Pavement Materials & Design

Asphalt Materials

SuperPave Physical Tests For Asphalt Binders

Dr. Hamza Alkuime

SuperPave: The Future of Asphalt

- ❑ SuperPave is an acronym for Superior Performing Asphalt Pavements
- ❑ SuperPave is a new, comprehensive asphalt mix design and analysis system, a product of the Strategic Highway Research Program.
- ❑ Congress established SHRP in 1987 as a five-year, $150 million research program to improve the performance and durability of United States roads and to make those roads safer for both motorists and highway workers.
  - ➢ *$50 million of the SHRP research funds were used for the development of performance-based asphalt material specifications to relate laboratory analysis with field performance*

Performance Graded(PG) system philosophy

- With the advent of the Performance Graded (PG) system, specifying a single temperature for a particular test became obsolete.
- Rather than specifying a test temperature for a physical property,
  - *a desired property parameter was set*
  - *the temperature that **achieved** this desired value was then determined via the prescribed test method.*
- This was a fundamental change in binder testing philosophy.
  - *It allowed asphalt to be graded for the expected environmental conditions.*
- Tests were incorporated in the PG system **to reflect**
  - *High temperature (rutting) behaviors*
  - *Low temperature (thermal cracking) behaviors*
  - *Binder aging (fatigue) behaviors*

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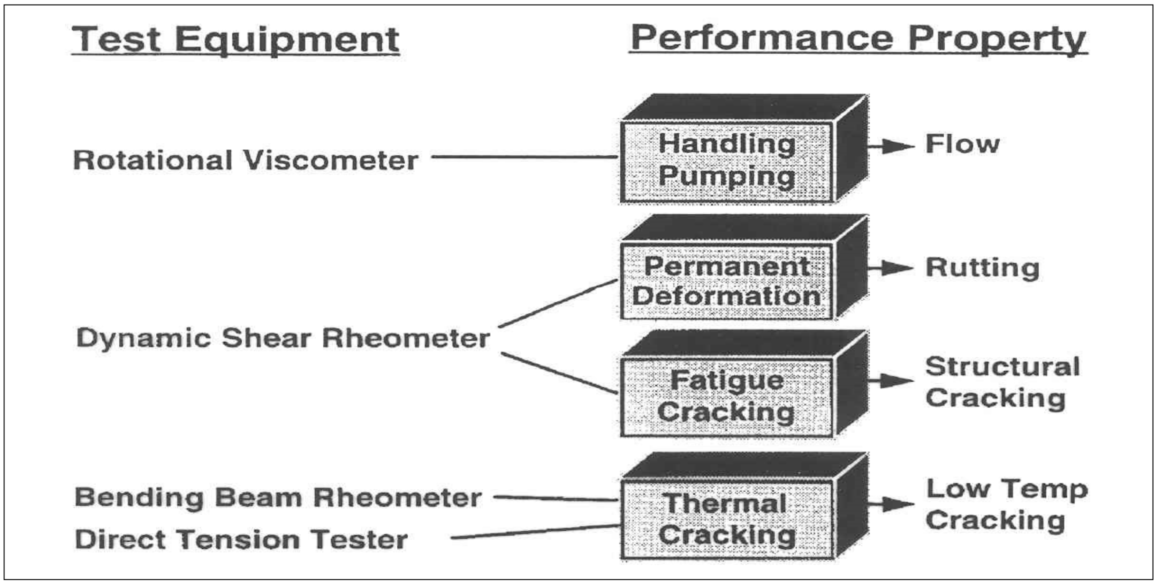
SuperPave binder property measurements



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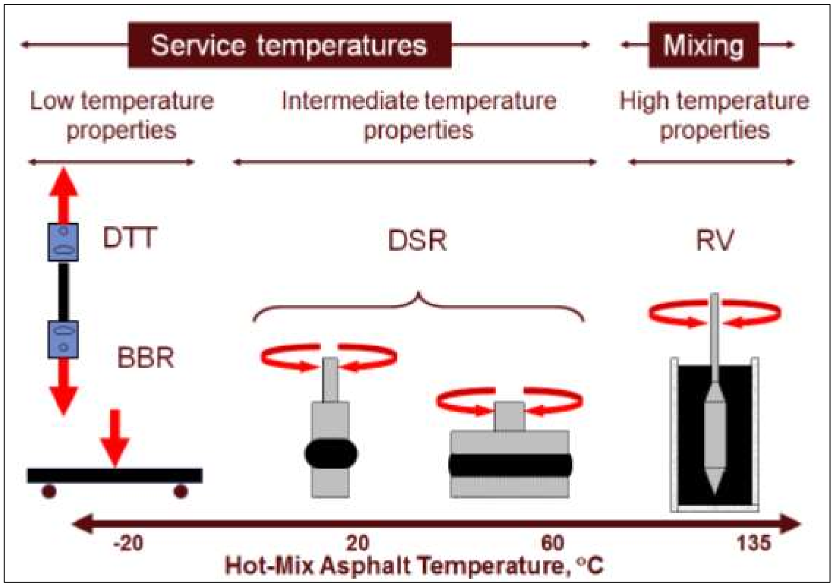

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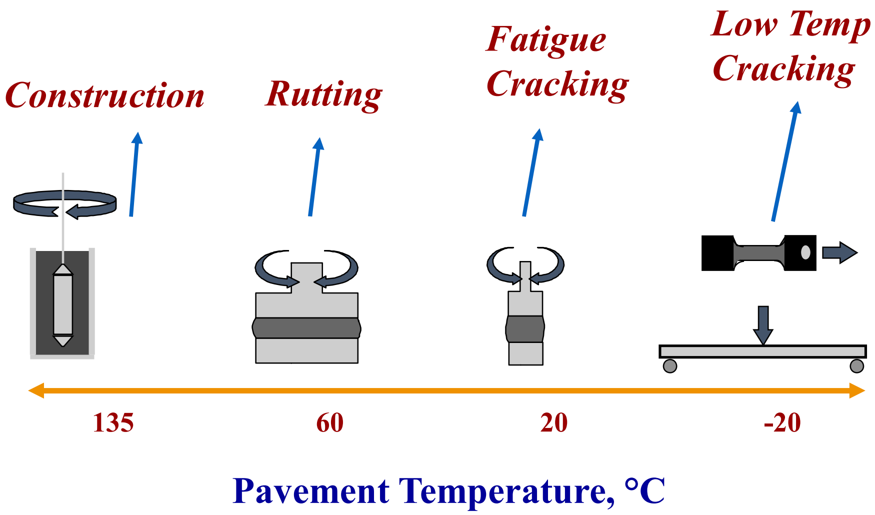


Construction

Rutting

Fatigue Cracking

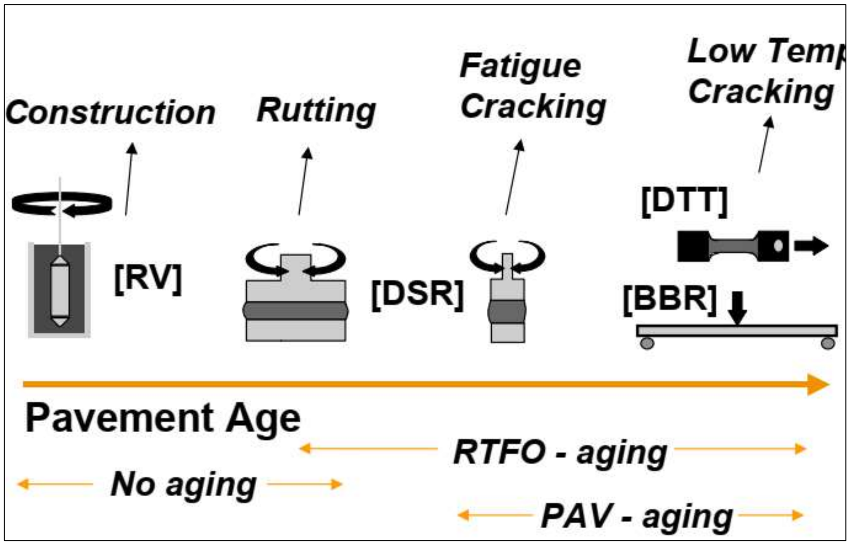
Low Temp Cracking

135 **60** **20** **-20**

Pavement Temperature, °C

SuperPave: The Future of Asphalt

SuperPave binder property measurements



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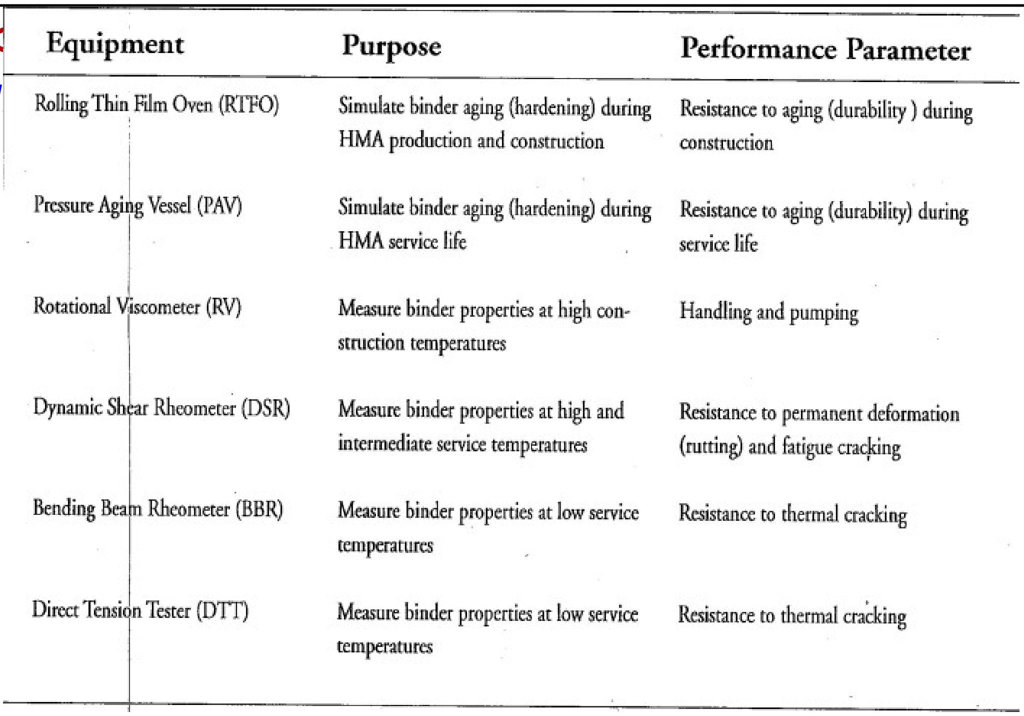
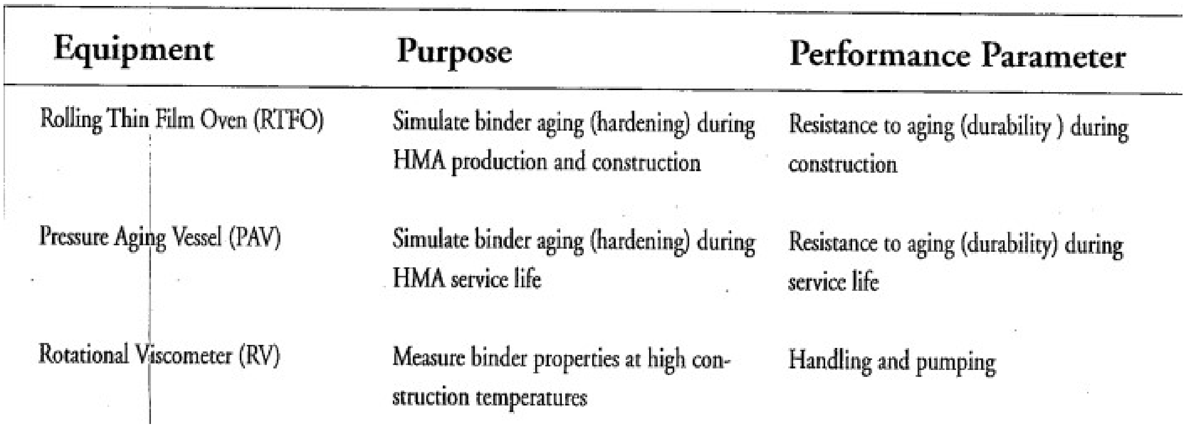


Equipment	Purpose	Performance Parameter
Rolling Thin Film Oven (RTFO)	Simulate binder aging (hardening) during HMA production and construction	Resistance to aging (durability) during construction
Pressure Aging Vessel (PAV)	Simulate binder aging (hardening) during HMA service life	Resistance to aging (durability) during service life
Rotational Viscometer (RV)	Measure binder properties at high construction temperatures	Handling and pumping
Dynamic Shear Rheometer (DSR)	Measure binder properties at high and intermediate service temperatures	Resistance to permanent deformation (rutting) and fatigue cracking
Bending Beam Rheometer (BBR)	Measure binder properties at low service temperatures	Resistance to thermal cracking
Direct Tension Tester (DTT)	Measure binder properties at low service temperatures	Resistance to thermal cracking

Superpave: The Future of Asphalt

Superpave binder property measurements



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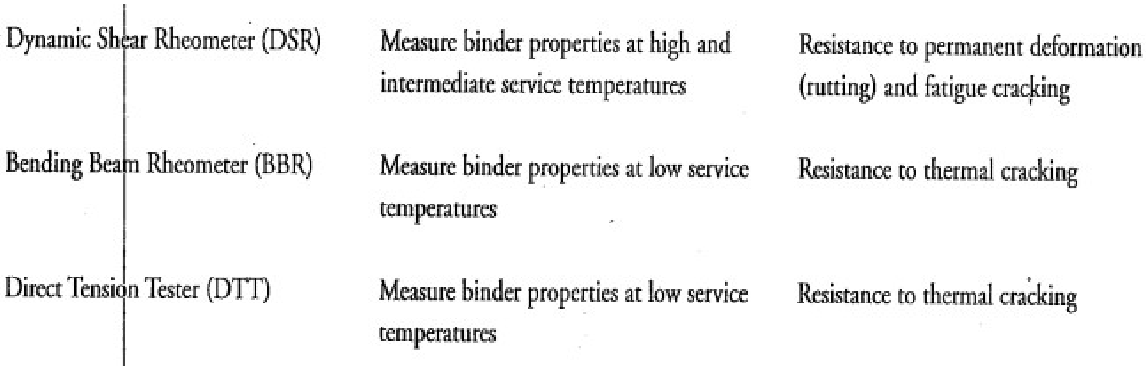
Rotational Viscometer (RV)	Measure binder properties at high construction temperatures	Handling and pumping

Superpave: The Future of Asphalt

Superpave binder property measurements



Dynamic Shear Rheometer (DSR)	Measure binder properties at high and intermediate service temperatures	Resistance to permanent deformation (rutting) and fatigue cracking
Bending Beam Rheometer (BBR)	Measure binder properties at low service temperatures	Resistance to thermal cracking
Direct Tension Tester (DTT)	Measure binder properties at low service temperatures	Resistance to thermal cracking

