SHRP Asphalt Binder Specification

Presented by

Prof. Hamad I. Al-Abdul Wahhab

Civil Engineering Department
King Fahd University of Petroleum & Minerals
Dhahran, Saudi Arabia

Superpave Asphalt Binder Specification

The grading system is based on Climate

PG 70 - 10

Performance Grade

Average 7-day max pavement temperature

Min pavement temperature

PG Specifications

- Based on rheological testing (study of flow and deformation)
  - Asphalt cement is a viscoelastic material
- Behavior depends on:
  - Temperature
  - Time of loading
  - Aging (properties change with time)

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1.7.3

SHRP Asphalt Binder Spec

- **Performance Based**
  - **-- permanent deformation**
  - **-- fatigue cracking**
  - **-- low temperature cracking**
- **Physical Properties**
  - **-- criteria remain the same**
  - **-- temperature at which criteria achieved varies**
  - **-- measured on aged binder**

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1.7.4

ASPHALT GRADING SUMMARY SHEET - SHRP BINDER PERFORMANCE SPECIFICATION

Asphalt ID

Grade	Original	RTFOT	RTFOT + PAV residue				
	Flash Pt: °C (Min: 230 °C) Vis@135: cP (Max: 3000 cP)	Loss: % (Max: 1.0%)	Time/Temp after PAV 20 HRS @ 110°C				
	Dynamic Shear 10 rad/s (1.6Hz)	Dynamic Shear 10 rad/s (1.6Hz)	Dynamic Shear 10 rad/s (1.6Hz)		Flexural Creep (at 60 sec)		DT * (1mm/min)
	G*/sinδ (kPa) > 1 kPa	G*/sinδ (kPa) > 2.2 kPa	Temp °C	G*sinδ (MPa) < 5 MPa	Temp °C	Stiffness, S < 300 MPa	Slope, m > 0.30	F. Strain > 1.0%
PG 58			25		-6			
			22		-12			
			19		-18			
			16		-24			
			13		-30			
PG 64	√	√	28		-6			
			25		-12	√		
			22	√	-18	x		
			19	x	-24			
			16		-30			
PG 70	√	x	34		0			
			31		-6			
			28		-12			
			25		-18			
			22		-24			
PG 76	x	x	37		0			
			34		-6			
			31		-12			
			28		-18			
PG 82			40		0			
			37		-6			
			34		-12			
			31		-18			

* Required only if Creep Stiffness(S) is between 300 and 600 Mpa, and m > 0.30

Asphalt Grade : PG

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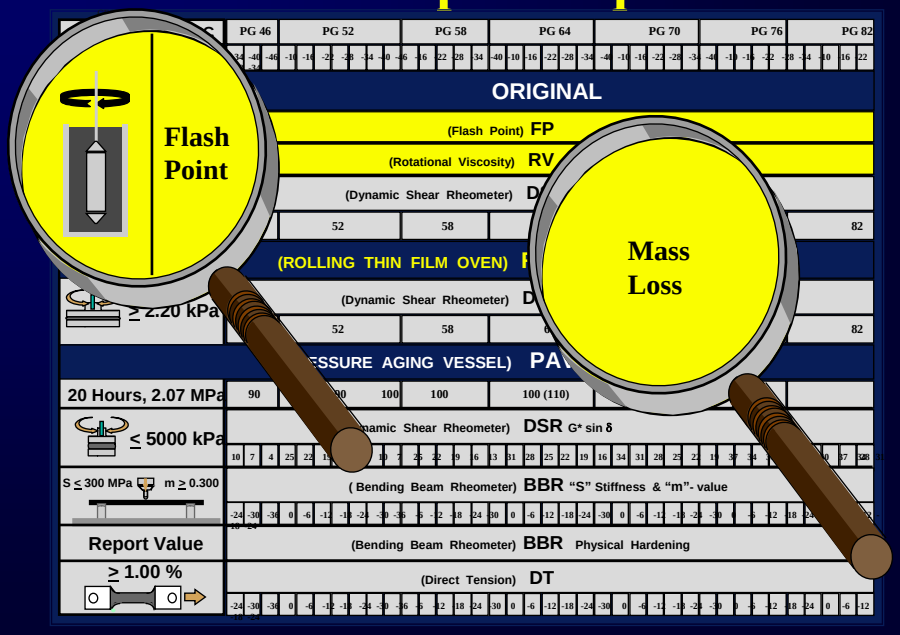
1.7.5

Miscellaneous Spec Requirements



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Miscellaneous Spec Requirements

- **Pumping and Handling**
  - -- rotational viscometer
  - -- controlled by unaged binder vis. @ 135 C ≤ 3 Pa-s
- **Safety**
  - -- flash point COC
  - -- controlled by flash point ≥ 230 C
- **Aging During Hot Mixing/Construction**
  - -- RTFO
  - -- controlled by mass loss ≤ 1.00 %

