INNOVATIVE AIRPORT ASPHALT MIXES – ASPHALT CEMENT AND SUPERPAVE SUMMARY

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SWIFT, CAPTG
Halifax, September 21, 2017

PRESENTATION OUTLINE

- Previous presentations
- Need for innovative airport asphalt mixes
- Asphalt cement impact
- Recently observed asphalt issues
- Advanced testing
- MSCR
- Superpave
- Summary

PREVIOUS CAPTG PRESENTATIONS

- **2010, Chris Stewart, “Best Practices in the Design and Construction of Airfield Asphalt Pavements”**
- **2010, Sandy Brown, “Use of Superpave Specifications for Airport Pavements”**
- **2013, Kevin Chee, “Asphalt Mix Design Improvements at Toronto Pearson”**
- **2015, Rabiah Rizvi, “Advanced Asphalt Technology to Address Shear Distresses on Airfield Facilities”**
- **2016, Guy Zummo, “Concrete Case Study – JFK Runway 4L-22R, Unbonded Overlay”**

NEED FOR INNOVATIVE MIXES

- Continuously increasing traffic with larger aircraft
- Localized areas experiencing very high horizontal forces
- Asphalt shear, shoving, cracking and deformation
- Occurs despite adequate structural capacity
- Not considered during pavement design process
- Asphalt materials sensitive to shear
- Airports in Canada, USA, Asia, Caribbean, Europe

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NEED FOR INNOVATIVE MIXES

- Problems due to asphalt shear failures
  - Safety hazard by creating FOD
  - Additional strain on airport budget
  - Operational constrains
  - Additional dynamic stress on aircraft body

- Take advantage of advancements in asphalt technology

ASPHALT MIX DESIGN

- Currently extensive research ongoing
  - GTAA, University of Waterloo, Golder
- Fundamental mechanistic properties – determine strains due to applies stress
- Investigate shear impact
- Some delays

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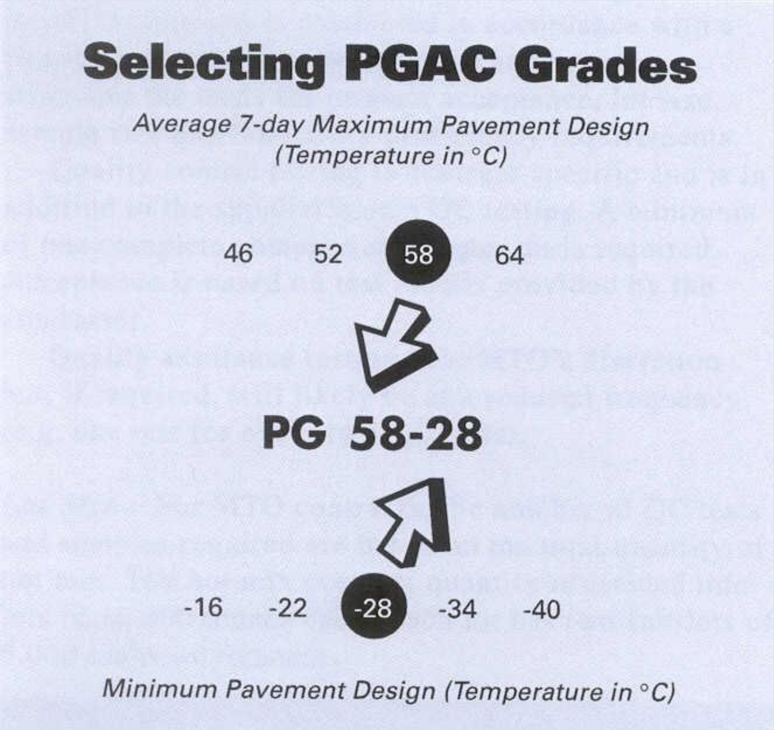
ASPHALT CEMENT

- Focus of this presentation
- Previous classifications based on viscosity and penetration
- Since late 1990s – performance graded system part of Superpave methodology
- PGAC 58-28
- Grade bumping



ASPHALT CEMENT

- Asphalt cement modification
  - Oxidation
  - Polymer modification
- Conventional M320 PGAC testing
  - DSR
  - RTFO
  - PAV

CONVENTIONAL AC TESTING

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

TS-2b

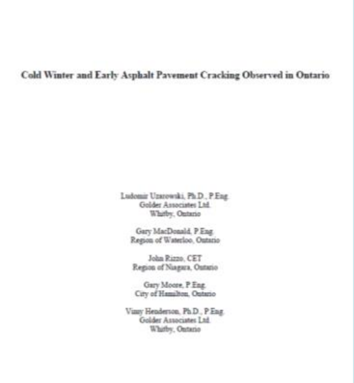
Table 1—Performance-Graded Asphalt Binder Specification

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

M 320-4

ASPHALT PAVEMENT CRACKING

- Premature asphalt cracking on number of municipal roads
- Extensive field and laboratory investigation
- Good QC/QA results
- Asphalt cement properties investigated
- Customized asphalt cement specification in 2015
- New OPSS.MUNI.1101 November 2016
- LU member of OPSS committee


Cold Winter and Early Asphalt Pavement Cracking Observed in Ontario

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OPSS.MUNI 1101 November 2016

■ Restrictions on PPA and other additives

PGAC shall not contain more than 0.3% polyphosphoric acid (PPA)

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.

ASPHALT CEMENT TESTING

- Additional tests
  - Ash test
  - Double Edge Notched Test (DENT)
  - Extended Bending Beam Rheometer (exBBR) test
  - Multiple Stress Creep Recovery (MSCR) test

ASH TEST

- **LS-227 Determination of Ash Content**
- The Ash test is used to control the presence of inorganic materials which will not burn off (and hence leave an ash content) in asphalt cement binders.

DOUBLE EDGE NOTCHED TEST

- **LS-299 Determining Asphalt Cement's Resistance to Ductile Failure Using Double Edge Notched Tension (DENT)**
- DENT is used to better reflect fatigue cracking properties at intermediate temperatures. PAV residue is poured into rectangular moulds that are notched on two sides. The samples are pulled after conditioning at an intermediate temperature. This test is based on fracture mechanics principles.

EXTENDED BBR

- **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**
- BBR is used to evaluate the cracking properties of asphalt cement binders at low temperatures. PAV residue is moulded into a thin beam. The flexural creep stiffness and the rate of deflection are measured at low temperatures. Beams are conditioned for 1 hour.
- Extended BBR test is used to measure low temperature PG properties after the beam has been conditioned at low temperatures for 72 hours (3 days).