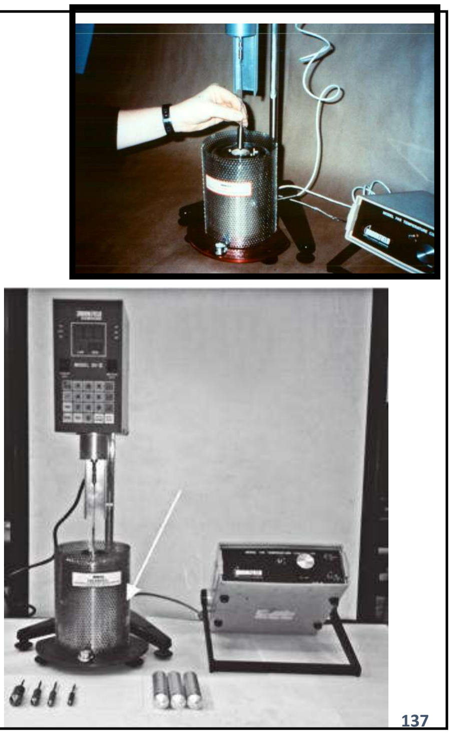
Pressure Ageing vessel

https://www.youtube.com/watch?v=FVQ455_KlYQ

Rotational viscosity

ASTM D4402

- Used to determine the flow characteristics of the asphalt binder
  - *To ensure that the asphalt is fluid enough to be pumped and handled at the hot mix facility*
- Measured on the original asphalt binder
- Test temperature at 135 C
- Maximum viscosity 3 Pa.s



Absolute (dynamic) viscosity test

ASTM D4402

Video source :https://www.youtube.com/watch?v=qhFVc5bw3bc

Rolling Thin Film Oven Test

ASTM D2872

- ❑ Scope
  - ➢ *It has the same purpose as the TFO, but the test setup was modified to achieved several advantages over the TFO including*
    - ❖ Less testing time
    - ❖ Ability to test large number of samples
- ❑ The differences between the TFOT and the RTFOT methods are
  - ❖ Type of oven used
  - ❖ The quantity of the asphalt sample
  - ❖ The type of containers
  - ❖ The duration of rotation and the absence of applying airflow on the samples

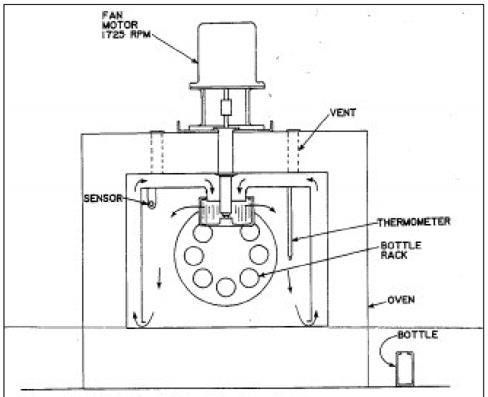


Figure 2–18. Rolling Thin Film Oven Test

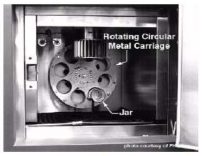


Figure : Rolling Thin-Film Oven Test

Figure : RTFO Samples
(left - after aging in the RTFO,
center - before aging in the RTFO,
right - empty sample jar)

Dynamic Shear Rheometer (DS

AASHTO T 315

- ☐ DSR test evaluates the effect of loading time and temperature to characterize both elastic and viscous behavior
- ☐ Intermediate to high temperatures
- ☐ Specimen types:
  - ➢ *Original binder*
  - ➢ *RTFO residues*
  - ➢ *PAV residues*

(PDF) Effects of exposure time and temperature in aging test on asphalt binder properties (researchgate.net)

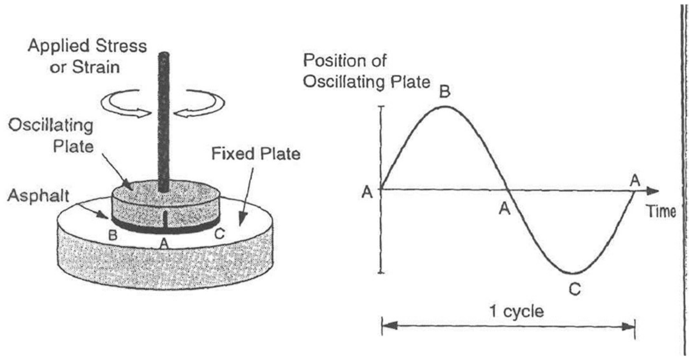
Dynamic Shear Rheometer (DSR)

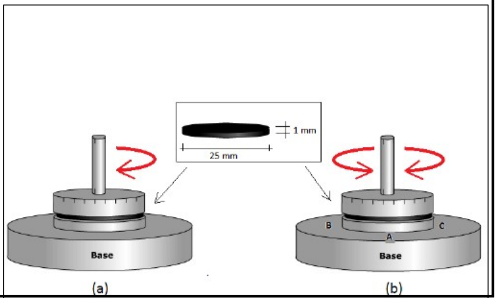
AASHTO T 315

https://www.youtube.com/watch?v=Rv6eA_p9Mpw

Dynamic Shear Rheometer (DSR)

AASHTO T 315





Rotation speed = 10 rad/sec

(PDF) Effects of exposure time and temperature in aging test on asphalt binder properties (researchgate.net)

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Dynamic Shear Rheometer (DSR)

AASHTO T

Lecture 23
Asphalt Binders and Asphalt
Mixtures (3)

Congrui Grace Jin

Apr 22, 2020

Rotation speed = 10 rad/sec

(PDF) Effects of exposure time and temperature in aging test on asphalt binder properties (researchgate.net)

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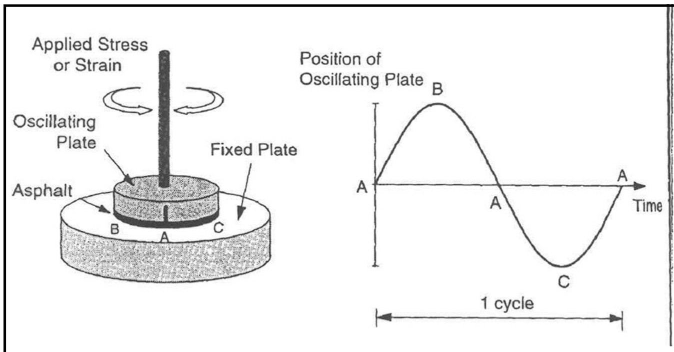
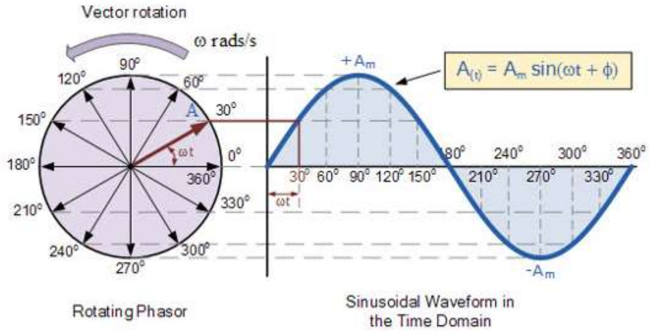
143



$$G^* = \frac{\tau_{max} - \tau_{min}}{\gamma_{max} - \gamma_{min}}$$

Δt = time lag → δ

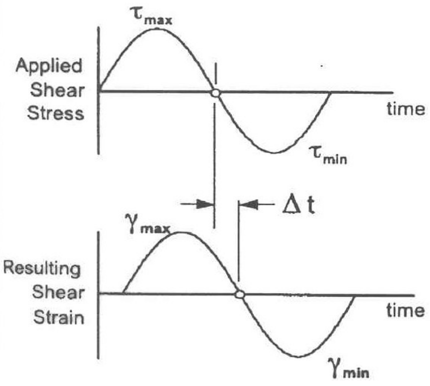


Dynamic Shear Rheometer (DSR)

AASHTO T 315

- ☐ The DSR measures a specimen's complex shear modulus (G*) and phase angle (δ).
- ☐ The complex shear modulus (G*)
  - ➢ *can be considered the sample's total resistance to deformation when repeatedly sheared*
- ☐ while the phase angle (δ),
  - ➢ *is the lag between the applied shear stress and the resulting shear strain.*
  - ➢ *The larger the phase angle (δ), the more viscous the material.*
  - ➢ *indicates the relative amounts of recoverable and non-recoverable deformation*
- ☐ Phase angle (δ) limiting values are:
  - ➢ *Purely elastic material: δ = 0 degrees*
  - ➢ *Purely viscous material: δ = 90 degrees*

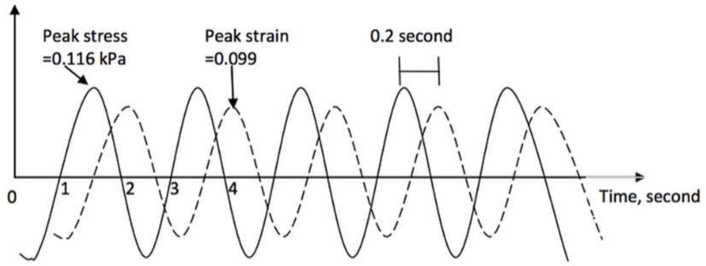
Viscoelastic: 0 < δ < 90°



$$G^* = \frac{\tau_{max} - \tau_{min}}{\gamma_{max} - \gamma_{min}}$$

Δt = time lag → δ

For a dynamic shear rheometer (DSR) test on a **RTFO-aged asphalt binder** at temperature of 64°C, the test results are shown in Figure below.

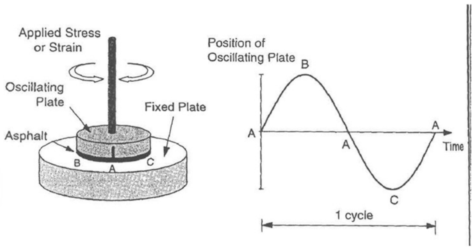


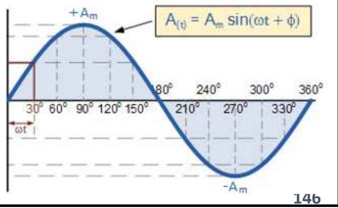
(1) Determine the complex modulus (G*) and phase angle (δ) of this RTFO-aged asphalt binder.

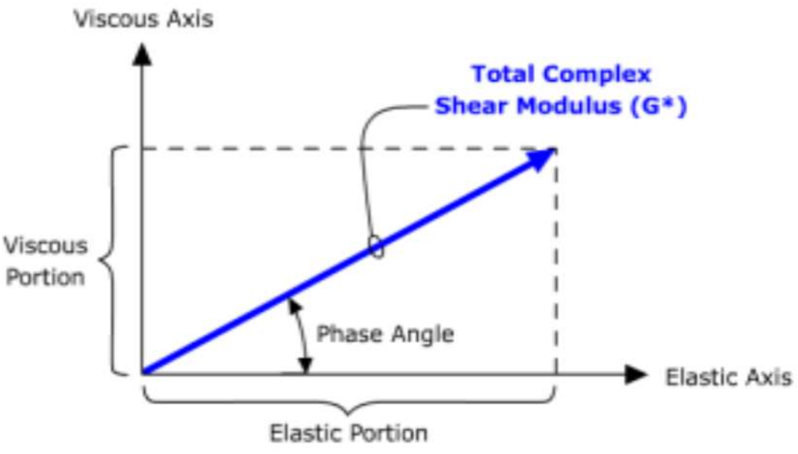
(2) Determine the rutting parameter and the fatigue parameter of this asphalt binder.

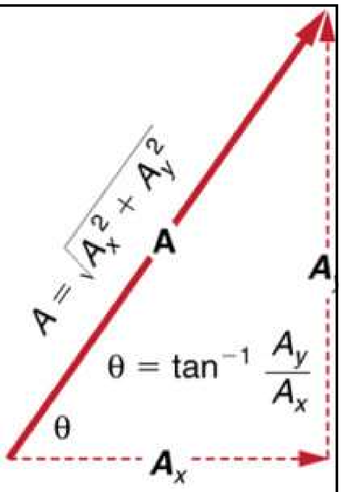
$$G^* = \frac{\tau_{max} - \tau_{min}}{\gamma_{max} - \gamma_{min}}$$

Δt = time lag → δ



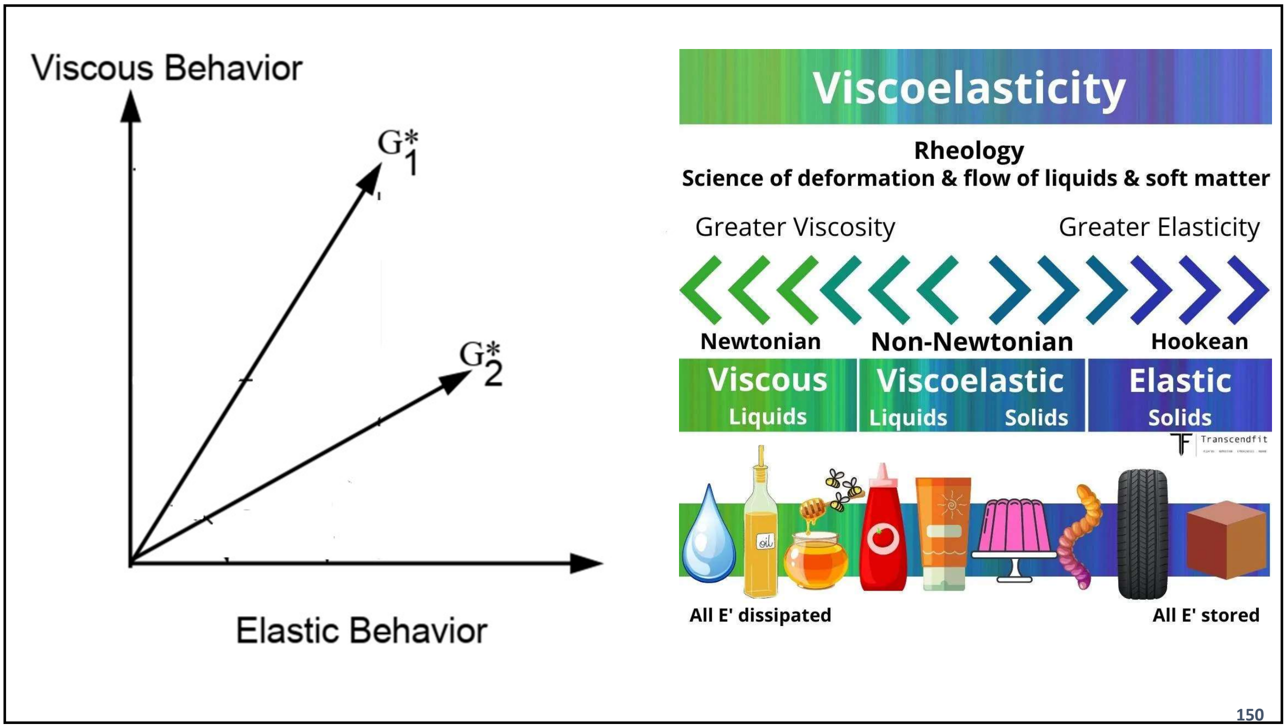






- *G* : measures the total resistance of the asphalt to deformation*
- *δ indicates the relative amounts of recoverable and non-recoverable deformation*

- ❑ G* and δ components
  - *Elastic component (recoverable deformation)*
  - *Viscous component (non-recoverable deformation*