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Performance Grades

Avg 7-day Max, °C	PG 46	PG 52	PG 58	PG 64	PG 70	PG 76	PG 82
1-day Min, °C	-34 -40 -46	-10 -16 -22 -28 -34	-10 -16 -22 -28 -34	-40 -10 -16 -22 -28 -34	-40 -10 -16 -22 -28 -34	-10 -16 -22 -28 -34	-40 -10 16 22
ORIGINAL							
≥ 230 °C	(Flash Point) FP						
≤ 3 Pa·s @ 135 °C	(Rotational Viscosity) RV						
≥ 1.00 kPa	(Dynamic Shear Rheometer) DSR G*/sin δ						
	46	52	58	64	70	76	82
(ROLLING THIN FILM OVEN) RTFO Mass Loss ≤ 1.00 %							
≥ 2.20 kPa	(Dynamic Shear Rheometer) DSR G*/sin δ						
	46	52	58	64	70	76	82
(PRESSURE AGING VESSEL) PAV							
20 Hours, 2.07 MPa	90	90 100	100	100 (110)	100 (110)	110 (110)	
≤ 5000 kPa	(Dynamic Shear Rheometer) DSR G* sin δ						
	10 7 4	25 22 19 16 13 10 7	25 22 19 16 13	31 28 25 22 19 16	34 31 28 25 22 19	37 34 31 28 25	40 37 34
S ≤ 300 MPa m ≥ 0.300	(Bending Beam Rheometer) BBR "S" Stiffness & "m"- value						
	-24 -30 -36	0 -6 -12 -18 -24 -30	0 -6 -12 -18 -24 -30	0 -6 -12 -18 -24 -30	0 -6 -12 -18 -24 -30	0 -6 -12 -18 -24	0 -6 -12
Report Value	(Bending Beam Rheometer) BBR Physical Hardening						
≥ 1.00 %	(Direct Tension) DT						
	-24 -30 -36	0 -6 -12 -18 -24 -30	0 -6 -12 -18 -24 -30	0 -6 -12 -18 -24 -30	0 -6 -12 -18 -24 -30	0 -6 -12 -18 -24	0 -6 -12

