., top 80 to 100 mm of hot mix.
B. Alternatively, Multiple Stress Creep Recovery (MSCR) graded PGAC acceptance criteria, according to Appendix B and Appendix Table A-3, can be used.

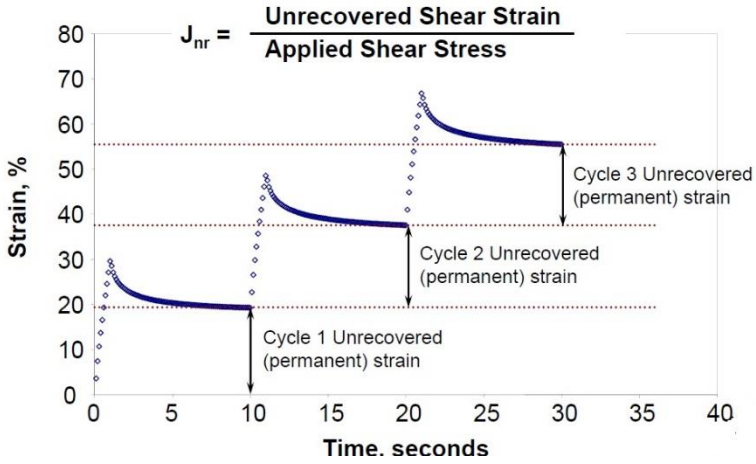
1. Consideration should be given to an increase in the high temperature grade for roadways which experience a high percentage of heavy truck or bus traffic at slow operating speeds, frequent stops and starts, and historical concerns with instability rutting.

MSCR

- Multiple Stress Creep Recovery (MSCR)
- AASHTO T 350-14 – Standard Method for Multiple Creep Recovery (MSCR) Test of Asphalt Binder Using Dynamic Shear Rheometer (DSR)
- AASHTO M 332-14 Standard - Standard Specification for Performance-Graded Asphalt Binder Using MSCR
- The present test methods for AC grading do not adequately characterize rutting or polymer modification of asphalts (PMA)
- The current PG system (AASHTO M-320) is “blind” to modification and requires PG plus tests such as Elastic Recovery to characterize PMA binders