Viscoelasticity

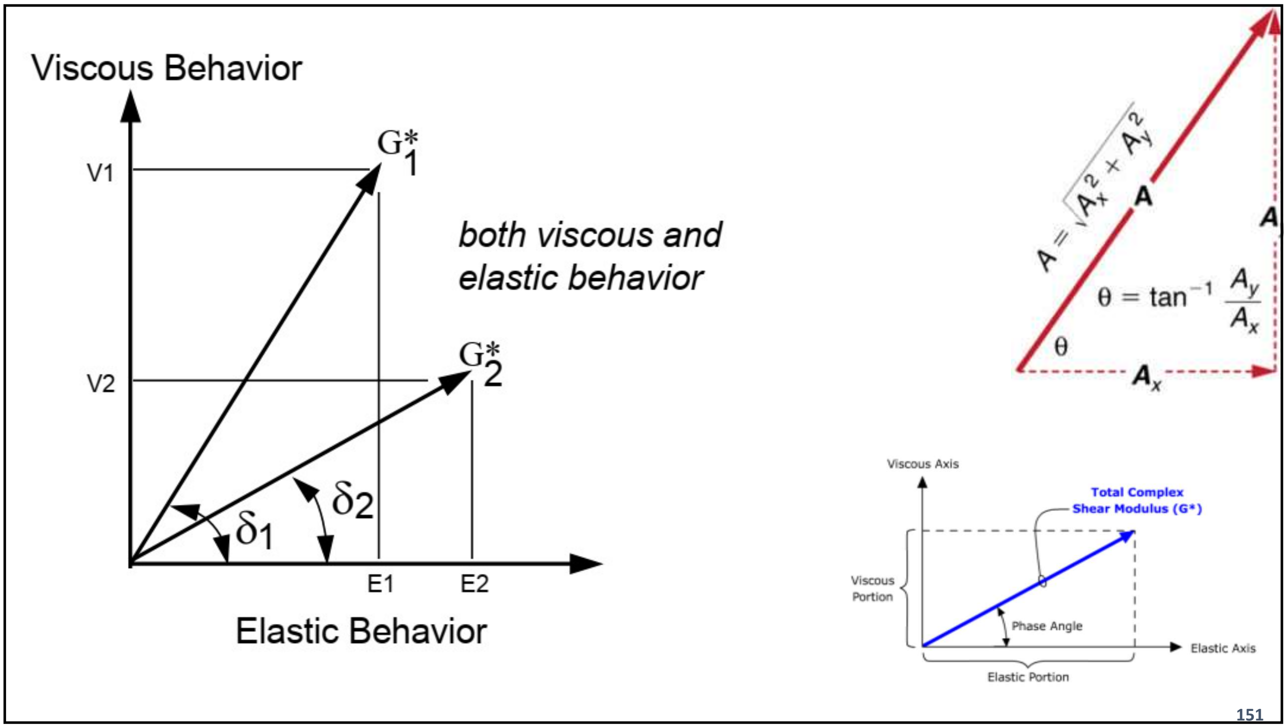
Rheology

Science of deformation & flow of liquids & soft matter

Greater Viscosity ‹‹‹‹‹‹ ›››››› Greater Elasticity

Newtonian	**Non-Newtonian**		**Hookean**
Viscous	**Viscoelastic**		**Elastic**
Liquids	**Liquids**	**Solids**	**Solids**

All E' dissipated **All E' stored**



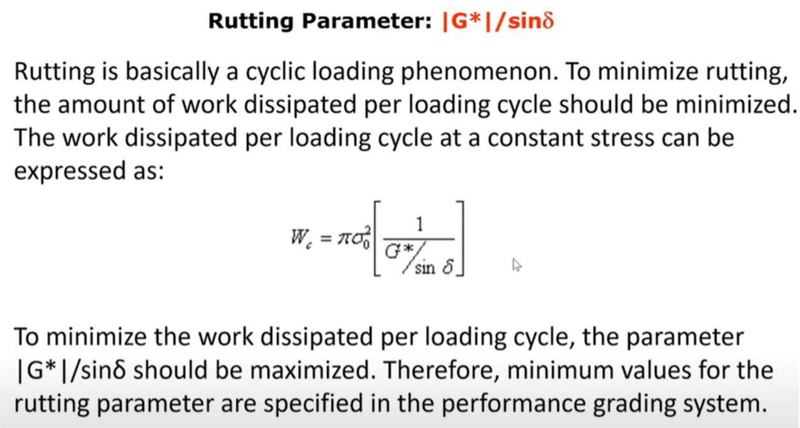
both viscous and elastic behavior

$A = \sqrt{A_x^2 + A_y^2}$

$\theta = \tan^{-1} \frac{A_y}{A_x}$

Dynamic Shear Rheometer (DSR)

AASHTO T 315



Rutting Parameter: |G*|/sinδ

Rutting is basically a cyclic loading phenomenon. To minimize rutting, the amount of work dissipated per loading cycle should be minimized. The work dissipated per loading cycle at a constant stress can be expressed as:

$$W_c = \pi\sigma_0^2\left[\frac{1}{G^*/\sin\delta}\right]$$

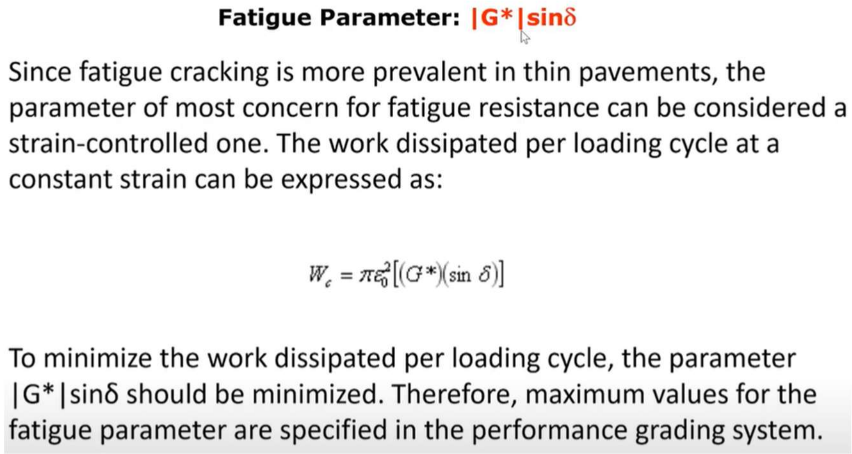
To minimize the work dissipated per loading cycle, the parameter |G*|/sinδ should be maximized. Therefore, minimum values for the rutting parameter are specified in the performance grading system.

Permanent Deformation (Rutting)

- G*/sin δ at test temperature > 1.00 kPa original binder
- G*/sin δ at test temperature > 2.20 kPa RTFOT binder

Dynamic Shear Rheometer (DSR)

AASHTO T 315



Fatigue Parameter: |G*|sinδ

Since fatigue cracking is more prevalent in thin pavements, the parameter of most concern for fatigue resistance can be considered a strain-controlled one. The work dissipated per loading cycle at a constant strain can be expressed as:

$$W_c = \pi\varepsilon_0^2\left[(G^*)(\sin\delta)\right]$$

To minimize the work dissipated per loading cycle, the parameter |G*|sinδ should be minimized. Therefore, maximum values for the fatigue parameter are specified in the performance grading system.

Fatigue Cracking

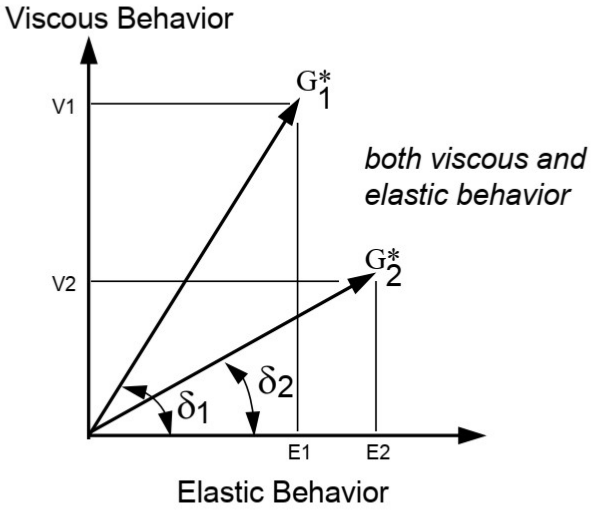
G* (sin δ) at test temperature < 5000 kPa PAV binder

Dynamic Shear Rheometer (DSR)

AASHTO T 315

SuperPave asphalt binder specification

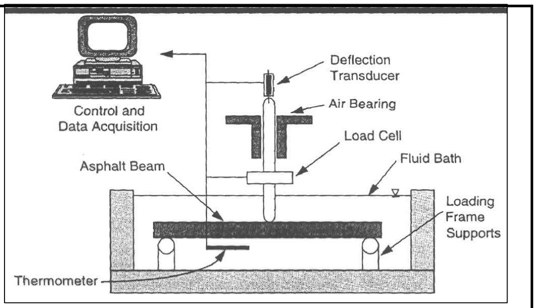
- Permanent Deformation (Rutting)
  - *G*/sin δ at test temperature > 1.00 kPa original binder*
  - *G*/sin δ at test temperature > 2.20 kPa RTFOT binder*
- Fatigue Cracking
  - *G* (sin δ) at test temperature < 5000 kPa PAV binder*

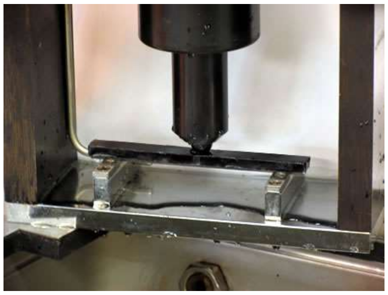


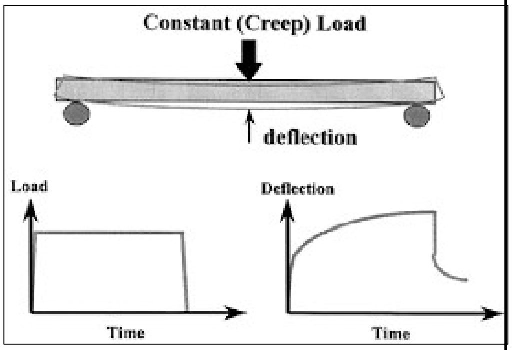
Bending Beam Rheometer (BBR)

AASHTO T 321

- Measures low temperature properties of asphalt that are <u>too stiff</u> to be measured by the DSR
- BBR measures deflection or creep under a constant load and temperature
- BBR (stiffness) used in conjunction with the Direct Tension Test (strength and stretching ability before breaking)







Bending Beam Rheometer (BBR)

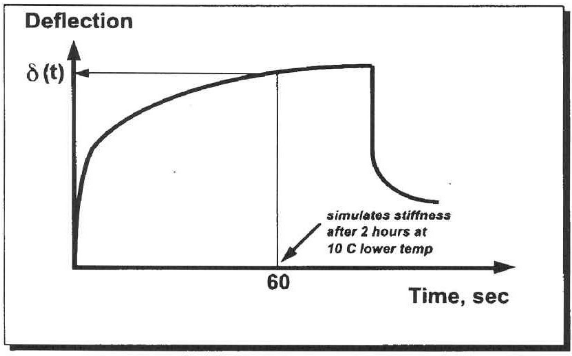
AASHTO T 321

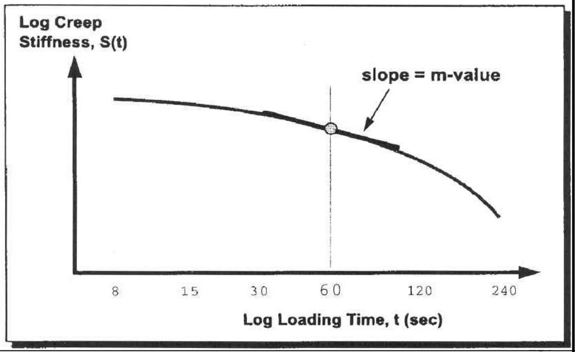
- ☐ Low temperature cracking
  - ➢*Creep Stiffness (S) @ 60s < = 300 Mpa*
  - ➢*S is between 300 to 600 MPa the Direct Tension test may be used in lieu of the creep stiffness requirement*
  - ➢*m-value (m) @ 60s > = .3*

$$S(t) = \frac{PL^3}{4\,bh^3\,\delta(t)}$$

where,

S(t) = creep stiffness (MPa) at time, t,
P = applied constant load, N,
L = distance between beam supports, 102 mm,
b = beam width, 12.5 mm,
h = beam thickness, 6.25 mm, and
δ(t) = deflection (mm) at time, t.





Bending Beam R

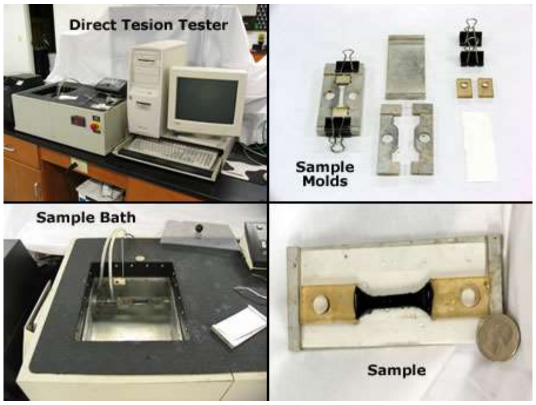
AASHTO T 321

https://www.youtube.com/watch?v=7XIZ4xArIM0

Direct Tension Test

AASHTO T 314

- Strong relationship between stiffness of asphalt binders and the amount of stretching they undergo before breaking
- Ductile Asphalts
  - *Asphalts that undergo considerable stretching before failure*
- Brittle Asphalts
  - *Asphalts those that break without much stretching*
- Typically,
  - *Stiffer asphalts are more brittle*
  - *Softer asphalts more ductile*
- It is important that asphalts be capable of a minimal amount of elongation
- Creep stiffness as measured by the BBR is not adequate enough to completely characterize the capacity of asphalts to stretch before breaking



Direct Tension Test

AASHTO T 314

- Some asphalts exhibit high creep stiffness but can also stretch farther before breaking
  - *therefore, SHRP specifications recognize these stiff but ductile binders*
- These asphalts are allowed to have high creep stiffness (300 to 600 Mpa) if they can also display reasonable ductile behavior at low temperatures
- Specification
  - *if creep stiffness < 300 Mpa the direct tension test is not required*
- PAV asphalt binder
  - *test measures the performance characteristics of binders as if they had been exposed to hot mixing and some in-service aging*