FAA SPECIFICATION

- FAA AC 150/5370-10G
- P-401 asphalt mix
- PGAC grade
- Polymer modification allowed
- Grade bumping for airport pavements
- PG Plus testing required
- PG selection based on tire pressure, loading and speed
  - LTPPBind software – climate, traffic loading and speed, reliability

FAA SPECIFICATION

- PG Plus – includes
  - Elastic recovery
  - Ductility
  - Toughness and Tenacity

USA

- Research
  - Premature cracking observed as early as 3 years on airfield HMA pavements
  - Top down cracking, typically shallow
  - Aging – loss of flexibility and ductility
  - The main cause of premature top down fatigue cracking is from the binder rheological properties

NEW YORK PORT AUTHORITY

- Very advanced asphalt paving specification
- Marshall mixes
- Polymer modified PG 70-22, 76-22, 82-22 from designated sources
- PG Plus required

MSCR

- M320 works well for neat binders, for modified binders non-linear testing is required
- 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
- Multiple Stress Creep Recovery (MSCR)
  - FHWA, AI - Technical Advisory Committee, Asphalt Binder ETG

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MSCR

- USA – FHWA and some states
- MSCR to replace PG Plus testing – no more elastic recovery or ductility or tenacity testing

- Canada – no uniform approach
- Various grades of PGAC
- No PG Plus or elastic recovery required
- Generally, MSCR not required

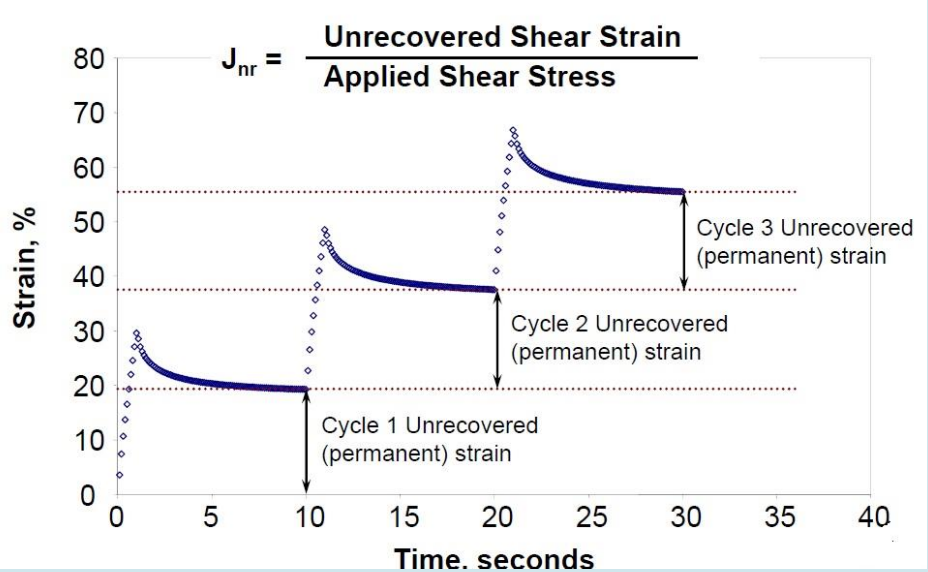
MSCR

- 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

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



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MSCR

- Creep and recovery testing of the binder at different stress levels is needed to describe binder properties in non-linear range
- J_{nrDiff} – Nonrecoverable creep compliance for 10 cycles at a creep stress of 3.2 kPa
- Required to be < 75%

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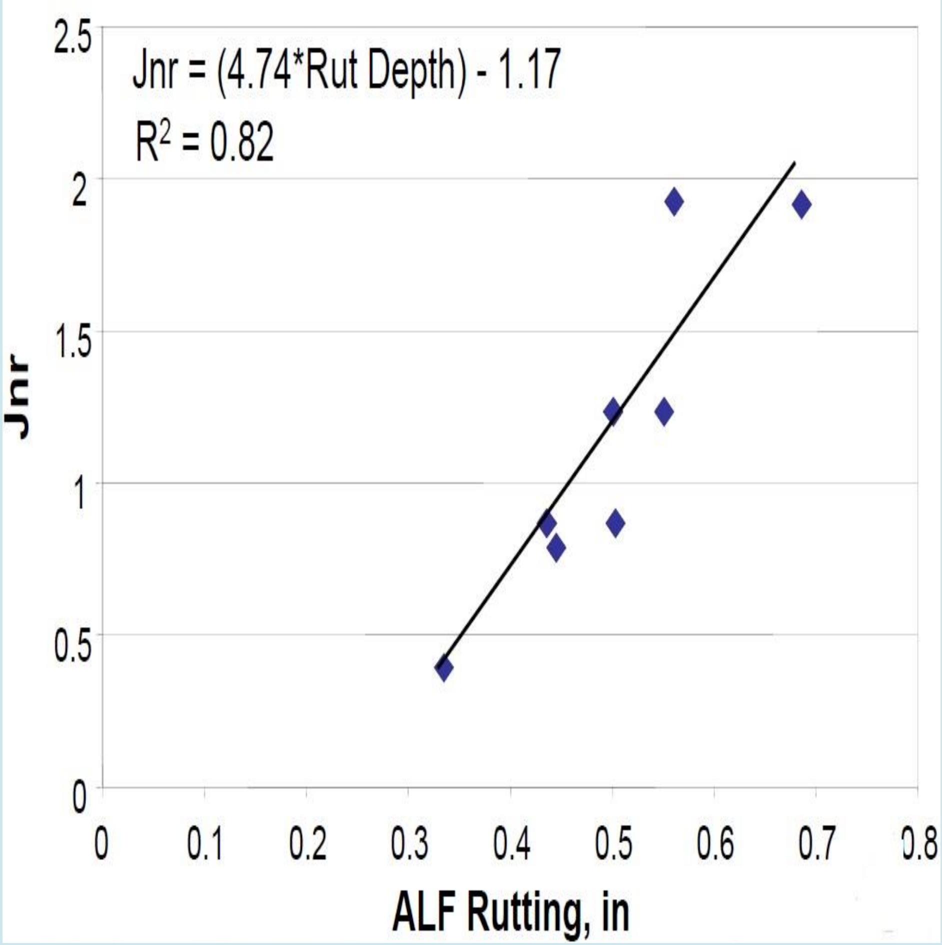
MSCR

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



EXAMPLE OF MSCR SPECIFICATION IN ONTARIO

- Additional asphalt cement testing
  - Ash test
  - MSCR
- J_{nrdiff} should be not more than 75%
  - Requirement temporarily suspended