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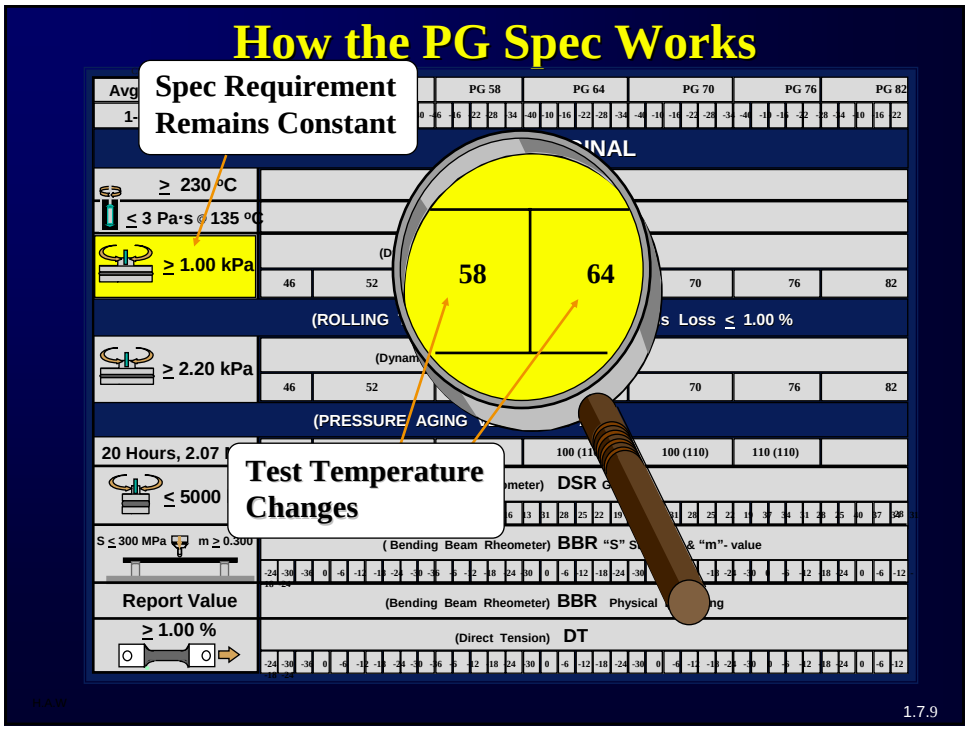
How the PG Spec Works
Spec Requirement Remains Constant
PG 58
PG 64
PG 70
PG 76
PG 82
≥ 230 °C
≥ 1.00 kPa
≥ 2.20 kPa
≤ 5000
Report Value
≥ 1.00 %
58
64
Test Temperature Changes
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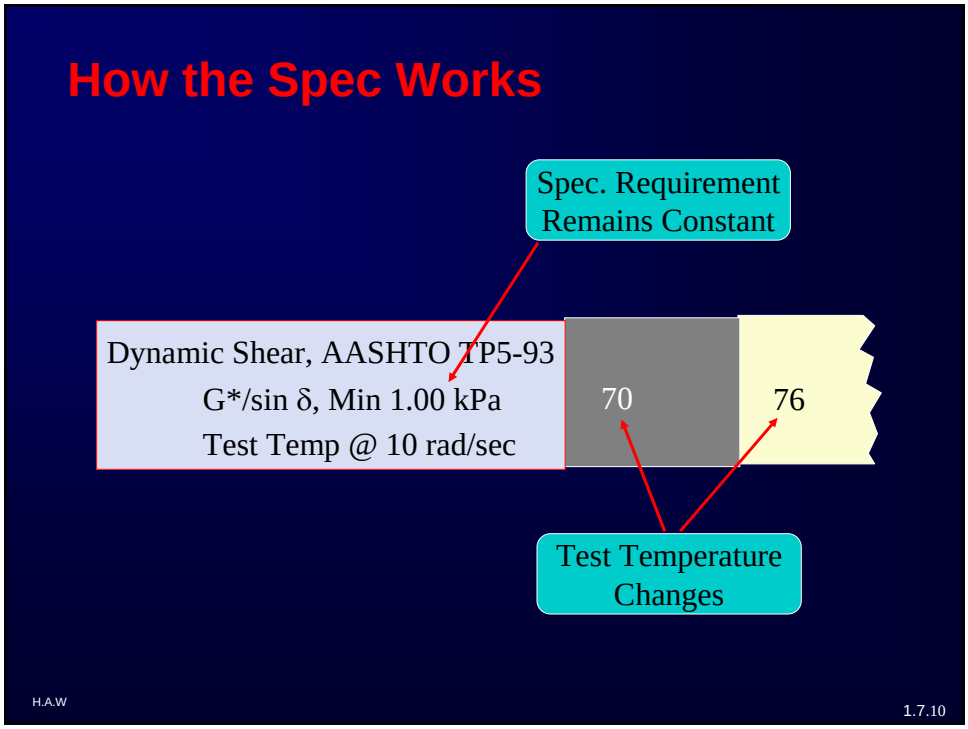
1.7.9


How the Spec Works
Spec. Requirement Remains Constant
Dynamic Shear, AASHTO TP5-93
G*/sin δ, Min 1.00 kPa
Test Temp @ 10 rad/sec
70
76
Test Temperature Changes
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1.7.10

Permanent Deformation

Function of warm weather and traffic

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1.7.11

High Temperature Behavior

- High in-service temperature
  - Desert climates
  - Summer temperatures
- Sustained loads
  - Slow moving trucks
  - Intersections

⇨ ***Viscous Liquid***

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Pavement Behavior (Warm Temperatures)

- Permanent deformation (rutting)
- Mixture is plastic
- Depends on asphalt source, additives, and aggregate properties

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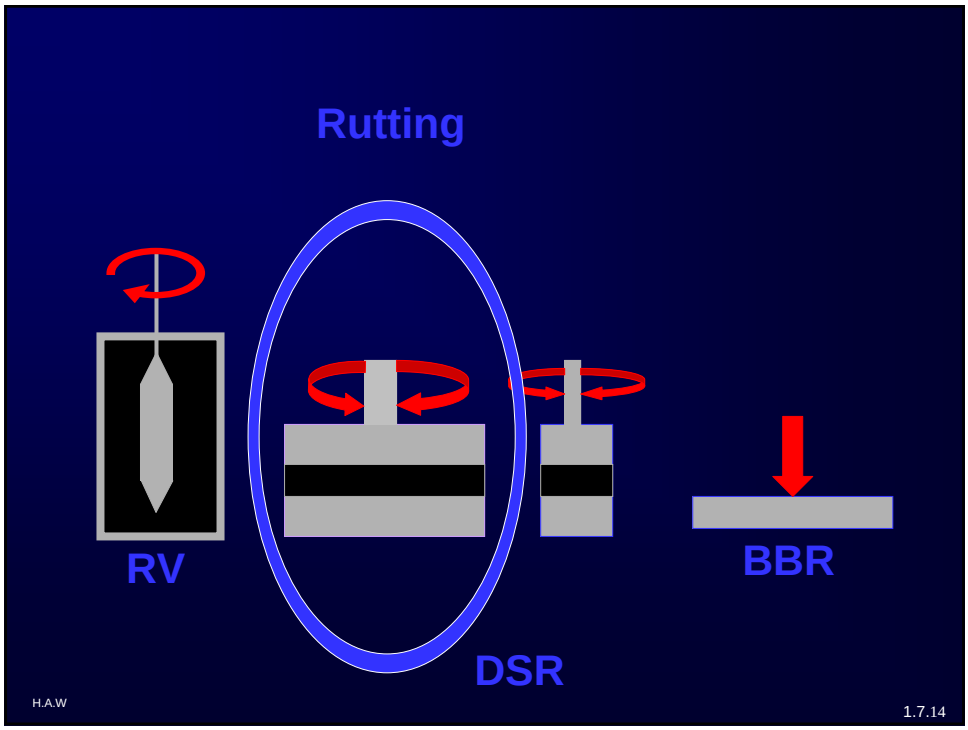
1.7.13