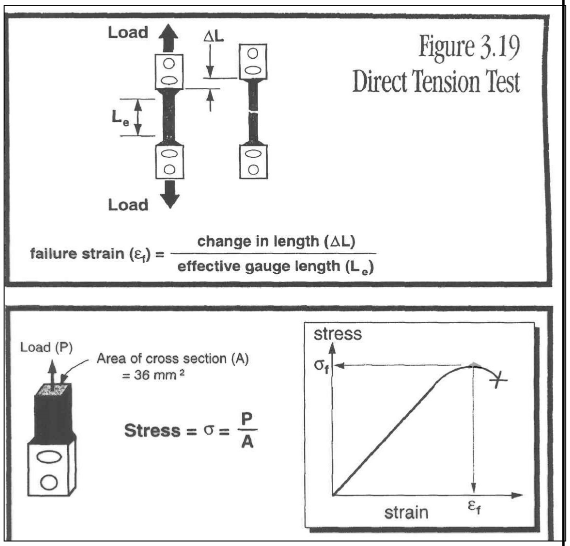


Figure 3.19
Direct Tension Test

Superpave: The Future of Asphalt

Superpave binder property measurements

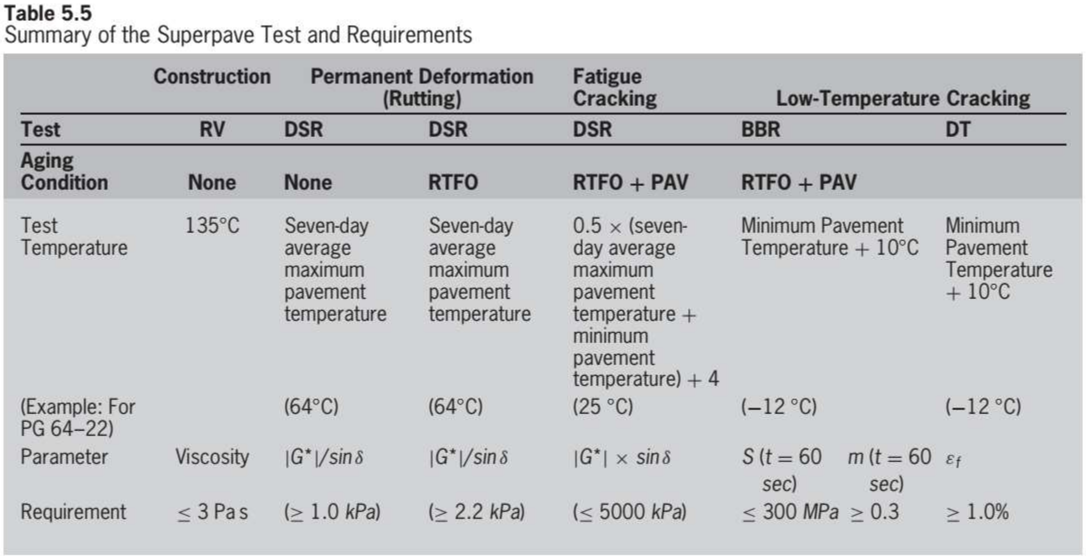
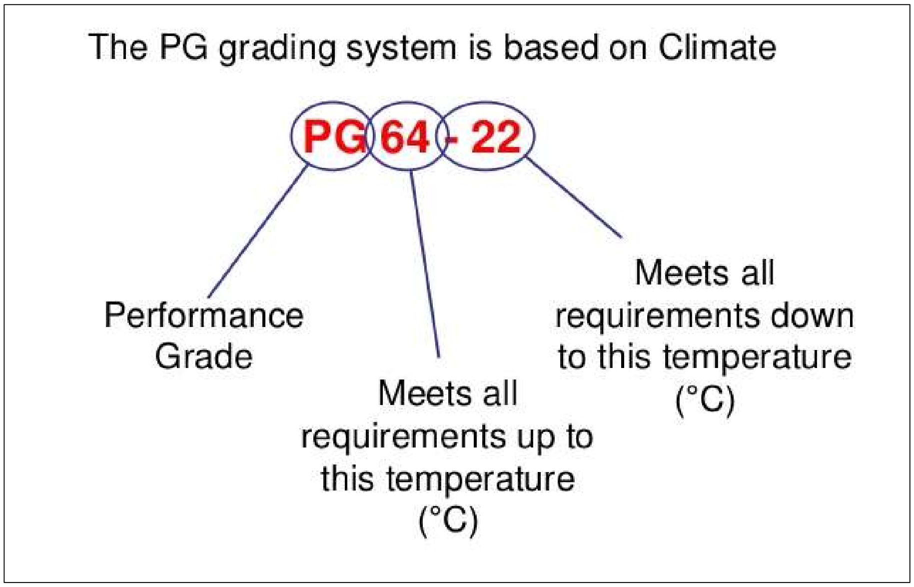


Table 5.5
Summary of the Superpave Test and Requirements

	Construction	Permanent Deformation (Rutting)		Fatigue Cracking	Low-Temperature Cracking		
Test	**RV**	**DSR**	**DSR**	**DSR**	**BBR**		**DT**
Aging Condition	**None**	**None**	**RTFO**	**RTFO + PAV**	**RTFO + PAV**		
Test Temperature	135°C	Seven-day average maximum pavement temperature	Seven-day average maximum pavement temperature	0.5 × (seven-day average maximum pavement temperature + minimum pavement temperature) + 4	Minimum Pavement Temperature + 10°C		Minimum Pavement Temperature + 10°C
(Example: For PG 64–22)		(64°C)	(64°C)	(25 °C)	(−12 °C)		(−12 °C)
Parameter	Viscosity	$\lvert G^*\rvert/\sin\delta$	$\lvert G^*\rvert/\sin\delta$	$\lvert G^*\rvert \times \sin\delta$	S ($t = 60$ sec)	m ($t = 60$ sec)	ε_f
Requirement	≤ 3 Pa s	(≥ 1.0 kPa)	(≥ 2.2 kPa)	(≤ 5000 kPa)	≤ 300 MPa	≥ 0.3	≥ 1.0%

SuperPave Performance Grading

Grading system

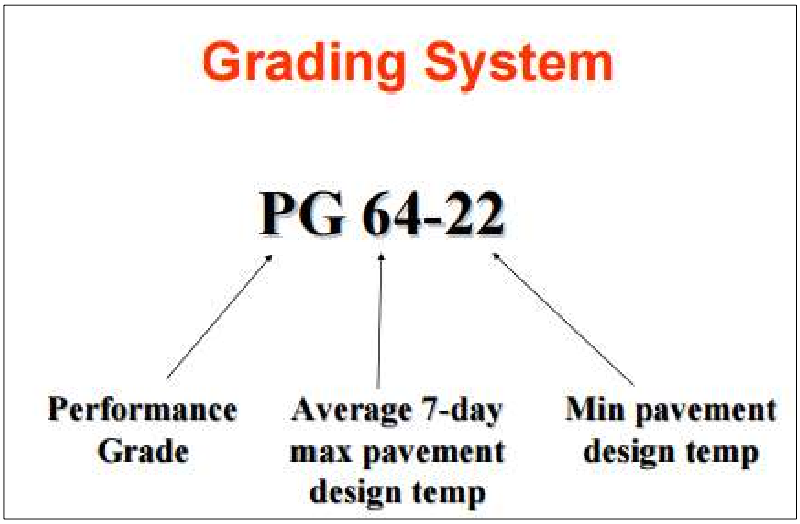


The PG grading system is based on Climate

Image source: https://www.slideshare.net/CaliforniaAsphalt/asphalt-binders-101

SuperPave Performance Grading

Grading system



Grading System

PG 64-22

Performance Grade

Average 7-day max pavement design temp

Min pavement design temp

Image source: http://rahabitumen.com/performance-grade-pg-bitumen/

SuperPave Performance Grading

Grading system

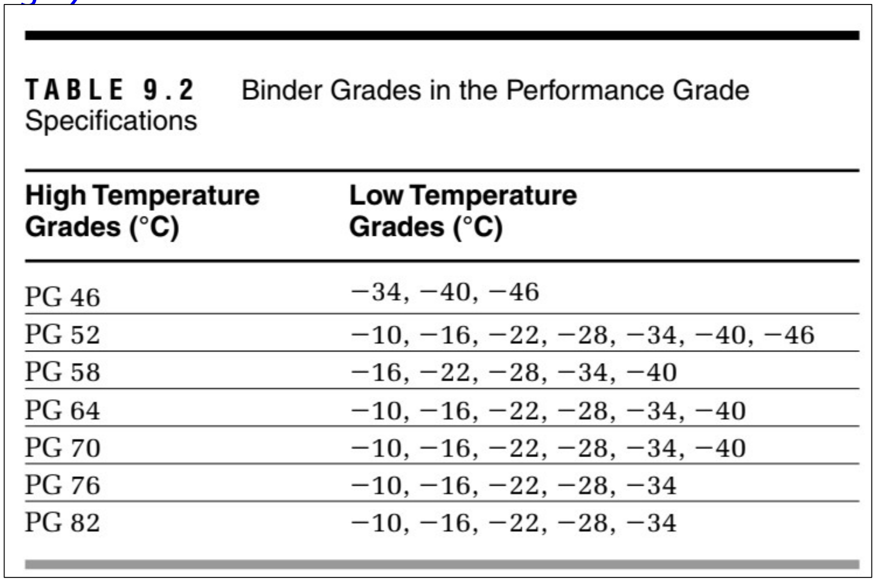
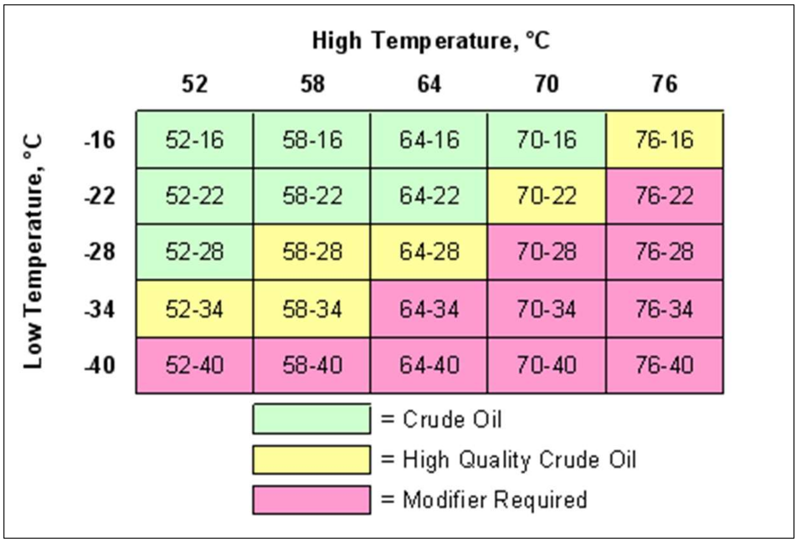


TABLE 9.2 Binder Grades in the Performance Grade Specifications

High Temperature Grades (°C)	Low Temperature Grades (°C)
PG 46	−34, −40, −46
PG 52	−10, −16, −22, −28, −34, −40, −46
PG 58	−16, −22, −28, −34, −40
PG 64	−10, −16, −22, −28, −34, −40
PG 70	−10, −16, −22, −28, −34, −40
PG 76	−10, −16, −22, −28, −34
PG 82	−10, −16, −22, −28, −34

SuperPave Performance Grading

Grading system



Low Temperature, °C	High Temperature, °C				
	52	58	64	70	76
-16	🟩 52-16	🟩 58-16	🟩 64-16	🟩 70-16	🟨 76-16
-22	🟩 52-22	🟩 58-22	🟩 64-22	🟨 70-22	🟥 76-22
-28	🟩 52-28	🟨 58-28	🟨 64-28	🟥 70-28	🟥 76-28
-34	🟨 52-34	🟨 58-34	🟥 64-34	🟥 70-34	🟥 76-34
-40	🟥 52-40	🟥 58-40	🟥 64-40	🟥 70-40	🟥 76-40

🟩 = Crude Oil
🟨 = High Quality Crude Oil
🟥 = Modifier Required

Pavement Materials & Design

Asphalt Materials

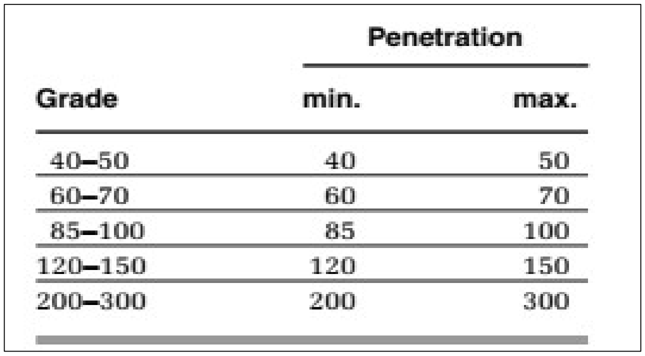
1.20_ SuperPave Grading procedures

Dr. Hamza Alkuime

Penetration Grading system

ASTM D946

- ❑ Binder are classified based on penetration test results
- ❑ Five penetration grades are specified

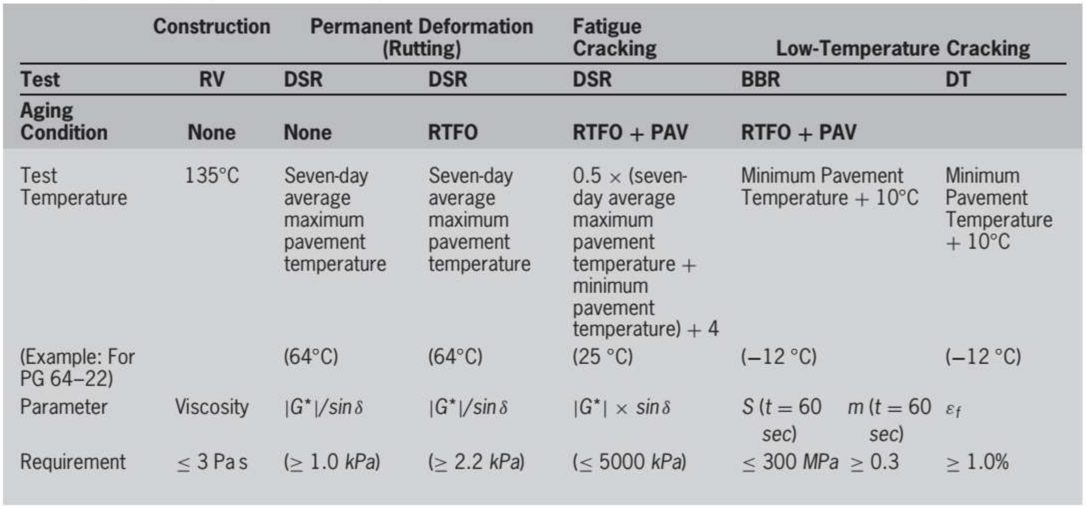


Grade	Penetration min.	Penetration max.
40–50	40	50
60–70	60	70
85–100	85	100
120–150	120	150
200–300	200	300