Property and Attributes (Unit)	Test Method	Results Reported Rounded to the Nearest	Acceptance Criteria	Rejectable
Ash Content, % by mass of residue (%)	LS-227	0.1	≤ 0.6	>0.6
Non-recoverable creep compliance at 3.2 kPa (Jnr-3.2) (kPa-1) when PGAC 58S-28 is specified	Multiple Stress Creep and Recovery (MSCR) testing according to AASHTO T 350 testing conducted at a temperature of 58 °C	0.01	≤ 4.5	> 4.5
Non-recoverable creep compliance at 3.2 kPa (Jnr-3.2) (kPa-1) when PGAC 58H-28 is specified		0.01	≤ 2.0	> 2.0
Non-recoverable creep compliance at 3.2 kPa (Jnr-3.2) (kPa-1) when PGAC 58V-28 is specified		0.01	≤ 1.0	> 1.0
Non-recoverable creep compliance at 3.2 kPa (Jnr-3.2) (kPa-1) when PGAC 58E-28 is specified		0.01	≤ 0.5	> 0.5
Average percent recovery at 3.2 kPa (R3.2) (%)		0.1	> the lesser of [(29.371) (Jnr-3.2)$^{-0.2633}$] or 55	≤ the lesser of [(29.371) (Jnr-3.2)$^{-0.2633}$ -10] or 45
Percent difference in non-recoverable creep compliance between 0.1 kPa and 3.2 kPa, Jnrdiff (%)		0.1	N/A Testing carried out only for information purpose	

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EXAMAPLE OF MSCR SPECIFICATION IN ONTARIO

- Asphalt Cement MSCR Guidelines

Table 800-3
Guidelines for Selection of PGAC Graded Using MSCR Test

Road Type	Recommended PGAC Grade Using MSCR Test	Optional Grade Increase (Note 1)
Urban Freeway	58V-28	N/A
Rural Freeway Urban Arterial	58H-28	58V-28
Rural Arterial Urban Collector	Consider specifying 58H-28 if truck traffic is greater than 20% of AADT	58V-28
Rural Collector Rural Local Urban/Suburban Collector	58S-28	58-28 or 58V-28
Toll Plaza Port Facility Dedicated Transitways Truck Marshalling Yards (standing traffic)	58E-28	N/A

Notes:

A. It is recommended that MSCR graded PGAC is used in both surface and top binder courses, i.e. top **80 mm 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 Trucks or bus traffic at slow operating speeds, frequent stops and starts, and historical concerns with instability rutting.

MSCR vs PG GRADE

1	PG Gra	PG Ty	Ash	DEN	eBBR L	eBBR	eBBR	MSCR	MSCR	Jnr, D	R29 Hi	R29 Lo	Supplie	Notes	Minimu	Recove	JnrDiff	MSCR (	Final M	Final AC Grad
2	58-28		0.0	8.4	-25.0	-29.3	-4.3	2.16	2.3	14	Yes	Yes	[redacted]		24	N	Y	S		
3	58-28		0.04	8.0	-25.1	-30.0	-4.9	3.20	1.3	11	Yes	Yes	[redacted]		22	N	Y	S		
4	58-28		0.12	10.4	-26.1	-28.2	-2.1	3.51	1.0	10	Yes	Yes	[redacted]		21	N	Y	S		
5	58-28		0.05	10.8	-26.0	-29.4	-3.4	2.85	1.3	10	Yes	Yes	[redacted]		22	N	Y	S		
6	58-28		0.07	10.2	-26.1	-29.8	-3.7	3.57	0.9	11	Yes	Yes	[redacted]		21	N	Y	S		
7	64-28		0.1	12.2	-27.0	-30.7	-3.7	0.47	50.1	31	Yes	Yes	[redacted]		36	Y	Y	E	E	64-28
8	64-28	-28Y	0.1	16.8	-31.1	-34.2	-3.1	0.80	56.6	51	Yes	Yes	[redacted]		31	Y	Y	V	V	64-28
9	64-28		0.0	12.7	-26.6	-29.9	-3.3	0.56	44.4	53	Yes	Yes	[redacted]		34	Y	Y	V	V	64-28
10	64-28		0.1	9.7	-25.8	-29.8	-4.0	0.44	49.6	32	Yes	Yes	[redacted]		36	Y	Y	E	E	64-28
11	64-28		0.09	29.4	-30.3	-33.1	-2.8	0.48	73.9	31	No	Yes	[redacted]	Failed RTFO G*/Sin	36	Y	Y	E	E	
12	64-28	-28Y	0.1	12.3	--	--	--	1.74	15.3	20	No	Yes	[redacted]	Failed Original G*/Sin, RTFO G*/Sin	25	N	Y	H		
13	64-28		0.09	29.4	-30.3	-33.1	-2.8	0.48	73.9	31	No	Yes	[redacted]	Failed RTFO G*/Sin	36	Y	Y	E	E	
14	64-28	-28MD	0.0	12.1	-27.3	-31.1	-3.8	0.35	66.5	59	Yes	Yes	[redacted]		39	Y	Y	E	E	64-28
15	64-28		0.2	--	--	--	--	0.97	36.9	19	Yes	Yes	[redacted]		30	N	Y	V		
16	64-28	PMA	0.2	--	--	--	--	0.48	58.1	174	Yes	Yes	[redacted]		36	Y	N	E		
17	64-28	PMA	0.1	--	--	--	--	0.46	58.4	67	Yes	Yes	[redacted]		36	Y	Y	E	E	64-28
18	64-28	PMA	0.0	--	--	--	--	0.43	59.6	62	Yes	Yes	[redacted]		37	Y	Y	E	E	64-28
19	64-28	PMA	0.0	--	--	--	--	0.61	44.1	51	Yes	Yes	[redacted]		33	Y	Y	V	V	64-28
20	64-28	PMA	0.3	--	--	--	--	1.01	35.5	39	Yes	Yes	[redacted]		29	Y	Y	H	H	64-28
21	64-28	PMA	0.1	--	--	--	--	0.66	47.4	48	Yes	Yes	[redacted]		33	Y	Y	V	V	64-28
22	64-28	PMA	0.1	--	--	--	--	0.47	52.2	67	Yes	Yes	[redacted]		36	Y	Y	E	E	64-28
23	64-28	PMA	0.0	--	--	--	--	0.67	47.1	41	Yes	Yes	[redacted]		33	Y	Y	V	V	64-28
24	64-28	PMA	0.1	--	--	--	--	0.48	52.6	47	Yes	Yes	[redacted]		36	Y	Y	E	E	64-28
25	64-28	PMA	0.1	--	--	--	--	0.46	53.6	52	Yes	Yes	[redacted]		36	Y	Y	E	E	64-28
26	64-28	PMA	0.1	--	--	--	--	0.77	41.7	41	Yes	Yes	[redacted]		31	Y	Y	V	V	64-28
27	64-28	PMA	0.0	--	--	--	--	0.64	47.6	62	Yes	Yes	[redacted]		33	Y	Y	V	V	64-28
28	64-28	PMA	0.1	--	--	--	--	0.88	39.2	91	Yes	Yes	[redacted]		30	Y	N	V		
29	64-28	PMA	0.0	--	--	--	--	0.83	40.9	77	Yes	Yes	[redacted]		31	Y	N	V		
30	64-28	PMA	0.1	--	--	--	--	0.99	34.3	57	Yes	Yes	[redacted]		29	Y	Y	V	V	64-28
31	64-28	PMA	0.0	--	--	--	--	0.89	40.1	37	Yes	Yes	[redacted]		30	Y	Y	V	V	64-28
32	64-28		0.0	--	--	--	--	1.58	8.3	35	Yes	Yes	[redacted]		26	N	Y	H		
33	64-28		0.5	6.7	-26.0	-30.6	-4.6	1.28	10.3	33	Yes	Yes	[redacted]		28	N	Y	H		
34	64-28		0.04	9.3	-24.0	-28.7	-4.7	1.81	2.6	14	No	Yes	[redacted]	Failed Original G*/Sin, eBBR LTLG	25	N	Y	H		
35	64-28		0.3	10.3	-24.1	-29.8	-5.7	1.35	20.7	32	Yes	Yes	[redacted]		27	N	Y	H		
36	64-28	XY	0.1	8.8	-24.3	-27.4	-3.1	1.46	3.6	10	Yes	No	[redacted]	Failed PAV BBR	27	N	Y	H		
37	64-28	XY	0.0	8.2	-22.7	-27.6	-4.9	1.62	3.2	9	Yes	Yes	[redacted]	Failed eBBR LTLG	26	N	Y	H		
38	64-28		0.2	10.0	-25.7	-28.9	-3.2	1.69	4.0	13	Yes	Yes	[redacted]		26	N	Y	H		
39	64-28	EX	0.0	30.2	-32.3	-35.1	-2.8	0.18	84.9	98	Yes	Yes	[redacted]		46	Y	N	E		
40	64-28		0.08	10.0	-25.3	-30.0	-4.7	0.82	37.3	36	Yes	Yes	[redacted]		31	N	Y	V		
41	64-28		0.1	19.0	-31.5	-33.8	-2.3	0.51	62.8	55	Yes	Yes	[redacted]		35	Y	Y	V	V	64-28