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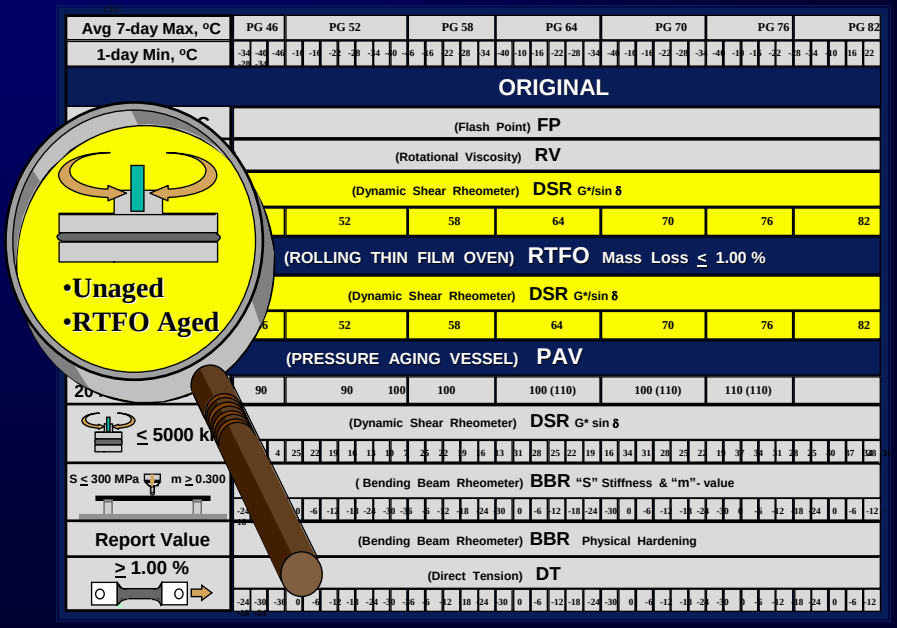
Permanent Deformation



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Spec Requirements To Control Rutting

Dynamic Shear, TP5:

G*/sin δ, Min 1.00 kPa

Test Temp @ 10 rad/sec

Dynamic Shear, TP5:

G*/sin δ, Min 2.20 kPa

Test Temp @ 10 rad/sec

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7 - 6

1.7.16

Permanent Deformation

- Addressed by high temp stiffness
  - G*/sin δ on unaged binder ≥ 1.00 kPa
  - G*/sin δ on RTFO aged binder ≥ 2.20 kPa

For the early part of the service life

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Permanent Deformation

Question: Why a minimum G*/sin δ to address rutting

Answer: We want a *stiff, elastic* binder to contribute to mix rutting resistance

How: By increasing G* or decreasing δ

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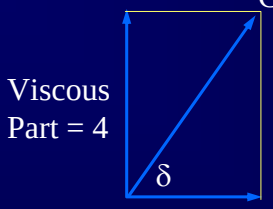
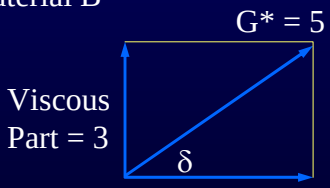
Material A



$$\sin\delta = \frac{\text{Viscous Part}}{G^*} = \frac{4}{5}$$

$$\frac{G^*}{\sin\delta} = \frac{5}{4/5} = 6.25$$

Material B



$$\sin\delta = \frac{\text{Viscous Part}}{G^*} = \frac{3}{5}$$

$$\frac{G^*}{\sin\delta} = \frac{5}{3/5} = 8.33$$

Large value means behaves more like elastic solid

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Fatigue Cracking

Function of repeated traffic loads over time (in wheel paths)