Superpave: The Future of Asphalt

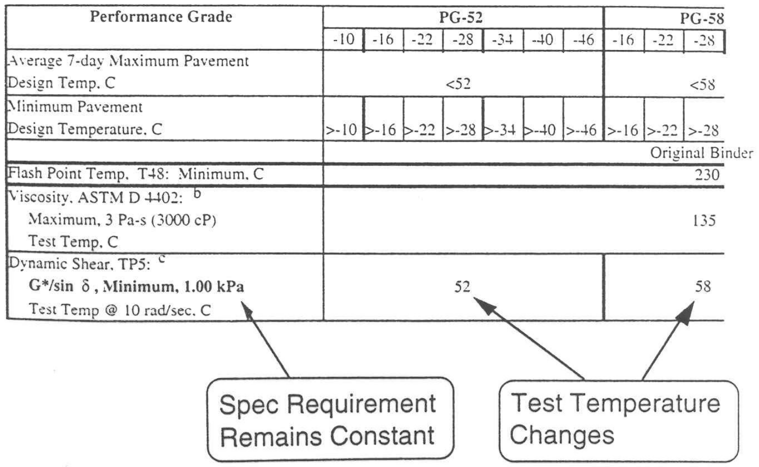
Superpave binder property measurements

Table 5.5
Summary of the Superpave Test and Requirements



	Construction	Permanent Deformation (Rutting)		Fatigue Cracking	Low-Temperature Cracking	
Test	**RV**	**DSR**	**DSR**	**DSR**	**BBR**	**DT**
Aging Condition	**None**	**None**	**RTFO**	**RTFO + PAV**	**RTFO + PAV**	
Test Temperature	135°C	Seven-day average maximum pavement temperature	Seven-day average maximum pavement temperature	0.5 × (seven-day average maximum pavement temperature + minimum pavement temperature) + 4	Minimum Pavement Temperature + 10°C	Minimum Pavement Temperature + 10°C
(Example: For PG 64–22)		(64°C)	(64°C)	(25 °C)	(–12 °C)	(–12 °C)
Parameter	Viscosity	$\|G^*\|/\sin\delta$	$\|G^*\|/\sin\delta$	$\|G^*\| \times \sin\delta$	S ($t = 60$ sec) m ($t = 60$ sec)	ε_f
Requirement	≤ 3 Pa s	(≥ 1.0 *kPa*)	(≥ 2.2 *kPa*)	(≤ 5000 *kPa*)	≤ 300 *MPa* ≥ 0.3	≥ 1.0%

SuperPave Performance Grading



Performance Grade	PG-52							PG-58		
	-10	-16	-22	-28	-34	-40	-46	-16	-22	-28
Average 7-day Maximum Pavement Design Temp, C	<52							<58		
Minimum Pavement Design Temperature, C	>-10	>-16	>-22	>-28	>-34	>-40	>-46	>-16	>-22	>-28
	Original Binder									
Flash Point Temp, T48: Minimum, C	230									
Viscosity, ASTM D 4402: b Maximum, 3 Pa-s (3000 cP) Test Temp, C	135									
Dynamic Shear, TP5: c **G*/sin δ, Minimum, 1.00 kPa** Test Temp @ 10 rad/sec, C	52							58		

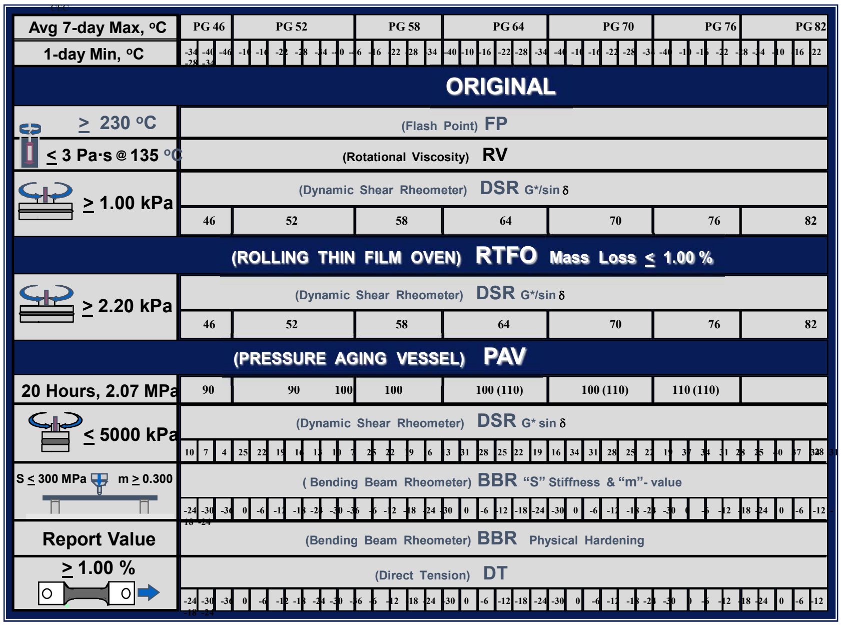
Spec Requirement Remains Constant

Test Temperature Changes

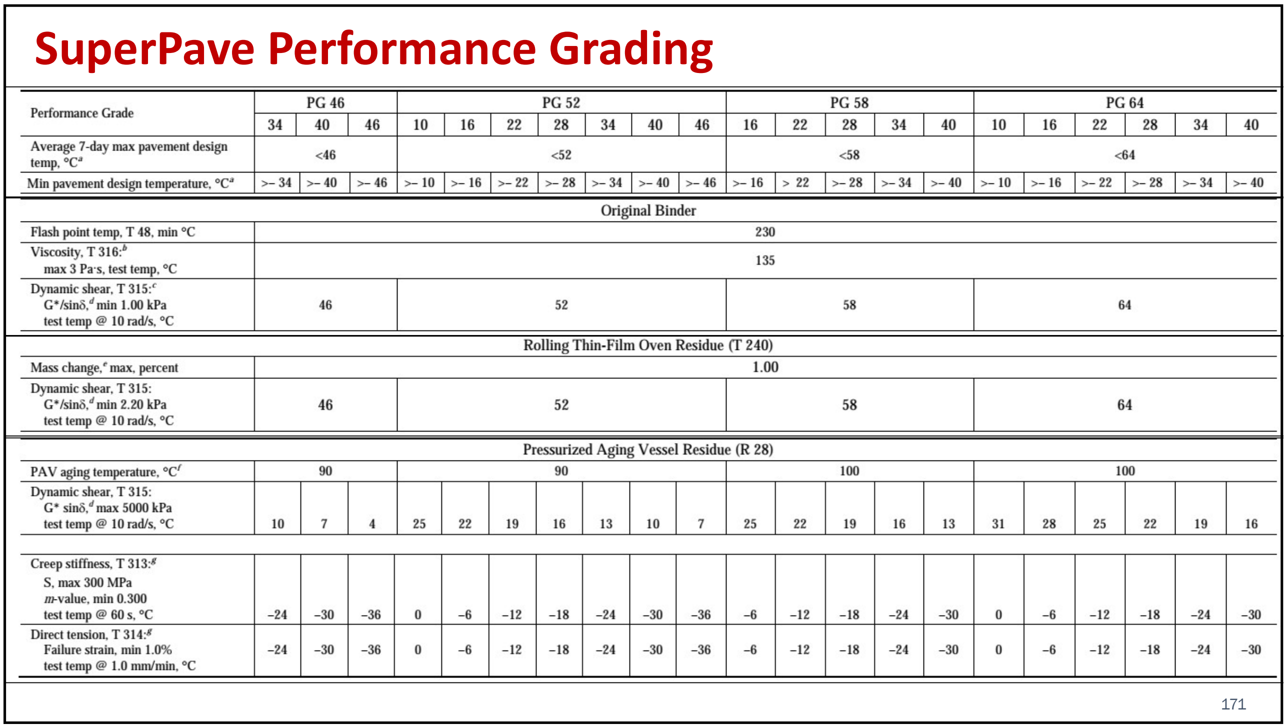
Figure 4.1

Superpave Binder Specification Format

SuperPave Performance Grading

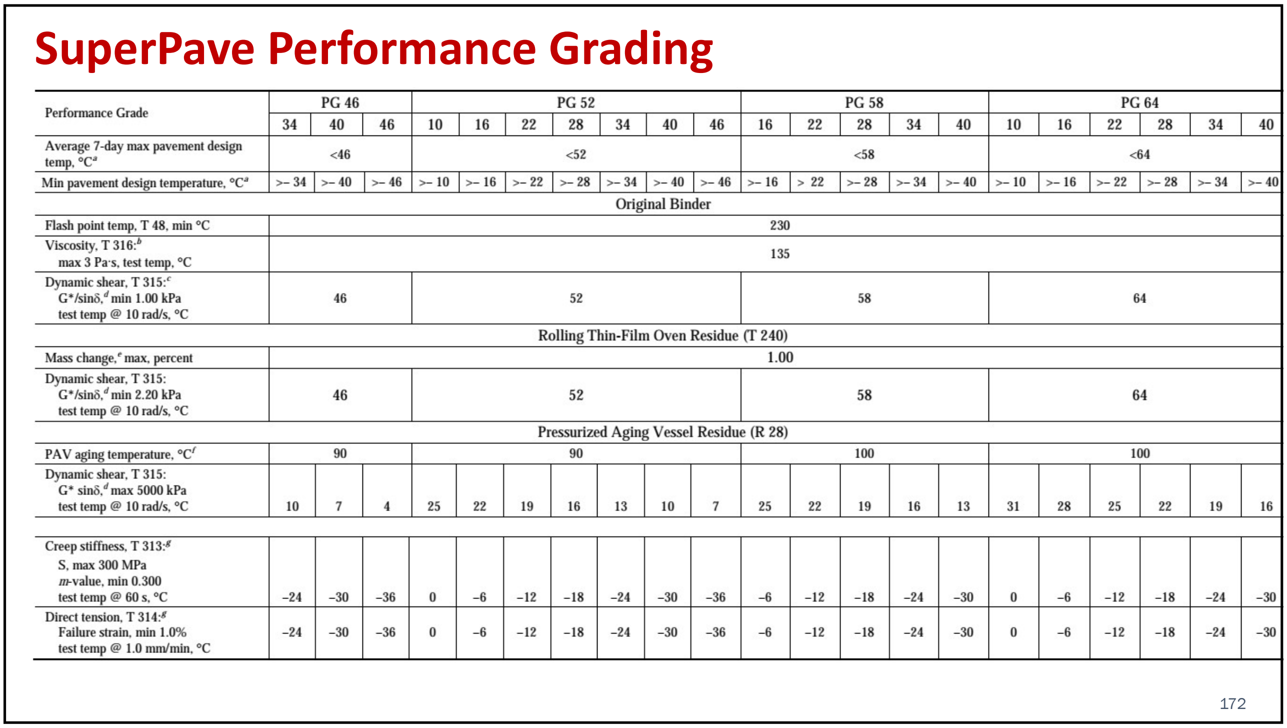


Avg 7-day Max, °C	PG 46	PG 52	PG 58	PG 64	PG 70	PG 76	PG 82
1-day Min, °C	-34 -40 -46	-10 -16 -22 -28 -34 -40 -46	-16 -22 -28 -34	-40 -10 -16 -22 -28 -34	-40 -10 -16 -22 -28 -34	-40 -10 -16 -22 -28 -34	-10 -16 -22
ORIGINAL							
≥ 230 °C	(Flash Point) FP						
≤ 3 Pa·s @ 135 °C	(Rotational Viscosity) 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 -36	-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 -36	-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



SuperPave Performance Grading

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



SuperPave Performance Grading

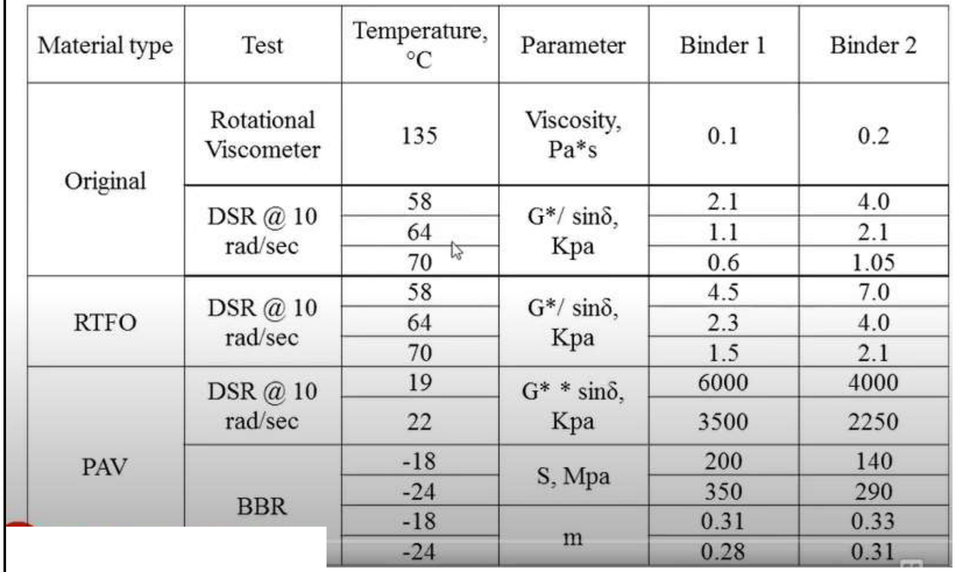
Performance Grade	PG 46			PG 52							PG 58					PG 64					
	34	40	46	10	16	22	28	34	40	46	16	22	28	34	40	10	16	22	28	34	40
Average 7-day max pavement design temp, °C[a]	<46			<52							<58					<64					
Min pavement design temperature, °C[a]	>– 34	>– 40	>– 46	>– 10	>– 16	>– 22	>– 28	>– 34	>– 40	>– 46	>– 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

SuperPave Performance Grading

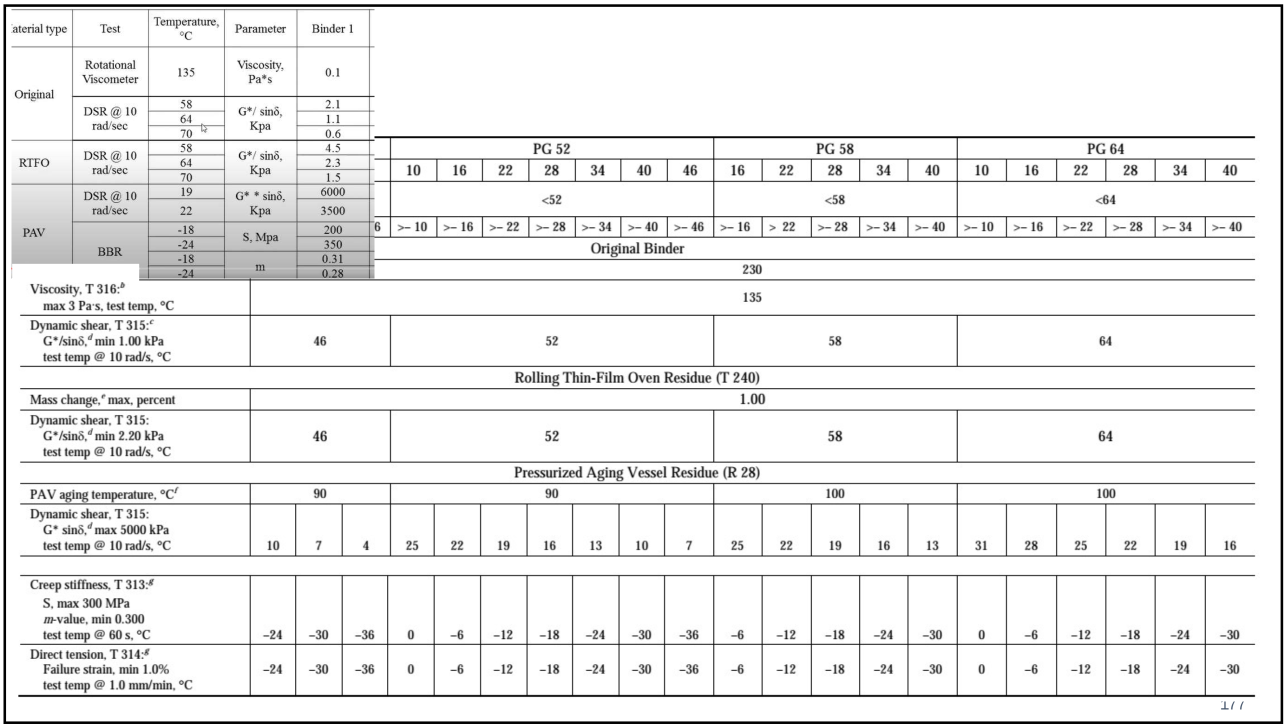
Performance Grade	PG 70						PG 76					PG 82				
	10	16	22	28	34	40	10	16	22	28	34	10	16	22	28	34
Average 7-day max pavement design temperature, °C[a]	<70						<76					<82				
Min pavement design temperature, °C[a]	>−10	>−16	>−22	>−28	>−34	>−40	>−10	>−16	>−22	>−28	>−34	>−10	>−16	>−22	>−28	>−34
Original 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	70						76					82				
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	70						76					82				
Pressurized Aging Vessel Residue (R 28)																
PAV aging temperature, °C[f]	100 (110)						100 (110)					100 (110)				
Dynamic shear, T 315: G* sinδ[d], max 5000 kPa test temp @ 10 rad/s, °C	34	31	28	25	22	19	37	34	31	28	25	40	37	34	31	28
Critical low cracking temp, R 49:[g] Critical cracking temp determined by R 49, test temp, °C	0	−6	−12	−18	−24	−30	0	−6	−12	−18	−24	0	−6	−12	−18	−24