MSCR vs PG GRADE

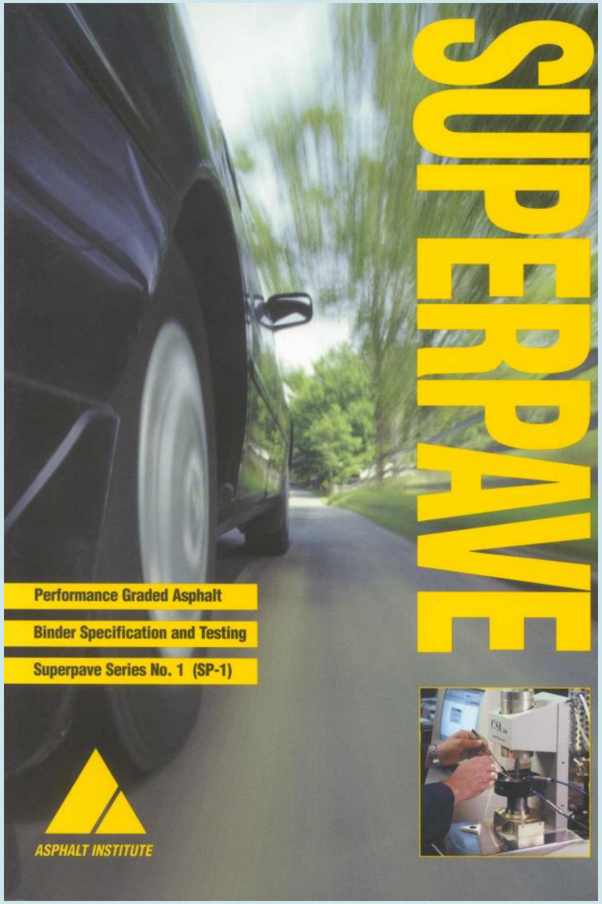
1	PG Gra	PG Ty	Ash (	DEN	eBBR L	eBBR	eBBR (	MSCR	MSCR	Jnr, D	R29 Hi	R29 Lo	Supplier	Notes	Minimu	Recove	JnrDiff	MSCR (	Final M	Final AC Grad
42	64-28		0.42	6.9	-27.3	-30.5	-3.2	1.03	13.4	56	Yes	Yes	[redacted]		29	N	Y	H		
43	64-28	P EXR	0.0	16.8	-27.6	-30.5	-2.9	0.84	46.7	65	Yes	Yes	[redacted]		31	Y	Y	V	V	64-28
44	64-28	XY	0.12	15.1	-31.0	-34.0	-3.0	0.88	49.9	59	No	Yes	[redacted]	Failed RTFO G*/Sin	30	Y	Y	V		
45	64-28	XY	0.0	17.7	-31.2	-34.7	-3.5	0.93	50.9	56	No	Yes	[redacted]	Failed Original G*/Sin	30	Y	Y	V		
46	64-28	XY	0.0	18.0	-31.2	-33.4	-2.2	0.68	59.1	265	No	Yes	[redacted]	Failed RTFO G*/Sin	33	Y	N	V		
47	64-28	D Ext	0.13	8.8	-25.9	-30.4	-4.5	3.48	1.2	13	No	Yes	[redacted]	Failed Origianl and RTFO G*/Sin	21	N	Y	S		
48	64-28		0.02	8.6	-24.9	-29.0	-4.1	3.12	1.4	11	No	Yes	[redacted]	Failed Original and RTFO G*/Sin	22	N	Y	S		
49	70-28		0.0	9.1	-24.9	-28.4	-3.5	0.51	43.7	23	Yes	Yes	[redacted]		35	Y	Y	V	V	
50	70-28		0.13	10.4	-25.6	-30.1	-4.5	0.52	44.4	24	Yes	Yes	[redacted]		35	Y	Y	V	V	70-28
51	70-28		0.44	4.1	-25.1	-28.8	-3.7	0.02	90.7	124	Yes	Yes	[redacted]		82	Y	N	E		