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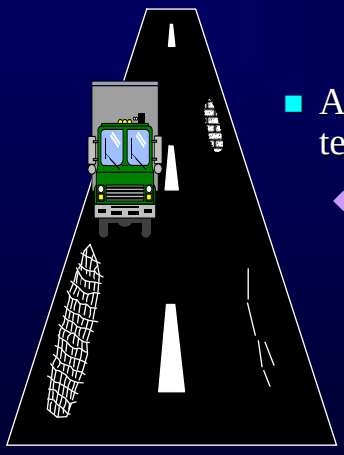
1.7.20

Fatigue Cracking



- Addressed by intermediate temperature stiffness
  - G*sin δ on RTFO + PAV aged binder ≤ 5000 kPa

> *Later part of pavement service life*

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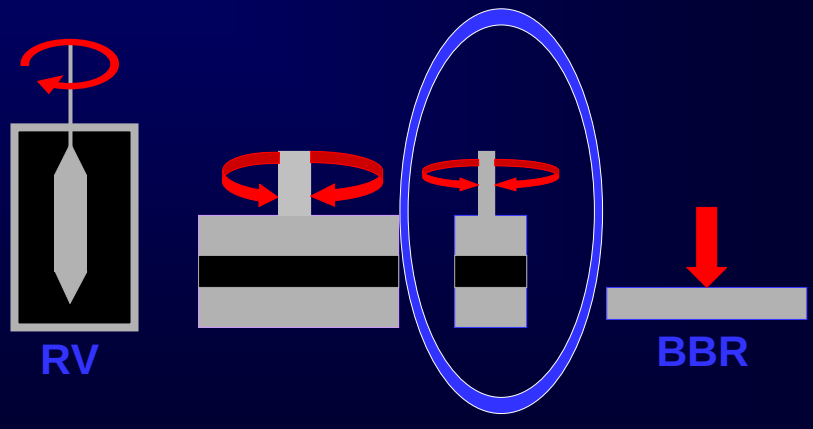
1.7.21



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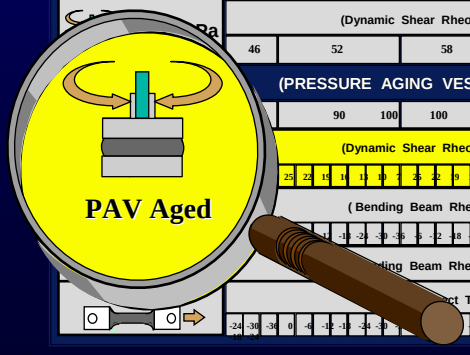
Fatigue Cracking

Avg 7-day Max, °C	PG 46	PG 52	PG 58	PG 64	PG 70	PG 76	PG 82
1-day Min, °C	-34 -40 -46 -10 -16 -22 -28 -34 -40 -46	-10 -16 -22 -28 -34 -40 -46	-16 -22 -28 -34 -40 -46	-10 -16 -22 -28 -34 -40 -46	-10 -16 -22 -28 -34 -40 -46	-10 -16 -22 -28 -34 -40	-10 -16 -22
ORIGINAL							
≥ 230 °C	(Flash Point) FP						
≤ 3 Pa·s @ 135 °C	(Rotational Viscosity) RV						
≥ 1.00 kPa	(Dynamic Shear Rheometer) DSR G*/sin δ						
	46	52	58	64	70	76	82
(ROLLING THIN FILM OVEN) RTFO Mass Loss ≤ 1.00 %							
	(Dynamic Shear Rheometer) DSR G*/sin δ						
	46	52	58	64	70	76	82
(PRESSURE AGING VESSEL) PAV							
	90	100	100	100 (110)	100 (110)	110 (110)	
	(Dynamic Shear Rheometer) DSR G* sin δ						
	25 22 19 16 13 10 7 25 22 19 16 13 11 28 25 22 19 16 34 31 28 25 22 19 37 34 31 28 25 22 40 37 34 31 28 25 43 40 37 34 31 28						
	(Bending Beam Rheometer) BBR "S" Stiffness & "m"- value						
	-18 -24 -30 -36 -6 -12 -18 -24 -30 0 -6 -12 -18 -24 -30 0 -6 -12 -18 -24 -30 0 -6 -12 -18 -24 -30 0 -6 -12 -18 -24 0 -6 -12						
	ling Beam Rheometer) BBR Physical Hardening						
	ct Tension) DT						
	-24 -30 -36 0 -6 -12 -18 -24 -30 0 -6 -12 -18 -24 -30 0 -6 -12 -18 -24 -30 0 -6 -12 -18 -24 -30 0 -6 -12 -18 -24 0 -6 -12						



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Specification requirement
To control fatigue cracking

Dynamic Shear, TP5:

G*sin δ, Max 5000 kPa

Test Temp @ 10 rad/sec, C

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1.7.24

Fatigue Cracking

- Question: Why a maximum G* sin δ to address fatigue?