Example

Superpave testing results for 2 binders are shown in the table below, Give the PG grade for both binders



Material type	Test	Temperature, °C	Parameter	Binder 1	Binder 2
Original	Rotational Viscometer	135	Viscosity, Pa*s	0.1	0.2
	DSR @ 10 rad/sec	58	G*/ sinδ, Kpa	2.1	4.0
		64		1.1	2.1
		70		0.6	1.05
RTFO	DSR @ 10 rad/sec	58	G*/ sinδ, Kpa	4.5	7.0
		64		2.3	4.0
		70		1.5	2.1
PAV	DSR @ 10 rad/sec	19	G* * sinδ, Kpa	6000	4000
		22		3500	2250
	BBR	-18	S, Mpa	200	140
		-24		350	290
		-18	m	0.31	0.33
		-24		0.28	0.31



aterial type	Test	Temperature, °C	Parameter	Binder 1
Original	Rotational Viscometer	135	Viscosity, Pa*s	0.1
	DSR @ 10 rad/sec	58	G*/ sinδ, Kpa	2.1
		64		1.1
		70		0.6
RTFO	DSR @ 10 rad/sec	58	G*/ sinδ, Kpa	4.5
		64		2.3
		70		1.5
PAV	DSR @ 10 rad/sec	19	G* * sinδ, Kpa	6000
		22		3500
	BBR	-18	S, Mpa	200
		-24		350
		-18	m	0.31
		-24		0.28

				PG 52							PG 58					PG 64					
				10	16	22	28	34	40	46	16	22	28	34	40	10	16	22	28	34	40
				<52							<58					<64					
			6	>– 10	>– 16	>– 22	>– 28	>– 34	>– 40	>– 46	>– 16	> 22	>– 28	>– 34	>– 40	>– 10	>– 16	>– 22	>– 28	>– 34	>– 40
Original Binder																					
	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

Pavement Materials & Design

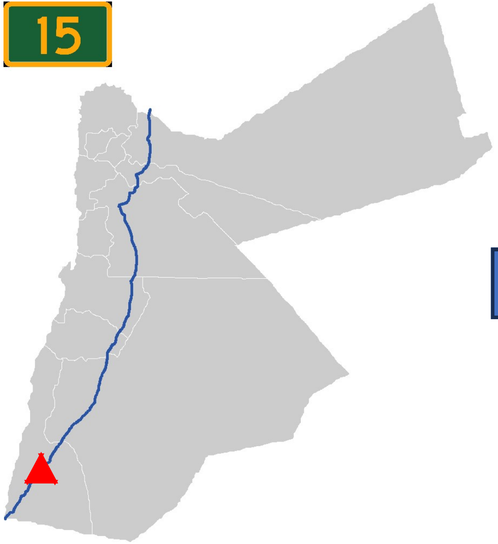
Asphalt Materials

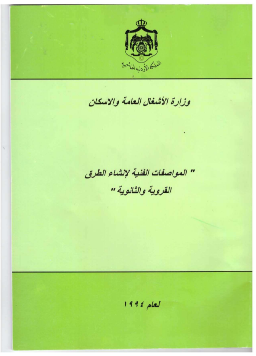
Binder Selection process

Dr. Hamza Alkuime

Binder Selection

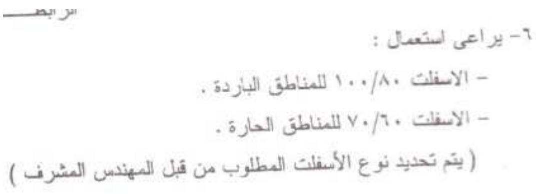
Penetration grade system




وزارة الأشغال العامة والاسكان

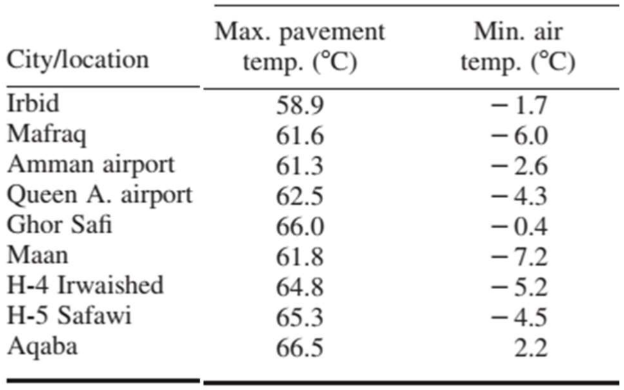
" المواصفات الفنية لإنشاء الطرق
القروية والثانوية "

لعام ١٩٩٤

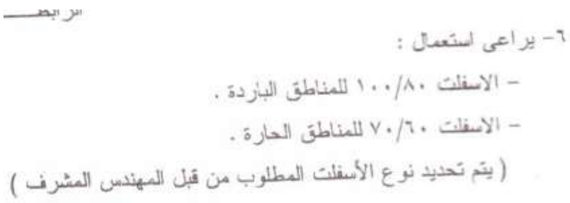

٦- يراعى استعمال :
- الاسفلت ٨٠/١٠٠ للمناطق الباردة .
- الاسفلت ٦٠/٧٠ للمناطق الحارة .
(يتم تحديد نوع الأسفلت المطلوب من قبل المهندس المشرف)

Which binder should be selected for this project ?

Pavement temperature contour Maps



City/location	Max. pavement temp. (°C)	Min. air temp. (°C)
Irbid	58.9	−1.7
Mafraq	61.6	−6.0
Amman airport	61.3	−2.6
Queen A. airport	62.5	−4.3
Ghor Safi	66.0	−0.4
Maan	61.8	−7.2
H-4 Irwaished	64.8	−5.2
H-5 Safawi	65.3	−4.5
Aqaba	66.5	2.2


٦- يراعى استعمال :
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- الاسفلت ٦٠/٧٠ للمناطق الحارة .
(يتم تحديد نوع الأسفلت المطلوب من قبل المهندس المشرف)

Source: Khalid A. Ghuzlan & Ghazi G. Al-Khateeb (2013) Selection and verification of performance grading for asphalt binders produced in Jordan, International Journal of Pavement Engineering, 14:2, 116-124, DOI: 10.1080/10298436.2011.650697

Binder Selection

SuperPave binder selection process

Steps

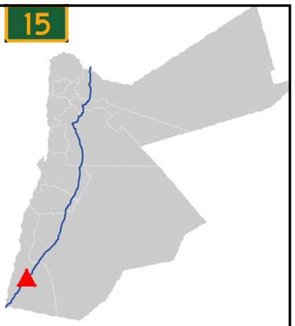
1. Climate analysis
2. Reliability analysis
3. Select the suitable **Base PG grade**

❑ PG grade bumping (Fine-tuning)

SuperPave binder selection process

1. Climate analysis

SuperPave binder selection process

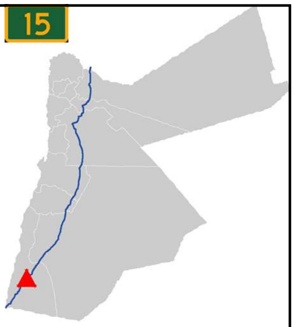


1. Climate analysis :

- Determine the following temperatures
  - *7-day maximum annual pavement temperature*
  - *1-day minimum annual pavement temperature*
- Methods
  1. *By Pavement Temperature*
  2. *By Air Temperature*
  3. *By Geographic Area*

---

1. Climate analysis :

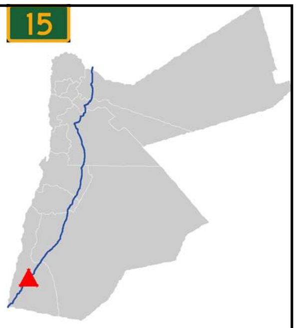


By Pavement Temperature:

- The designer would need to know design pavement temperature.

Unit of Time	Max. Pavement Temp. at 20mm	Min. Pavement Temp.
Daily (Five Years)	52.2	-6

1. Climate analysis :



By Air Temperature:

- ☐ The designer determines design air temperatures,
  - *which are converted to design pavement temperatures*
- ☐ The low pavement design temperature at the pavement surface
  - *is defined as the lowest air temperature*
- ☐ Highest pavement design temperature is determined using the following model

$$T_{20mm} = (T_{air} - 0.00618\, Lat^2 + 0.2289\, Lat + 42.2) (0.9545) - 17.78$$

where T_{20mm} = high pavement design temperature at a depth of 20 mm
T_{air} = seven-day average high air temperature
Lat = the geographical latitude of the project in degrees.

Air temperature data

Table 3. Maximum and minimum air temperatures for different weather stations in Jordan.

			Max. air temp.			Min. air temp.		
City/location	Latitude (°)	Longitude (°)	Mean	SD	Max. 7-day air temp.	Mean	SD	Min. temp.
Irbid	32.54	35.85	39.5	1.5	37.0	− 1.1	1.2	− 4.0
Mafraq	32.36	36.25	40.1	1.7	39.9	− 4.2	2.4	− 9.0
Amman airport	31.98	35.98	39.7	1.7	39.4	− 1.6	1.5	− 5.0
Queen A. airport	31.71	35.96	40.7	1.7	40.7	− 3.7	1.7	− 7.0
Ghor Safi	31.03	35.46	45.4	1.7	44.2	2.0	2.4	− 2.4
Maan	30.16	35.78	40.0	1.5	39.8	− 4.6	2.1	− 10.4
H-4 Irwaished	32.5	38.2	42.4	1.7	43.3	− 4.4	1.9	− 8.0
H-5 Safawi	32.2	37.13	42.4	1.3	43.8	− 3.3	1.8	− 7.2
Aqaba	29.55	35.01	44.7	1.5	44.6	1.9	1.6	0.6

Source: Khalid A. Ghuzlan & Ghazi G. Al-Khateeb (2013) Selection and verification of performance grading for asphalt binders produced in Jordan, International Journal of Pavement Engineering, 14:2, 116-124, DOI: 10.1080/10298436.2011.650697

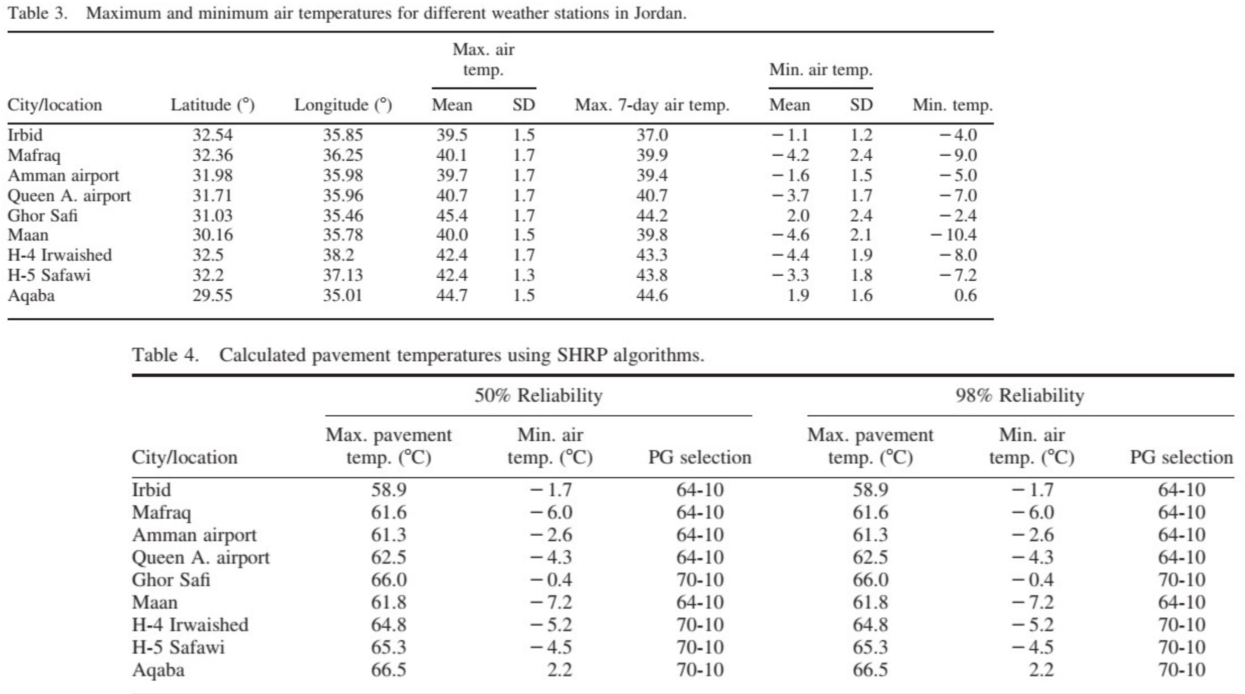


Table 3. Maximum and minimum air temperatures for different weather stations in Jordan.

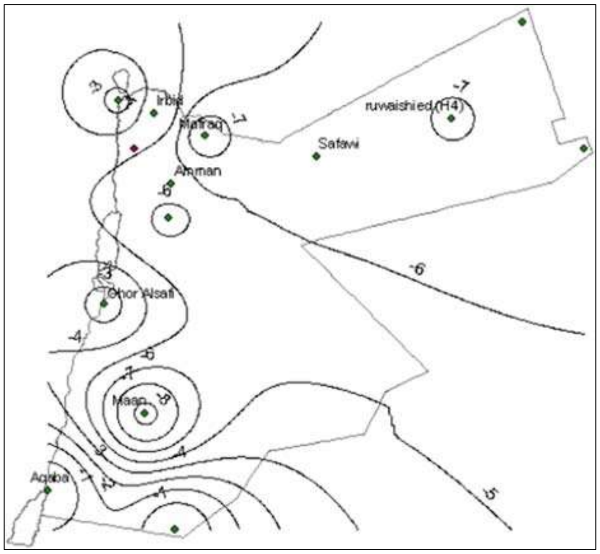
City/location	Latitude (°)	Longitude (°)	Max. air temp. Mean	Max. air temp. SD	Max. 7-day air temp.	Min. air temp. Mean	Min. air temp. SD	Min. temp.
Irbid	32.54	35.85	39.5	1.5	37.0	− 1.1	1.2	− 4.0
Mafraq	32.36	36.25	40.1	1.7	39.9	− 4.2	2.4	− 9.0
Amman airport	31.98	35.98	39.7	1.7	39.4	− 1.6	1.5	− 5.0
Queen A. airport	31.71	35.96	40.7	1.7	40.7	− 3.7	1.7	− 7.0
Ghor Safi	31.03	35.46	45.4	1.7	44.2	2.0	2.4	− 2.4
Maan	30.16	35.78	40.0	1.5	39.8	− 4.6	2.1	− 10.4
H-4 Irwaished	32.5	38.2	42.4	1.7	43.3	− 4.4	1.9	− 8.0
H-5 Safawi	32.2	37.13	42.4	1.3	43.8	− 3.3	1.8	− 7.2
Aqaba	29.55	35.01	44.7	1.5	44.6	1.9	1.6	0.6

Table 4. Calculated pavement temperatures using SHRP algorithms.