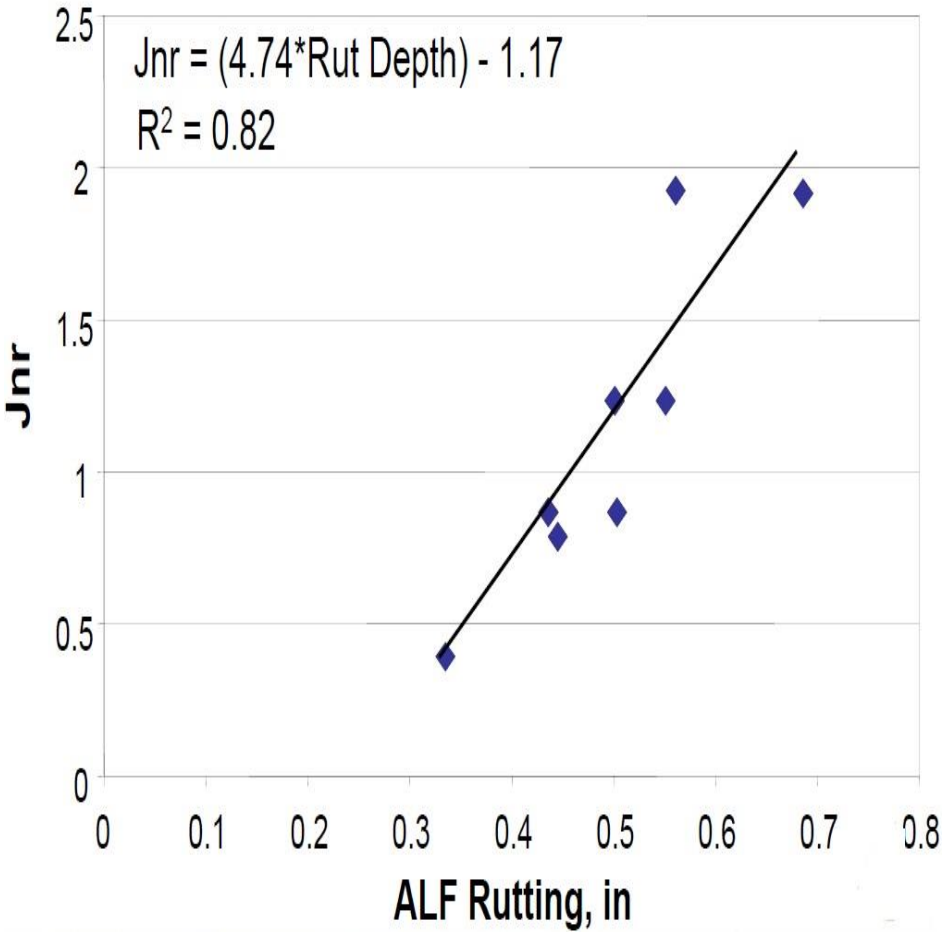
MSCR

- Uses Dynamic Shear Rheometer (DSR)
- Runs the sample 10 times. Load and relax.
- $J_{nr3.2}$ – Nonrecoverable creep compliance for 10 cycles at a creep stress of 3.2 kPa
- $J_{nr3.2}$ – S<4.5, H<2, V<1, E< 0.5
- % Average Recovery at a creep stress of 3.2 kPa



MSCR

- $J_{rn3.2}$ correlates well with observed rutting
- $J_{nr3.2}$ works with modified and non-modified binders



2016 AC SPECIFICATION

- OPSS.MUNI 1101, Nov 2016

Appendix Table A-3
OPSS 1101 - Guidelines for the Selection of PGAC Graded Using Multiple Stress Creep Recovery (MSCR) Test When Invoking Appendix "B" Based on Roadway Classification and Traffic Conditions

Highway Type	Recommended PGAC Grade Using MSCR Test	Optional Grade Increase (Note 1)
Urban Freeway	XXV-YY	N/A
Rural Freeway **Urban Arterial**	XXH-YY	XXV-YY
Rural Arterial **Urban Collector**	Consider specifying XXH-YY if heavy truck traffic is greater than 20% of AADT	XXV-YY
Rural Collector **Rural Local** **Urban/Suburban Collector**	XXS-YY	XXH-YY or XXV-YY
Toll Plaza **Port Facility** **Dedicated Transitways** **Truck Marshaling Yards** **(standing traffic)**	XXE-YY	N/A

Notes:

A. It is recommended that Multiple Stress Creep Recovery (MSCR) graded PGAC is used in both surface and top binder courses, i.e., top 80 to 100 mm of hot mix.

1. Consideration should be given to an increase in the high temperature traffic level for roadways which experience a high percentage of heavy truck or bus traffic at slow operating speeds, frequent stops and starts, and historical concerns with instability rutting.

2016 AC SPECIFICATION

- OPSS.MUNI 1101, Nov 2016

Appendix B Table -1
Additional Asphalt Cement Testing Requirements and Acceptance Criteria for All PG Grades

	Property and Attributes (Unit)		Test Method	Results Reported Rounded to the Nearest	Acceptance Criteria	Rejectable
All PGAC Grades	Ash Content, % by mass of residue (%)	for -YY = -28	LS-227	0.1	≤ 0.6	> 0.6
		for -YY = -34			≤ 0.6	> 0.6
		for -YY = -40			≤ 0.6	> 0.6
	Non-recoverable creep compliance at 3.2 kPa ($J_{nr3.2}$) (kPa^{-1}) when PGAC XXS-YY is specified		AASHTO T 350 testing conducted at high temperature grade of the PGAC (Note 1)	0.01	≤ 4.5	> 4.5
	Non-recoverable creep compliance at 3.2 kPa ($J_{nr3.2}$) (kPa^{-1}) when PGAC XXH-YY is specified			0.01	≤ 2.0	> 2.0
	Non-recoverable creep compliance at 3.2 kPa ($J_{nr3.2}$) (kPa^{-1}) when PGAC XXV-YY is specified			0.01	≤ 1.0	> 1.0
	Non-recoverable creep compliance at 3.2 kPa (Jnr3.2) (kPa-1) when PGAC XXE-YY is specified			0.01	≤ 0.55	> 0.55
All H, V and E Grades	Average percent recovery at 3.2 kPa ($R_{3.2}$) (%)			0.1	≥ the lesser of $[(29.371)(J_{nr-3.2})^{-0.2633}]$ or 50	< the lesser of $[(29.371)(J_{nr-3.2})^{-0.2633} - 10]$ or 50
	Percent difference in non-recoverable creep compliance between 0.1 kPa and 3.2 kPa, J_{nrdiff} (%)			0.1	N/A Testing carried out for information purpose	
All PGAC Grades Excluding PG 58S-28 and PG 52S-34	CTOD, δ_t (mm)	for -YY = -28	LS-299	0.1	≥ 8.0	< 8.0
		for -YY = -34			≥ 12.0	< 12.0
		for -YY = -40			≥ 16.0	< 16.0
	Low temperature limiting grade (LTLG) (°C)		LS-308	0.5	≤ (-YY +3)	> (-YY + 3)
	Grade Loss (°C)		LS-308	0.5	≤ 6.0	> 6.0