Answer: We want a *soft elastic* binder (to sustain many loads without cracking)

How: By decreasing G* or decreasing δ

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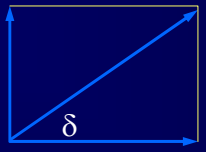
1.7.25

Material A

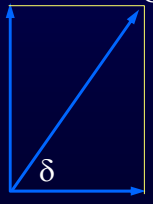


$$\text{Sin } \delta = \frac{\text{Viscous Part}}{G^*} = \frac{3}{5}$$

G* sin δ = 5 × 3/5 = 3

Smaller value means Better at dissipating stress

Material B



$$\text{Sin } \delta = \frac{\text{Viscous Part}}{G^*} = \frac{3.5}{5}$$

G* sin δ = 5 × 3.5/5 = 3.5

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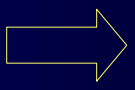
1.7.26

Low Temperature Behavior

- Low Temperature
  - Cold climates
  - Winter



Elastic Solid

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1.7.27

Pavement Behavior (Low Temperatures)

- Thermal cracks
  - Stress generated by contraction due to drop in temperature
  - Crack forms when thermal stresses exceed ability of material to relieve stress through deformation
    - Material is brittle
- Depends on source of asphalt and aggregate properties

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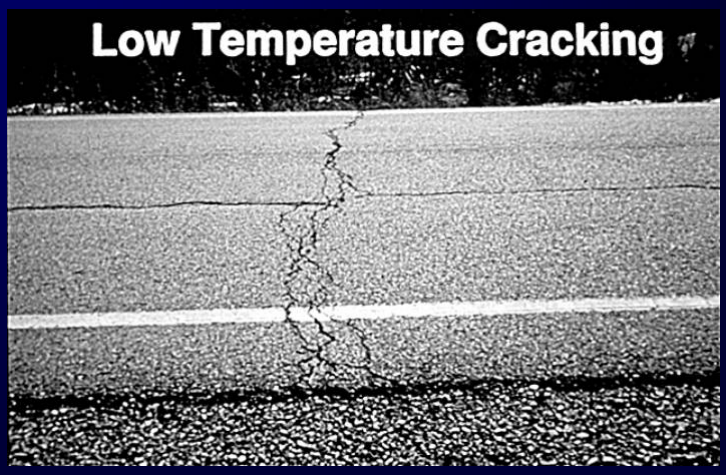
1.7.28

Thermal Cracking



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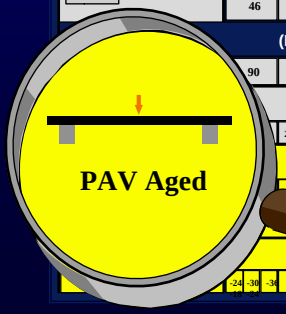
1.7.29

Low Temperature Cracking

Avg 7-day Max, °C	PG 46	PG 52	PG 58	PG 64	PG 70	PG 76	PG 82
1-day Min, °C	-34 -40 -46	-10 -16 -22 -28 -34	-40 -6 -16 -22 -28 -34	-40 -10 -16 -22 -28 -34	-40 -10 -16 -22 -28 -34	-40 -10 -16 -22 -28 -34	-40 -10 16 22
ORIGINAL							
≥ 230 °C	(Flash Point) FP						
≤ 3 Pa·s @ 135 °C	(Rotational Viscosity) RV						
≥ 1.00 kPa	(Dynamic Shear Rheometer) DSR G*/sin δ						
	46	52	58	64	70	76	82
(ROLLING THIN FILM OVEN) RTFO Mass Loss ≤ 1.00 %							
≥ 2.20 kPa	(Dynamic Shear Rheometer) DSR G*/sin δ						
	46	52	58	64	70	76	82
(PRESSURE AGING VESSEL) PAV							
	90	90 100	100	100 (110)	100 (110)	110 (110)	
	(Dynamic Shear Rheometer) DSR G* sin δ						
	25 22 19 16 13 10 7 34 31 28 25 22 19 16 34 31 28 25 22 19 37 34 31 28 25 40 37						
	(Bending Beam Rheometer) BBR "S" Stiffness & "m"- value						
	-6 -12 -18 -24 -30 0 -6 -12 -18 -24 -30 0 -6 -12 -18 -24 -30 0 -6 -12 -18 -24 0 -6 -12						
	Beam Rheometer) BBR Physical Hardening						
	sion) DT						
	-24 -30 -36 0 -6 -12 -18 -24 -30 -6 -12 -18 -24 -30 0 -6 -12 -18 -24 -30 0 -6 -12 -18 -24 0 -6 -12						