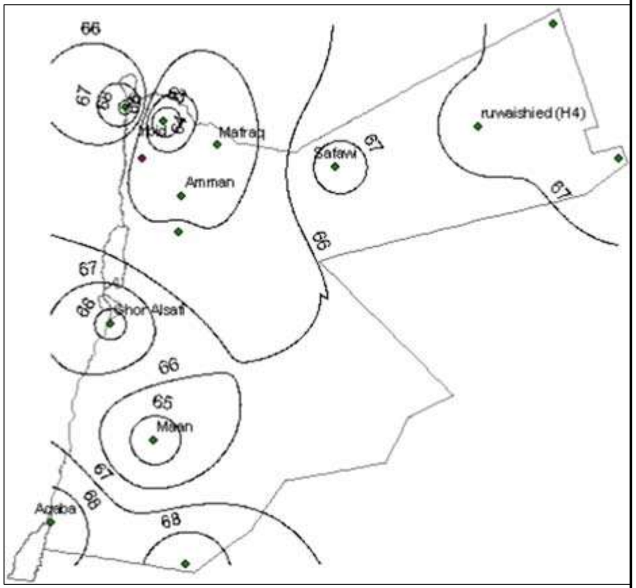
City/location	50% Reliability: Max. pavement temp. (°C)	50% Reliability: Min. air temp. (°C)	50% Reliability: PG selection	98% Reliability: Max. pavement temp. (°C)	98% Reliability: Min. air temp. (°C)	98% Reliability: PG selection
Irbid	58.9	− 1.7	64-10	58.9	− 1.7	64-10
Mafraq	61.6	− 6.0	64-10	61.6	− 6.0	64-10
Amman airport	61.3	− 2.6	64-10	61.3	− 2.6	64-10
Queen A. airport	62.5	− 4.3	64-10	62.5	− 4.3	64-10
Ghor Safi	66.0	− 0.4	70-10	66.0	− 0.4	70-10
Maan	61.8	− 7.2	64-10	61.8	− 7.2	64-10
H-4 Irwaished	64.8	− 5.2	70-10	64.8	− 5.2	70-10
H-5 Safawi	65.3	− 4.5	70-10	65.3	− 4.5	70-10
Aqaba	66.5	2.2	70-10	66.5	2.2	70-10

Source: Khalid A. Ghuzlan &

Pavement temperature contour Maps



Minimum pavement temperature



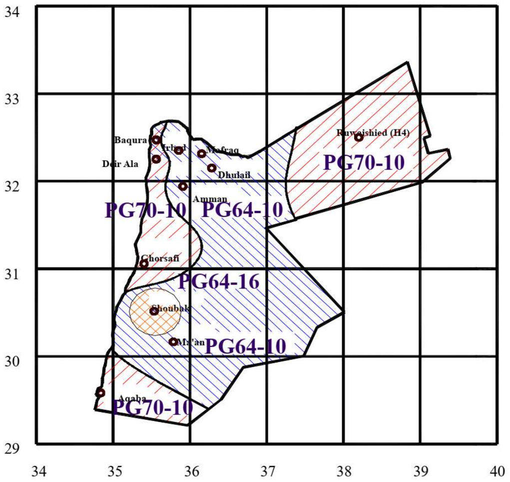
Maximum pavement temperature

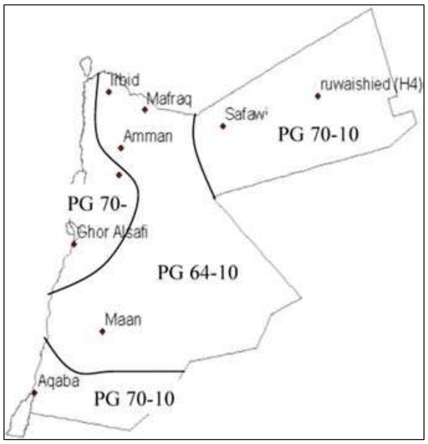
Source: Khalid A. Ghuzlan & Ghazi G. Al-Khateeb (2013) Selection and verification of performance grading for asphalt binders produced in Jordan, International Journal of Pavement Engineering, 14:2, 116-124, DOI: 10.1080/10298436.2011.650697

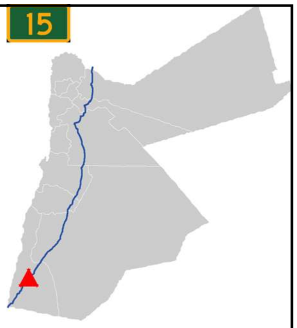
1. Climate analysis :

By Geographic Area

- ❑ An Agency would develop a map showing binder grade to be used by the designer based on weather and/or policy decisions

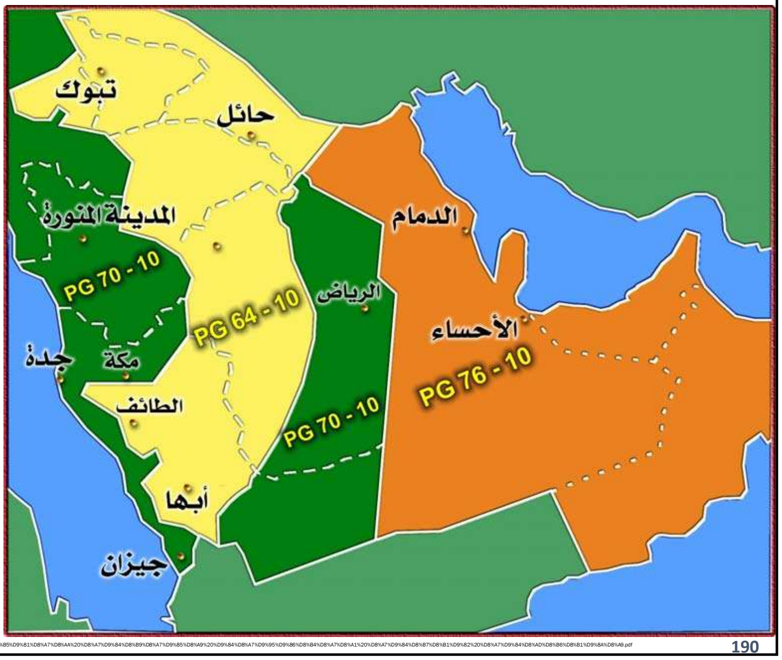






Base Binder selection

Application in Saudi Arabia



https://www.momra.gov.sa/sites/default/files/2020-03/%D8%A7%D9%84%D8%AC%D8%B2%D8%A1%20%D8%A7%D9%84%D8%A7%D9%94%D9%88%D9%84%20%D8%A7%D9%84%D9%85%D9%88%D8%A7%D8%B5%D9%81%D8%A7%D8%AA%20%D8%A7%D9%84%D8%B9%D8%A7%D9%85%D8%A9%20%D9%84%D8%A7%D9%95%D9%86%D8%B4%D8%A7%D8%A1%20%D8%A7%D9%84%D8%B7%D8%B1%D9%82%20%D8%A7%D9%84%D8%AD%D8%B6%D8%B1%D9%8A%D8%A9.pdf

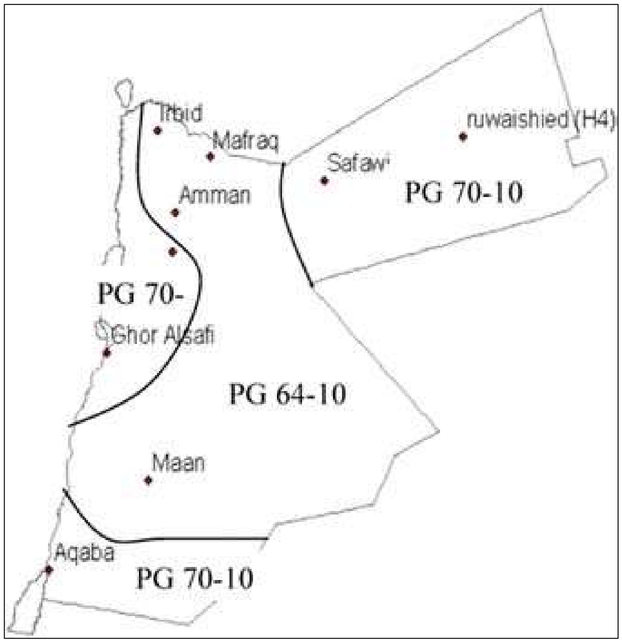
Asphalt Binder Selection in Jordan

٦- يراعى استعمال :

- الاسفلت ٨٠/١٠٠ للمناطق الباردة .

- الاسفلت ٦٠/٧٠ للمناطق الحارة .

(يتم تحديد نوع الأسفلت المطلوب من قبل المهندس المشرف)



- ❑ The two main types of original asphalt binders produced by the JPR are classified as
  - ➢ *PG 64-16 for the 60/70 penetration grade asphalt*
  - ➢ *PG 58-16 for the 85/100 penetration grade asphalt binder*

Source: Khalid A. Ghuzlan & Ghazi G. Al-Khateeb (2013) Selection and verification of performance grading for asphalt binders produced in Jordan, International Journal of Pavement Engineering, 14:2, 116-124, DOI: 10.1080/10298436.2011.650697

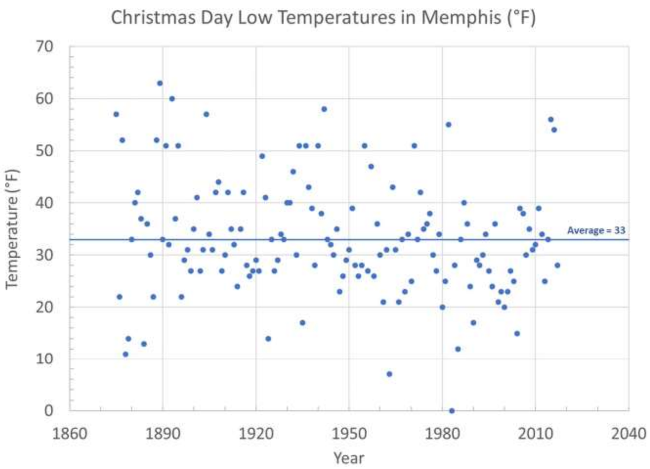
SuperPave binder selection process

2. Reliability analysis

SuperPave binder selection process

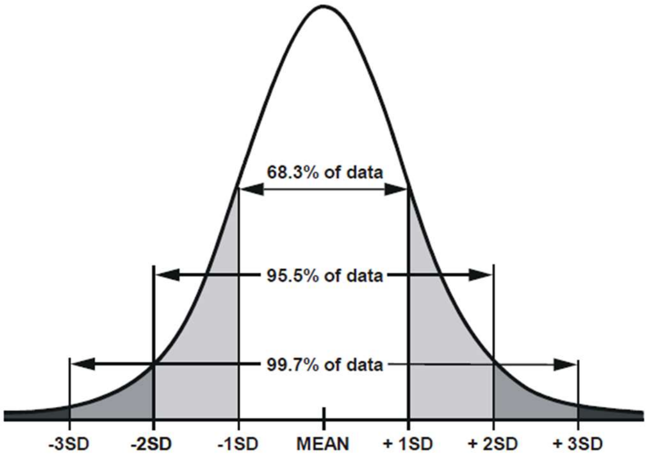
Reliability analysis

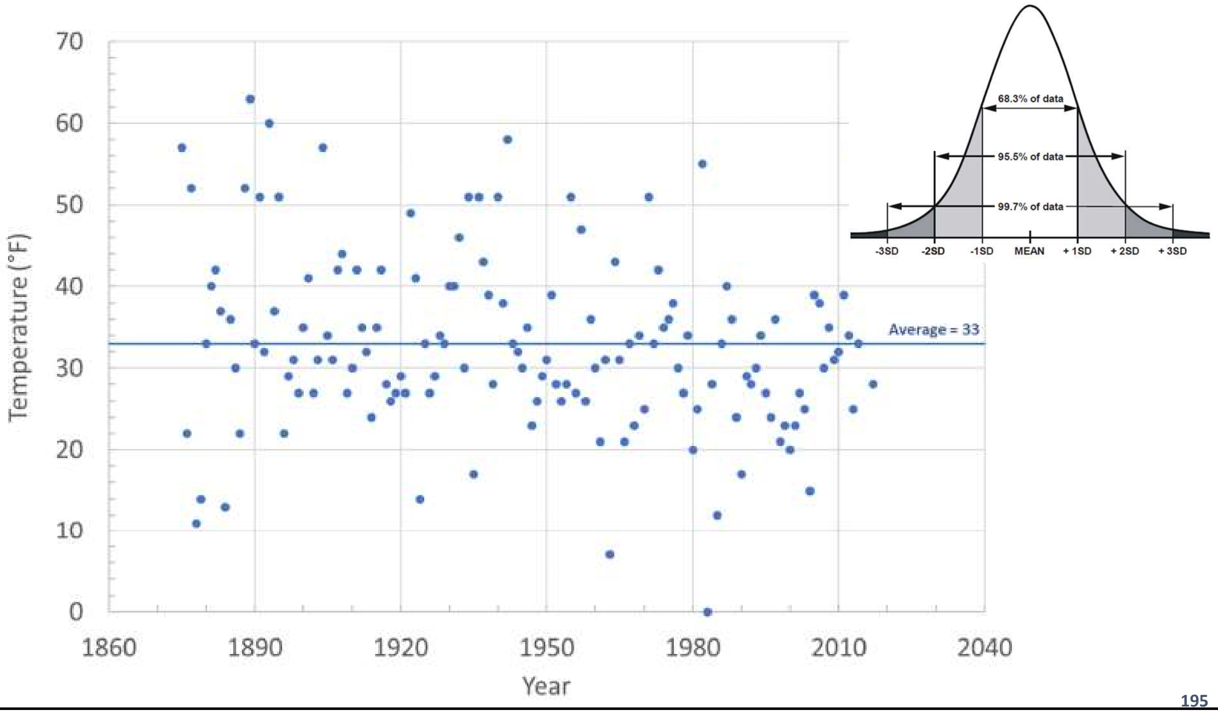
- The SuperPave system allows the designers to use reliability measurements to assign a degree of design risk to the high and low pavement temperatures used in selecting the binder grade.
- Reliability is defined as
  - *The percent probability in a single year that the actual temperature (one-day low or seven-day average high)* ***will not*** *exceed the design temperatures.*
- SuperPave binder selection is very flexible in that a different level of reliability can be assigned to high and low temperature grades.