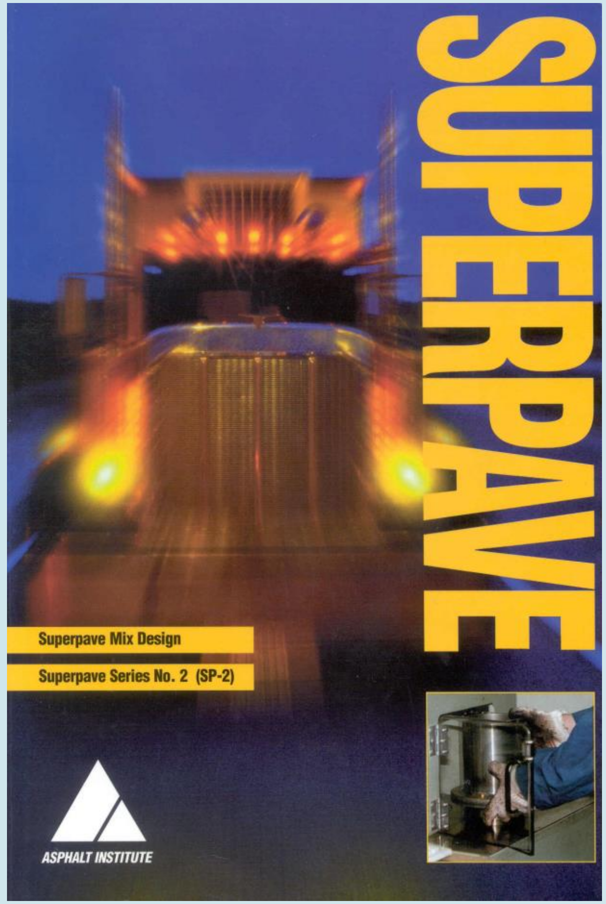
Multiple Stress Creep Recovery (MSCR)	AASHTO TP 70, Extremely Heavy Traffic "E" Grade $J_{nr3.2}$, max 0.5 kPa^{-1},	58	0.11	0.17
	J_{nrdiff}, max 75 %,		10	13.3
	Average % Recovery, $_{R3.2}$		52.5	46.8

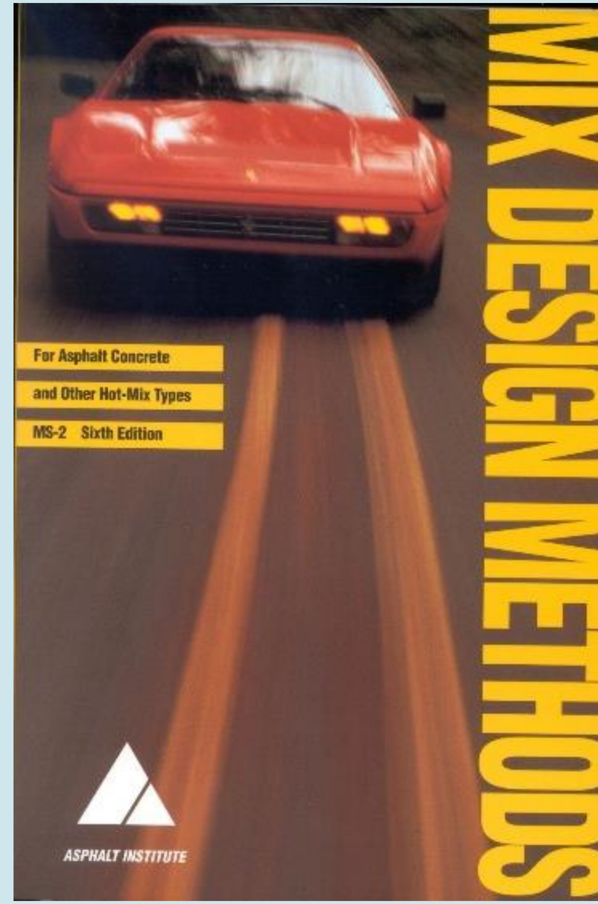
SUPERPAVE SUMMARY

- Superpave – Superior Performing Asphalt Pavements
- Superpave is a product of the Strategic Highway Research Program (SHRP) in the US – a five year US$150 million program started in 1987
- C-SHRP in Canada

SUPERPAVE – AI MANUALS

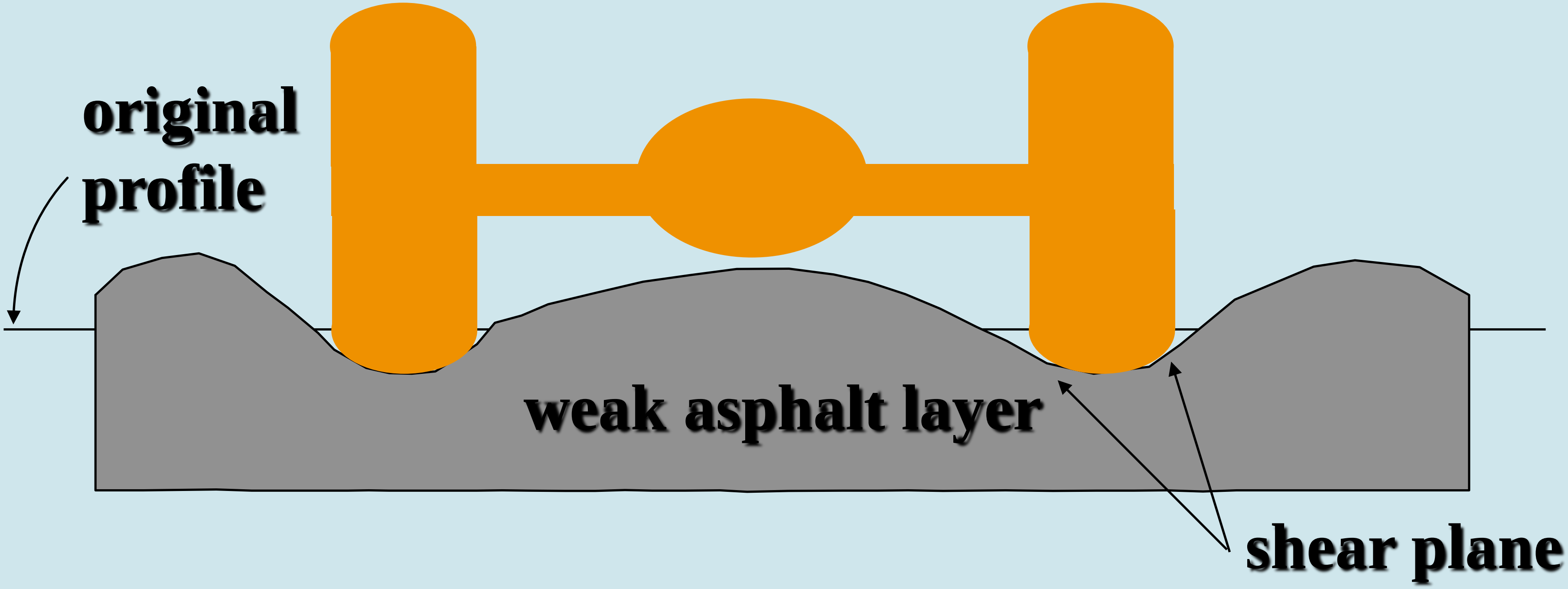






RUTTING FROM WEAK MIXTURE

HMA PLASTIC FLOW



Source: AI

FATIGUE AND LOW TEMPERATURE CRACKING

Source: GAL

SUPERPAVE MIX DESIGN

- Material Selection
  - Asphalt cement
  - Mineral aggregate
- Design Aggregate Structure
- Design Binder Content
- Moisture Sensitivity