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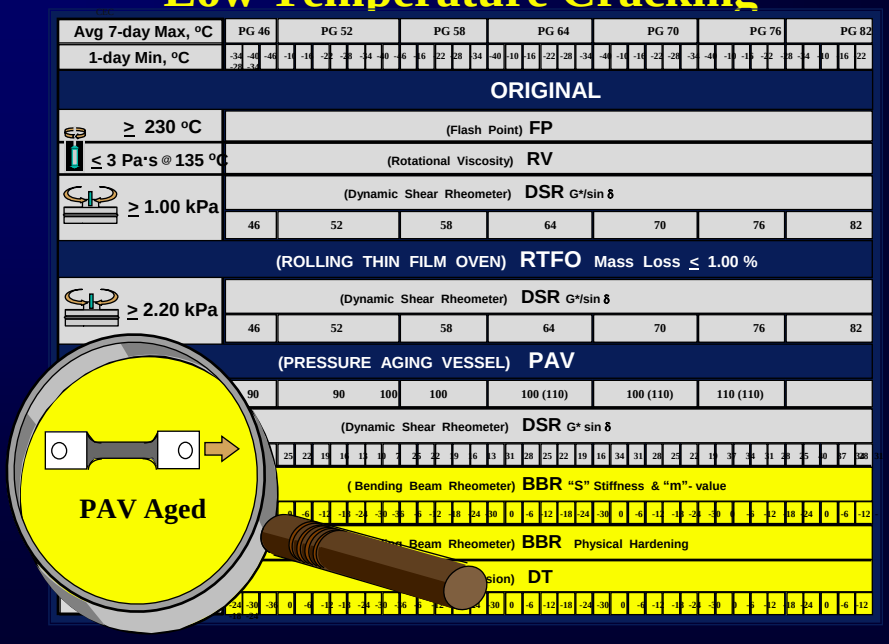
Low Temperature Cracking



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1.7.31

Creep Stiffness, TP1:

- S, Max, 300 MPa
- m-value, Min, 0.300
- Test Temp @ 60 sec, C

Specification requirement To control Low temperature cracking

Direct Tension, TP3:

- Failure Strain, Min 1.0 %
- Test Temp @ 1.0 mm/min, C

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1.7.32

Low Temperature Cracking

- **Controlled by**
  - -- S on RTFO/PAV aged materials ≤ 300 kPa
  - -- m-value on RTFO/PAV aged materials ≥ 0.300
- **Alternate Control**
  - -- S on RTFO/PAV aged materials 300 – 600 MPa
  - -- m-value on RTFO/PAV aged materials ≥ 0.300
  - -- tensile failure strain on RTFO/PAV aged materials ≥ 1.0%

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1.7.33

Effect of Loading Rate on Binder Selection

- Dilemma
  - specified DSR loading rate is 10 rad/sec (90kph)
  - what about longer loading times ?
- Use binder with more stiffness at higher temps
  - slow - - increase one high temp grade
  - stationary - - increase two high temp grades
  - *no effect on low temp grade*

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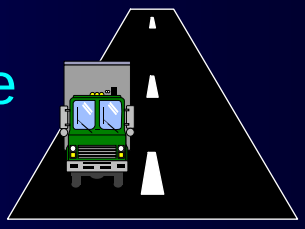
1.7.34

Effect of Loading Rate on Binder Selection



- Example
  - for toll road — PG 64-22
  - for toll booth — PG 70-22
  - for weigh stations — PG 76-22

90 kph

Slow

Stopping

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1.7.35

Effect of Traffic Amount on Binder Selection

- 10 - 30 x 10^6 ESAL
  - Consider increasing - - one high temp grade
- 30 x 10^6 + ESAL
  - Recommend increasing - - one high temp grade

Equivalent Single Axle Loads

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1.7.36

New Binder Selection Adjustments for Traffic Level and Speed MP2

Design ESAL's [1] (Millions)	Adjustment to Binder PG Grade [2]		
	Traffic Load Rate		
	Standing (Avg. Speed < 20 km/hr	Slow (Avg. Speed 20 to 70 km/hr	Avg. Speed > 70 km/hr
< 0.3	- [3]	-	-
0.3 to < 3	2	1	-
3 to <10	2	1	-
10 to < 30	2	1	- [3]
≥ 30	2	1	1

(1) Design ESAL's are anticipated project traffic level expected on the design lane over a 20 years period. Regardless of the actual design life of the roadway, determine the design ESAL's for 20 years and choose appropriate N_{design} level.
(2) Increases the high temperature grade by the number of grade equivalents indicate (1 grade equivalent to 6°C.
(3) Consideration should be given to increasing the high temperature grade by 1 grade equivalent.