Notes:
1. For example, the testing temperature for PG58V-28 is 58°C and for 52H-34 it is 52°C.

MUNICIPAL EXPERIENCE

SPECIFICATIONS ONTARIO

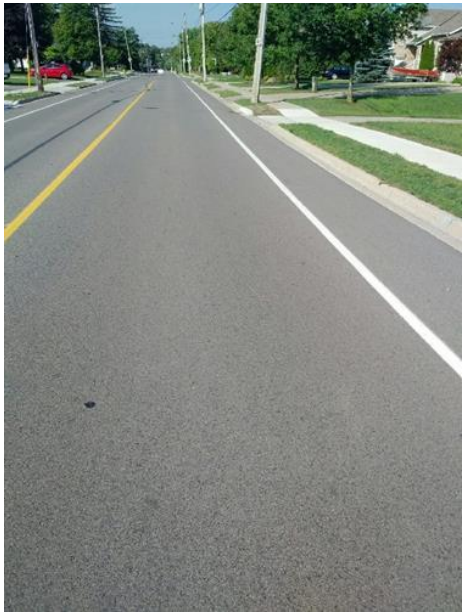
TESTS ON ORIGINAL ASPHALT		no AS	0.5 % AS	1.0 % AS	SPEC
Brookfield Viscosity, 135°C, Pa.s		0.960	0.955	0.950	3.0 max
Flash Point, COC, °C		230+	230+	230+	230 min
G*/sin(δ), 64 °C, kPa		1.51	1.50	1.50	1.0 min
Ash Content, % mass		0.15	0.15	0.15	0.8 max
TESTS ON RTFO RESIDUE					
Mass Change, %		-0.315	-0.326	-0.328	1.0 max
G*/sin(δ), 64 °C, kPa		2.34	2.30	2.32	2.2 min
MSCR Jnr, 3.2 kPa, 1/kPa	58°C	0.31	0.32	0.32	4.5 max
MSCR Recovery, 3.2 kPa, %	58°C	78.10	76.16	76.87	cond.
MSCR Percent Jnr-difference.,	58°C	42.0	42.5	43.5	N/A
TESTS ON PAV RESIDUE (AFTER RTFO)					
G*x sin(δ), 22 °C, kPa		1280	1278	1276	5000 max
BBR, Cr. Stiffness, -18 °C, MPa		124	125	125	300 max
BBR m-value, -18 °C		0.360	0.357	0.359	0.300 min
EBBR LTLG, °C		-28.4	-28.4	-28.4	-28.0 max
EBBR Grade Loss, °C		4.1	4.1	4.1	6.0 max
DENT CTOD, 15°C, mm		11.100	11.200	11.100	10 min