AGGREGATES

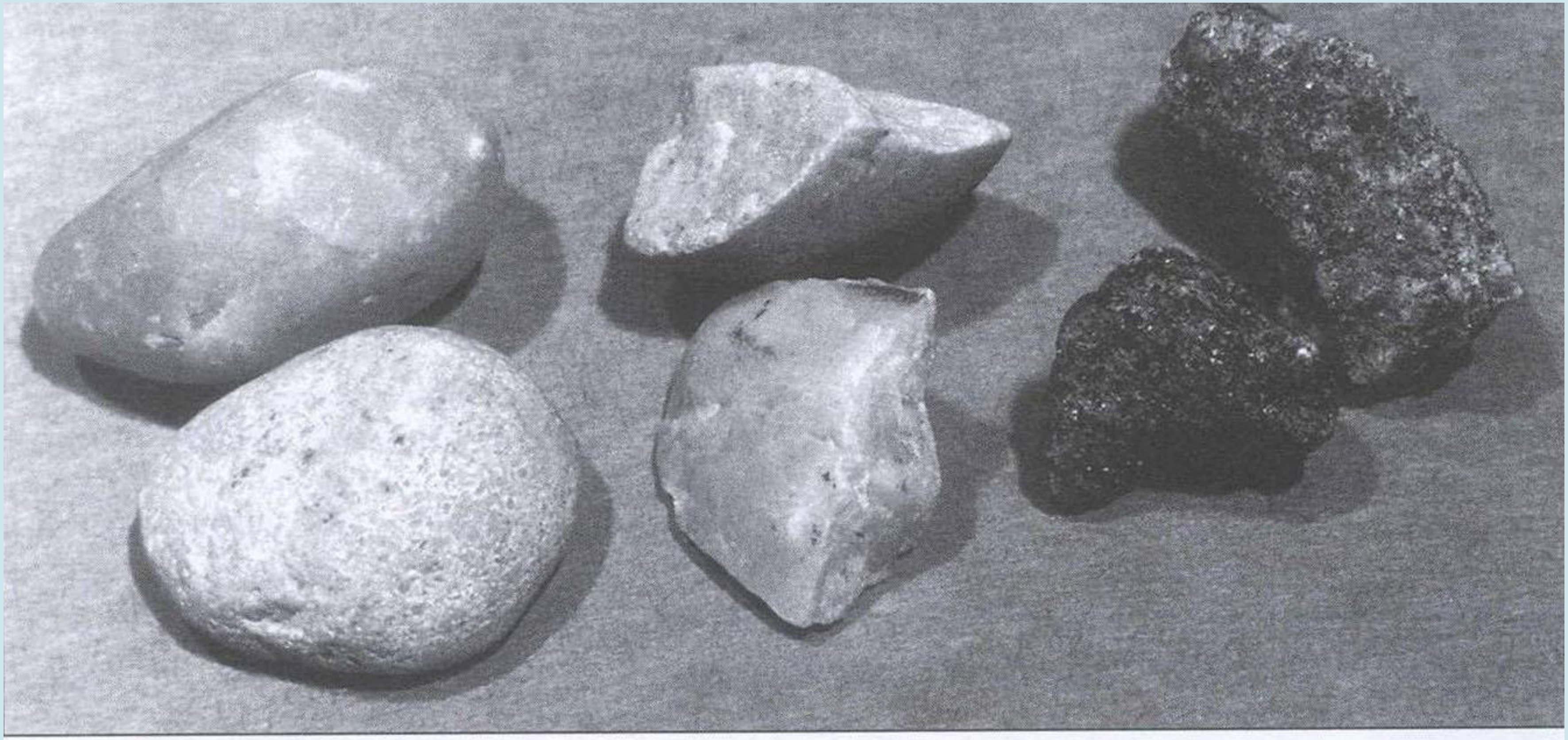


Figure 2.24 Aggregate of Various Shapes and Surface Textures

Source: AI

CONSENSUS PROPERTIES

Table 3.2 Superpave Aggregate Consensus Property Requirements

Design ESALs[1] (million)	Coarse Aggregate Angularity (Percent), minimum		Uncompacted Void Content of Fine Aggregate (Percent), minimum		Sand Equivalent (Percent), minimum	Flat and Elongated[3] (Percent), maximum
	≤ 100 mm	> 100 mm	≤ 100 mm	> 100 mm		
< 0.3	55/-	-/-	-	-	40	-
0.3 to< 3	75/-	50/-	40	40	40	10
3 to < 10	85/80[2]	60/-	45	40	45	10
10 to < 30	95/90	80/75	45	40	45	10
≥ 30	100/100	100/100	45	45	50	10

1. Design ESALs are the anticipated project traffic level expected on the design lane over a 20 year period. Regardless of the actual design life of the roadway determine the design ESALs for 20 years and choose the appropriate N_{design} level.
2. 85/80 denotes that 85% of the coarse aggregate has one fractued face and 80% has two or more fractured faces.
3. Criterion based upon a 5:1 maximum-to-minimum ratio.

(If less than 25% of a layer is within 100 mm of the surface, the layer may be considered to be below 100 mm for mixture design purposes.)

Source: SP2

GRADATION CONTROL POINTS

	Nominal Maximum Aggregate Size - Control Point (Percent Passing)									
	37.5 mm		25.0 mm		19.0 mm		12.5 mm		9.5 mm	
Sieve Size	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
50.0 mm	100									
37.5 mm	90	100	100							
25.0 mm		90	90	100	100					
19.0 mm				90	90	100	100			
12.5 mm						90	90	100	100	
9.5 mm								90	90	100
4.75 mm										90
2.36 mm	15	41	19	45	23	49	28	58	32	67
0.075 mm	0	6	1	7	2	8	2	10	2	10