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1.7.37

Summary of How to Use PG Specification

- Determine
  - 7-day max pavement temperatures
  - 1-day minimum pavement temperature
- Use specification tables to select test temperatures
- Determine asphalt cement properties and compare to specification limits

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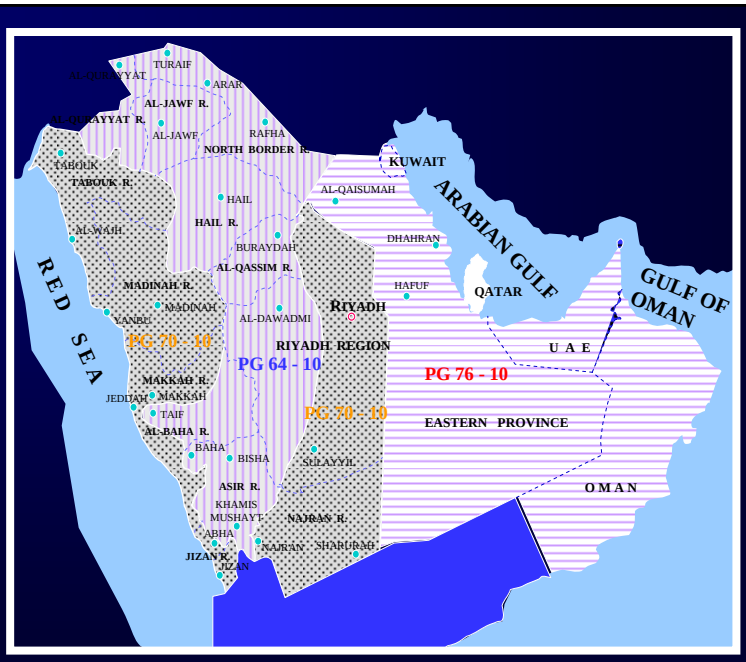
1.7.38



Tentative Temperature Zoning for Asphalt Binder Specifications for the Gulf Countries.

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1.7.39

ASPHALT GRADING SUMMARY SHEET - SHRP BINDER PERFORMANCE SPECIFICATION

Asphalt ID

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	Dynamic Shear 10 rad/s (1.6Hz)	Dynamic Shear 10 rad/s (1.6Hz)	Dynamic Shear 10 rad/s (1.6Hz)		Flexural Creep (at 60 sec)			DT * (1mm/min)
	G*/sinδ (kPa) > 1 kPa	G*/sinδ (kPa) > 2.2 kPa	Temp °C	G*sinδ (MPa) < 5 MPa	Temp °C	Stiffness, S < 300 MPa	Slope, m > 0.30	F. Strain > 1.0%
PG 58	2.7		25		-6			
			22		-12			
			19		-18			
			16		-24			
			13		-30			
PG 64	1.6	3.1	28	3.55	-6	193.5	0.308	
			25	4.64	-12	256.3	0.262	
			22	5.12	-18	Failed	Failed	
			19		-24			
			16		-30			
PG 70	0.82		34		0			
			31		-6			
			28		-12			
			25		-18			
			22		-24			
PG 76			37		0			
			34		-6			
			31		-12			
			28		-18			
PG 82			40		0			
			37		-6			
			34		-12			
			31		-18			

Required only if Creep Stiffness(S) is between300 and 600 Mpa, and m>0.30

Asphalt Grade : PG 64-16

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1.7.40

ASPHALT GRADING SUMMARY SHEET -
SHRP BINDER PERFORMANCE SPECIFICATION

Asphalt ID

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	Flash Pt: °C (Min: 230 °C) Vis@135: cP (Max: 3000 cP)	Loss: % (Max: 1.0%)	Time/Temp after PAV: 20 HRS @ 110°C				
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PG 58			25		-6			
			22		-12			
			19		-18			
			16		-24			
			13		-30			
PG 64	3.4		28		-6			
			25		-12			
			22		-18			
			19		-24			
			16		-30			
PG 70	2.3		34		0			
			31		-6			
			28		-12			
			25		-18			
			22		-24			
PG 76	1.5	2.4	37	3.62	0	95.18	0.312	
			34	4.18	-6	170.8	0.270	
			31	5.2	-12	Failed	Failed	
			28		-18			
PG 82	0.9		40		0			
			37		-6			
			34		-12			
			31		-18			

Required only if Creep Stiffness(S) is between 300 and 600 Mpa, and m>0.30

Asphalt Grade : PG 76-10

H.A.W

1.7.41

THANK YOU

H.A.W

1.7.42