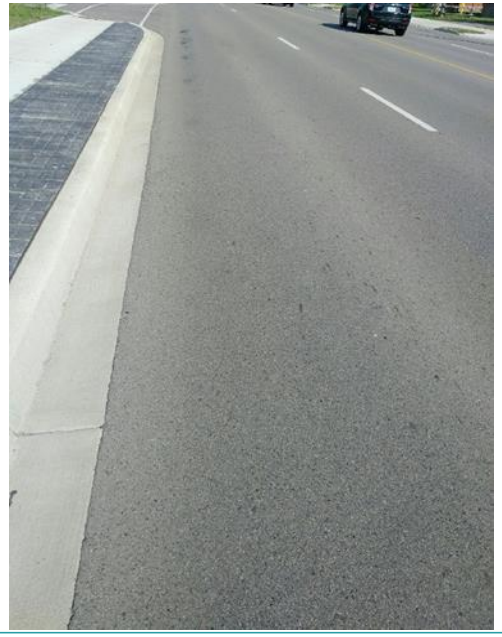
MUNICIPAL EXPERIENCE

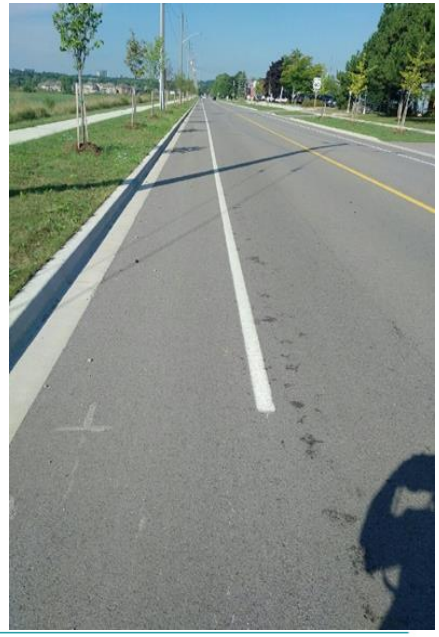
Municipalities 1 to 4

- Contractors had no issues obtaining the specified PG grade and did not identify any constructability issues related to the PGAC and new paving specification. No complaints about the new 2016 specification
- Recently placed pavements look good and all are performing well
- The specifications were met with no issues

MUNICIPAL EXPERIENCE







ASPHALT CEMENT NOMENCLATURE

Asphalt Cement Supplier Members of the Ontario Asphalt Pavement Council (OAPC) met on February 2nd, 2018 to discuss standardizing the nomenclature of common Asphalt Cement (AC) grades currently being specified in Ontario. OAPC is a council of the Ontario Road Builders Association (ORBA).

While the OAPC/ORBA and The Asphalt Institute fully support the implementation of AASHTO M-332 Multiple Stress Creep Recovery (MSCR) grading for all AC used in Ontario, we are aware of the confusion among AC suppliers, Hot Mix Producers and user agencies with regard to the different names used to designate the various grades. Because of the large number of different specifications being used at this time it is impractical to develop a system that will encompass them all, so it was decided to address the more common specifications. Individual suppliers may use their own unique names for grades meeting specifications other than those addressed below.

In consideration of these issues, the following was established and will be implemented by suppliers as of March 1st, 2018. While not all binder specifications may fall in one of these categories, it is hoped that most will.

Please see the back of this sheet to review nomenclature guidelines for AC Grades.

ASPHALT CEMENT NOMENCLATURE

"Standard" AASHTO M-320 grades will continue to be designated as "PG XX-YY".

AASHTO M-332 (MSCR) will continue to be designated as "PG XX**S**-YY", "PG XX**H**-YY", "PG XX**V**-YY", "PG XX**E**-YY".

M-320 grades with the "PG Plus" requirements Extended BBR (LS-308), DENT (LS-299) and MSCR % Recovery will bear the suffix "**X**".

M-320 or M-332 grades to which the supplier has not added any of the banned additives in the list found in many current Municipal specifications will bear the suffix "**J**".

Examples of grade designations under this system are provided below;

64-28	Meets AASHTO M-320
58V-28	Meets AASHTO M-332
64-28X	Meets AASHTO M-320, Extended BBR at -YY, DENT and MSCR % Recovery.
58-34XJ	Meets AASHTO M-320, Extended BBR at -YY, DENT and MSCR % Recovery, supplier has not added any of the materials from the banned additives list.
52-34J	Meets AASHTO M-320, supplier has not added any of the materials from the banned additives list.
58V-28X	Meets AASHTO M-332, Extended BBR at -YY, DENT and MSCR % Recovery.
58H-28J	Meets AASHTO M-332, supplier has not added any of the materials from the banned additives list.

ORBA, OAPC and the Asphalt Institute strongly recommend that specifications be unified and we encourage owner agencies to adopt this product naming in their Contract Documents. We recommend that any questions about this issue to be directed to OAPC or Ontario Asphalt Cement suppliers.

SUMMARY

- Early pavement cracking observed on municipal roads before 2015
- OPSS.MUNI Nov 2016
  - Asphalt cement modification limitations
  - New testing required
- Higher asphalt cement content
- Tighter construction requirements
- Slightly higher cost ($3.0 to $5.0 per tonne of mix)
- No significant construction problems with new specifications observed
- Much better pavement appearance, no distresses
- New cement nomenclature
- Municipalities appreciate industry's positive response!

Thank You

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