Source: SP2

SUPERPAVE 12.5 mm NMS

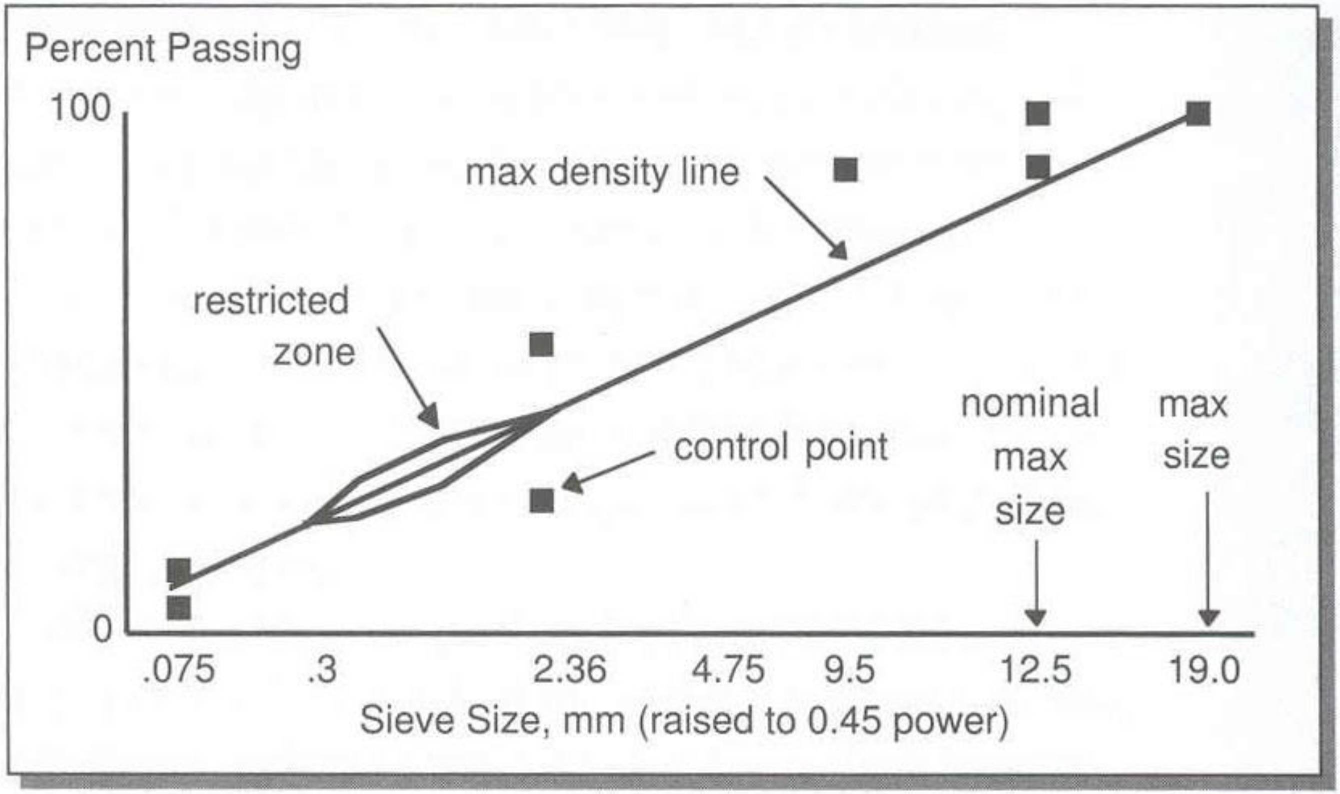
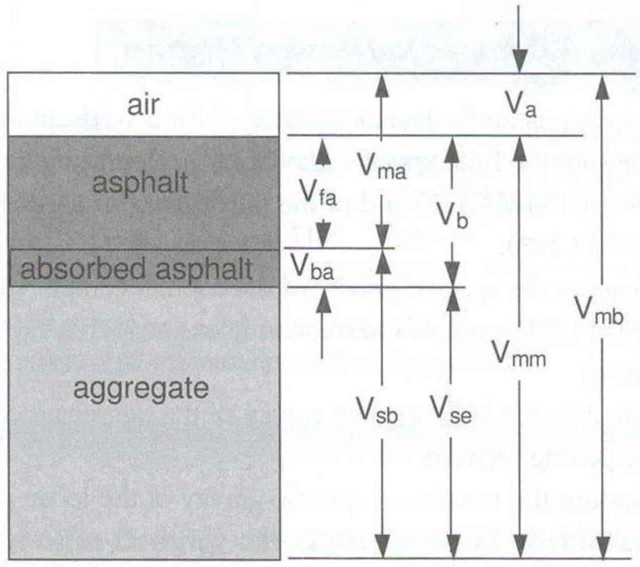


Figure 3.10 Superpave Gradation Limits

Source: SP2

ASPHALT MIX VOLUMETRICS



V_{ma} = Volume of voids in mineral aggregate
V_{mb} = Bulk volume of compacted mix
V_{mm} = Voidless volume of paving mix
V_{fa} = Volume of voids filled with asphalt
V_a = Volume of air voids
V_b = Volume of asphalt
V_{ba} = Volume of absorbed asphalt
V_{sb} = Volume of mineral aggregate (by bulk specific gravity)
V_{se} = Volume of mineral aggregate (by effective specific gravity)

Figure 4.2 Component Diagram of Compacted HMA Specimen

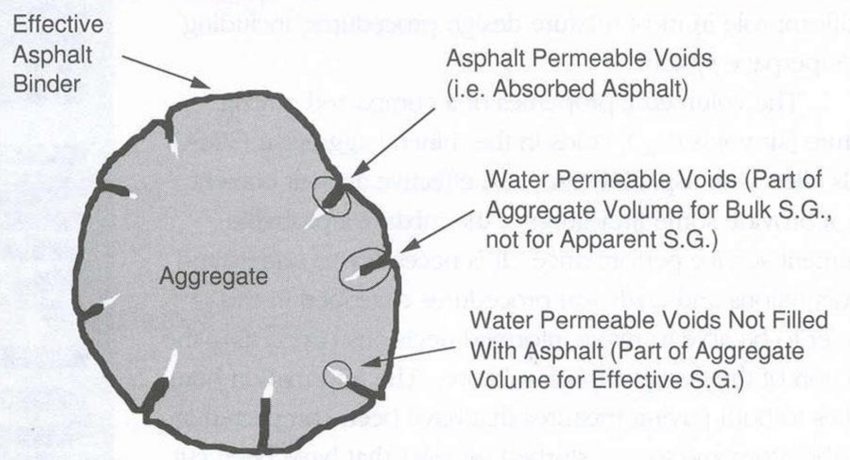


Figure 4.1 Illustrating Bulk, Effective and Apparent Specific Gravity, and Effective Asphalt Binder in Compacted Paving Mixtures

Source: AI

SUPERPAVE GYRATORY COMPACTOR

Source: GAL

DESIGN REQUIREMENTS

Table 5.2 Superpave Volumetric Mixture Design Requirements

<table>
<tr><th rowspan="3">Design ESALs (million)</th><th colspan="3">Required Density (% of Theoretical Maximum Specify Gravity)</th><th colspan="5">Voids-in-the Mineral Aggregate (Percent), minimum</th><th rowspan="3">Voids Filled With Asphalt (Percent)</th><th rowspan="3">Dust-to-Binder Ratio</th></tr>
<tr><th rowspan="2">$N_{initial}$</th><th rowspan="2">N_{design}</th><th rowspan="2">N_{max}</th><th colspan="5">Nominal Maximum Aggregate Size, mm</th></tr>
<tr><th>37.5</th><th>25.0</th><th>19.0</th><th>12.5</th><th>9.5</th></tr>
<tr><td>< 0.3</td><td>≤ 91.5</td><td rowspan="5">96.0</td><td rowspan="5">≤ 98.0</td><td rowspan="5">11.0</td><td rowspan="5">12.0</td><td rowspan="5">13.0</td><td rowspan="5">14.0</td><td rowspan="5">15.0</td><td>70 - 80</td><td rowspan="5">0.6 - 1.2</td></tr>
<tr><td>0.3 to < 3</td><td>≤ 90.5</td><td>65 - 78</td></tr>
<tr><td>3 to < 10</td><td rowspan="3">≤ 89.0</td><td rowspan="3">65 - 75</td></tr>
<tr><td>10 to < 30</td></tr>
<tr><td>≥ 30</td></tr>
</table>

Design ESALs are the anticipated project traffic level expected on the design lane over a 20-year period. Regardless of the actual design life of the roadway, determine the design ESALs for 20 years, and choose the appropriate N_{design} level.

For 9.5-mm nominal maximum size mixtures, the specified VFA range shall be 73% to 76% for design traffic levels ≥ 3 million ESALs.

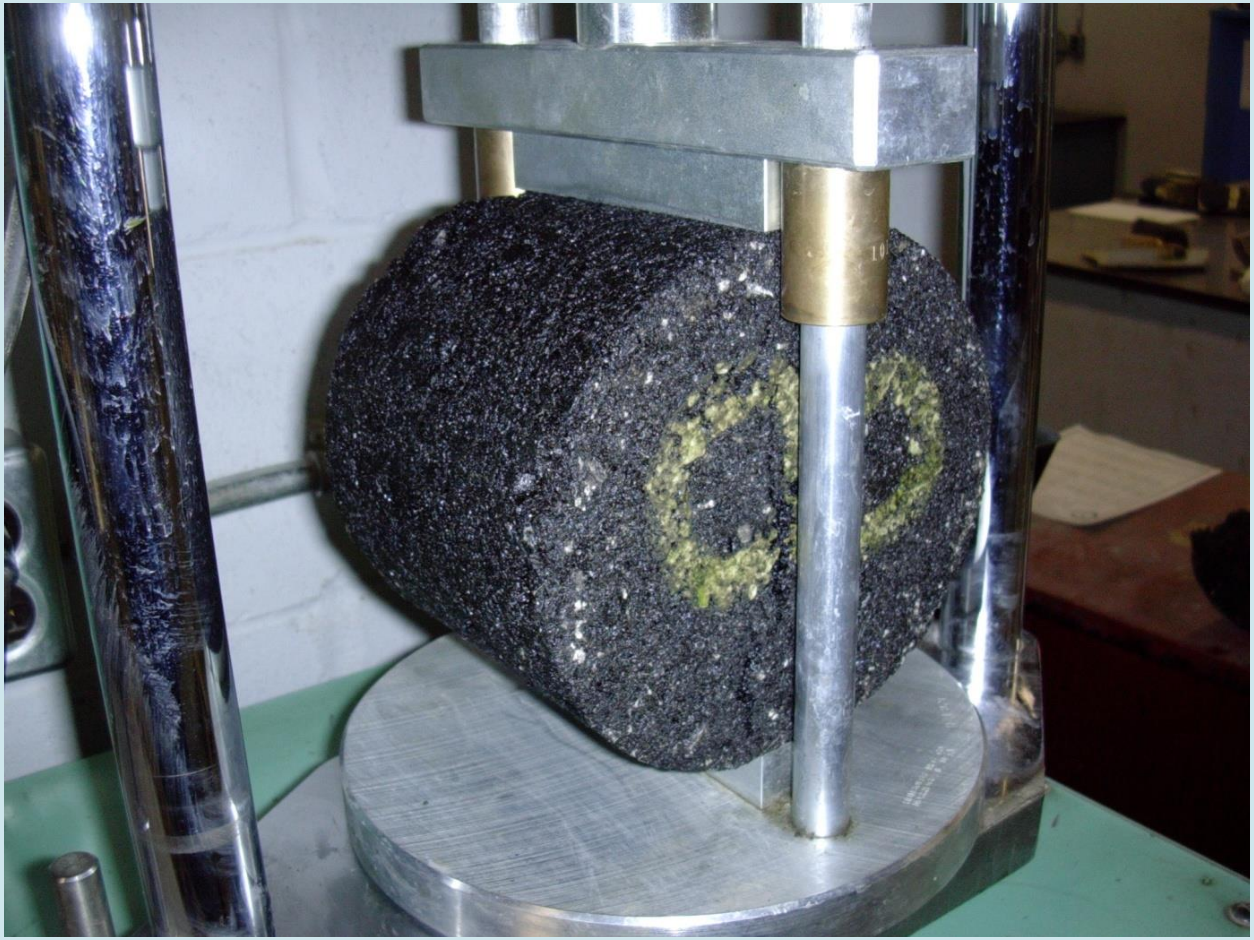
For 25.0-mm nominal maximum size mixtures, the specified lower limit of the VFA shall be 67% for design traffic levels < 0.3 million ESALs.

For 37.5-mm nominal maximum size mixtures, the specified lower limit of the VFA shall be 64% for all design traffic levels.

If the aggregate gradation passes beneath the boundaries of the aggregate restricted zone, consideration should be given to increasing the dust-to-binder ratio criteria from 0.6 - 1.2 to 0.8 - 1.6

Source: AI

MOISTURE SENSITIVITY



Source: GAL

CLOSE UP OF SUPERPAVE MIX

Source: OHMPA

SUPERPAVE SUMMARY

- Superpave was introduced in the US in 1994.
- By 2001, US DOT’s were using Superpave on 85% of paving projects.
- MTO started using PGAC in 1996, PGAC became mandatory in 1998.
- Ontario first Superpave municipal project was completed in 1996.
- MTO paving projects are 100% Superpave
- Numerous municipalities in Ontario are Superpave

PROBLEMS DURING PAVING

- Typical placement problems
  - Segregation
  - Low compaction
  - Fat spots
  - Roller marks
  - Poor joint construction
  - Tender zone

- Practical experience is critical

PERFORMANCE PROBLEMS – RAVELING AND CRACKING

- Initially observed and then addressed

THANK YOU!

QUESTIONS?

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