Reliability analysis

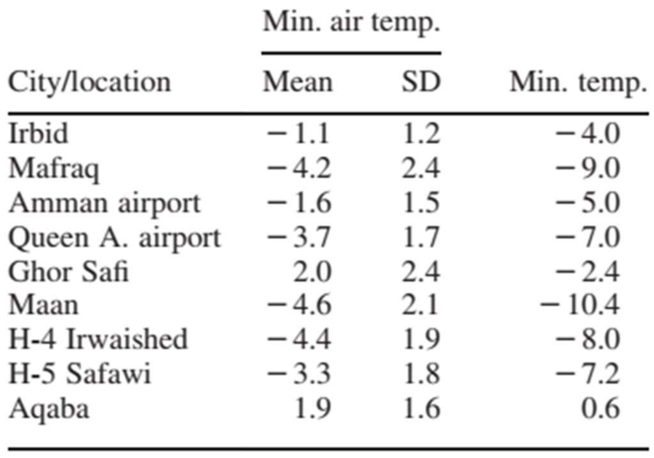
- The assumption we can make about the data that follows a normal curve is
  - *that the area under the curve is relative to how many standard deviations () we are away from the mean.*
- The area between plus and minus
  - *Average contains 50% of the data*
  - *Average ± 1 standard deviation from the mean contains 68% of the data.*
  - *Average ± 2 standard deviations contains 95.5% of the data*
  - *Average ± 3 standard deviations contains 99.7% of data.*





2. Reliability analysis

Importance



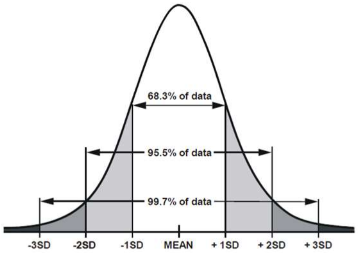
	Min. air temp.		
City/location	Mean	SD	Min. temp.
Irbid	−1.1	1.2	−4.0
Mafraq	−4.2	2.4	−9.0
Amman airport	−1.6	1.5	−5.0
Queen A. airport	−3.7	1.7	−7.0
Ghor Safi	2.0	2.4	−2.4
Maan	−4.6	2.1	−10.4
H-4 Irwaished	−4.4	1.9	−8.0
H-5 Safawi	−3.3	1.8	−7.2
Aqaba	1.9	1.6	0.6

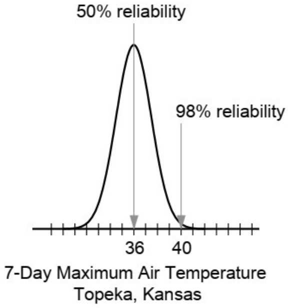
Source: Khalid A. Ghuzlan & Ghazi G. Al-Khateeb (2013) Selection and verification of performance grading for asphalt binders produced in Jordan, International Journal of Pavement Engineering, 14:2, 116-124, DOI: 10.1080/10298436.2011.650697

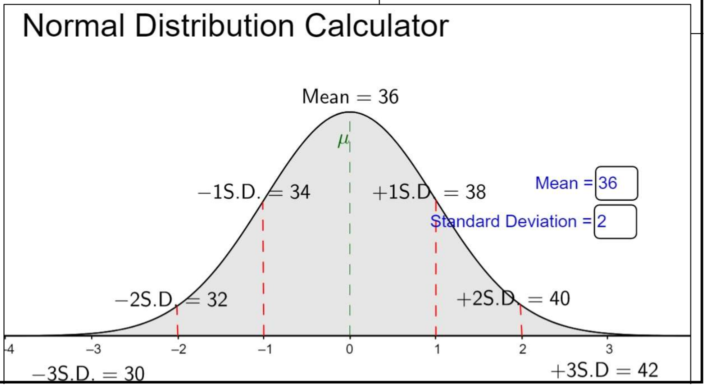
SuperPave binder selection process

Reliability analysis

- ❑ Example
  - ➢ *Consider summer air temperatures in Topeka, Kansas, which has a mean seven-day maximum of 36 °C and a standard deviation of 2°C.*
    - ❖ In an average year there is a 50 percent chance the seven day maximum air temperature will exceed 36°C.
    - ❖ However, only a two percent chance exists that the temperature will exceed 40°C; hence, a design air temperature of 40 °C will provide 99.7 percent reliability







SuperPave binder selection process

Example

- ❑ What base PG asphalt binder grade should be selected under the following conditions:
  - ➢ *The seven-day maximum pavement temperature has a*
    - ❖ Mean of 57 °C
    - ❖ Standard deviation of 2 °C.
  - ➢ *The minimum pavement temperature has a*
    - ❖ mean of - 6°C
    - ❖ Standard deviation of 3°C.
  - ➢ *Reliability is 99.7%*

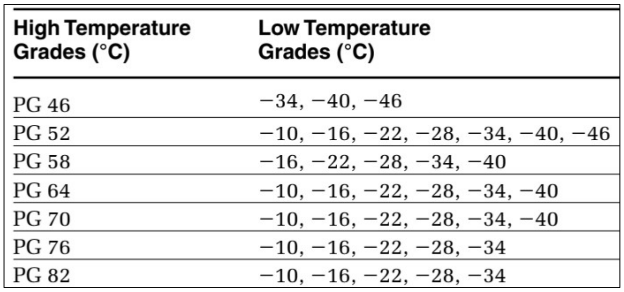
High Temperature Grades (°C)	Low Temperature Grades (°C)
PG 46	−34, −40, −46
PG 52	−10, −16, −22, −28, −34, −40, −46
PG 58	−16, −22, −28, −34, −40
PG 64	−10, −16, −22, −28, −34, −40
PG 70	−10, −16, −22, −28, −34, −40
PG 76	−10, −16, −22, −28, −34
PG 82	−10, −16, −22, −28, −34

SuperPave binder selection process

Solution

- ❑ High-temperature grade >= 57 + (2 X 2)…. >= 61 °C
- ❑ Low-temperature grade =< -6 - (2 X 3)…. =< -12 °C

The closest standard PG asphalt binder grade that satisfies the two temperature grades is PG 64–16



High Temperature Grades (°C)	Low Temperature Grades (°C)
PG 46	−34, −40, −46
PG 52	−10, −16, −22, −28, −34, −40, −46
PG 58	−16, −22, −28, −34, −40
PG 64	−10, −16, −22, −28, −34, −40
PG 70	−10, −16, −22, −28, −34, −40
PG 76	−10, −16, −22, −28, −34
PG 82	−10, −16, −22, −28, −34

SuperPave binder selection process

3. Base PG grade selection

SuperPave binder selection process

3. Base PG grade selection

☐ Select the suitable Base PG grade based on the determined

1. *Determine the 7-day maximum pavement temperature*
2. *1-day minimum pavement temperature*
3. *Desired level of reliability (50% vs 98%)*

Example : Select the base grade

Given the following information select a base PG grade

In a normal summer,

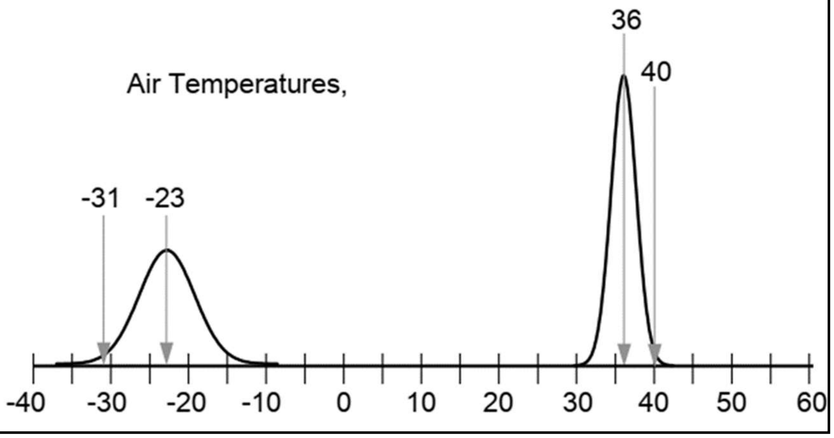
- *the average seven-day maximum **air** temperature is 36°C with*
- *a standard deviation of 2°C.*

☐ In a normal winter,

- *the average coldest **air** temperature is -23°C.*
- *standard deviation of 4°C*
- *very cold winter the temperature -31°C*

☐ Desired level of reliability

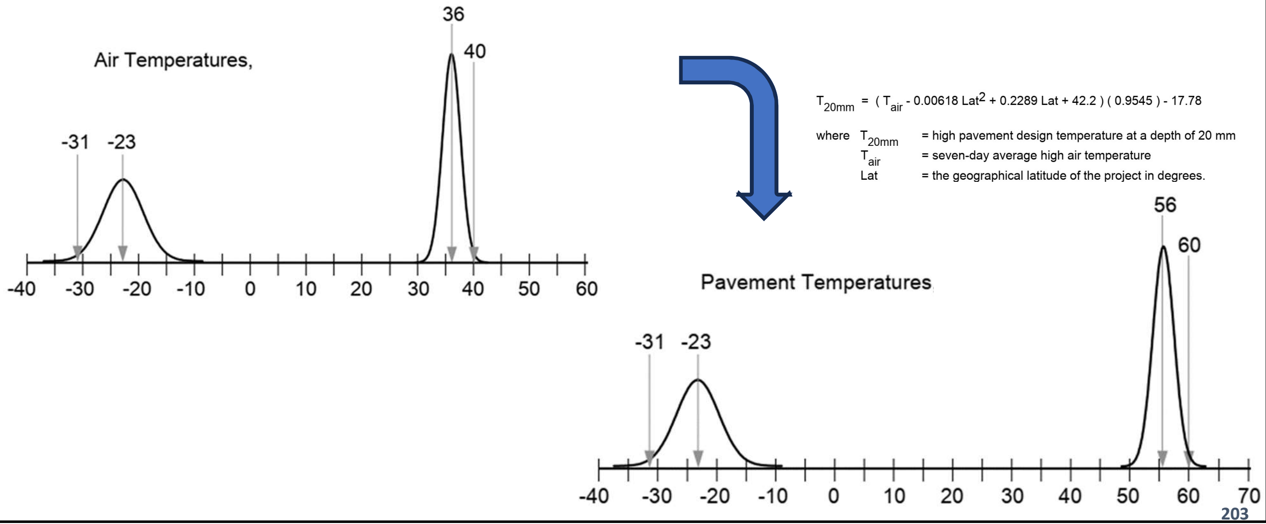
- *50% vs 98%*



Example : Select the base grade

Solution

- ☐ Convert Air to Pavement Temperature



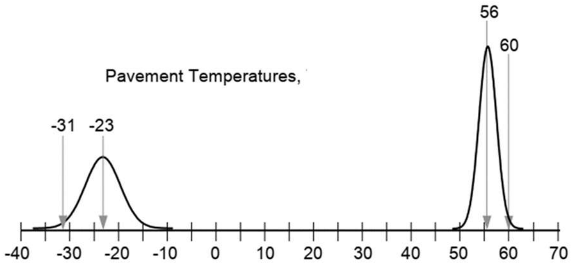
$T_{20mm} = (T_{air} - 0.00618\,Lat^2 + 0.2289\,Lat + 42.2) (0.9545) - 17.78$

where T_{20mm} = high pavement design temperature at a depth of 20 mm
T_{air} = seven-day average high air temperature
Lat = the geographical latitude of the project in degrees.

Example : Select the base grade

Reliability analysis for 50 % reliability

- ☐ High-PG >= 56…. >= 56 °C
- ☐ Low-PG =< -23 …. =< - 23°C



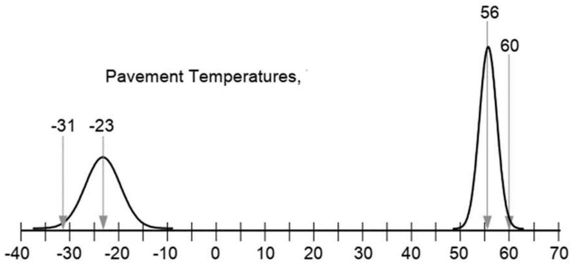
High Temperature Grades (°C)	Low Temperature Grades (°C)
PG 46	−34, −40, −46
PG 52	−10, −16, −22, −28, −34, −40, −46
PG 58	−16, −22, −28, −34, −40
PG 64	−10, −16, −22, −28, −34, −40
PG 70	−10, −16, −22, −28, −34, −40
PG 76	−10, −16, −22, −28, −34
PG 82	−10, −16, −22, −28, −34

The closest standard PG asphalt binder grade that satisfies the two temperature grades is PG 58–28

Example : Select the base grade

Reliability analysis for 98 % reliability

- ☐ High-PG >= 56 + (2 X 2)…. >= 61 °C
- ☐ Low-PG =< -23 - (2 X 4)…. =< - 31°C

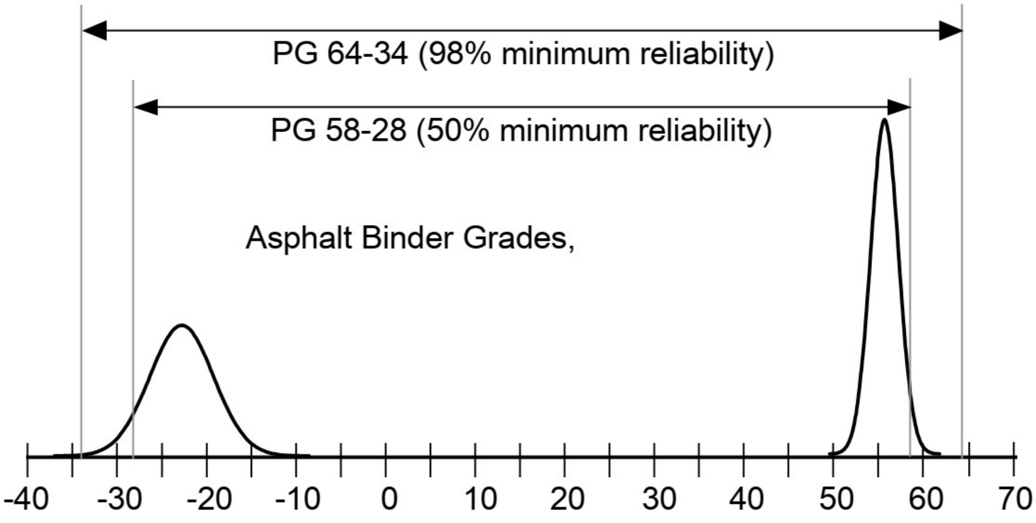


High Temperature Grades (°C)	Low Temperature Grades (°C)
PG 46	−34, −40, −46
PG 52	−10, −16, −22, −28, −34, −40, −46
PG 58	−16, −22, −28, −34, −40
PG 64	−10, −16, −22, −28, −34, −40
PG 70	−10, −16, −22, −28, −34, −40
PG 76	−10, −16, −22, −28, −34
PG 82	−10, −16, −22, −28, −34

The closest standard PG asphalt binder grade that satisfies the two temperature grades is PG 64–34

Example : Select the base grade

Reliability analysis for 98 % reliability



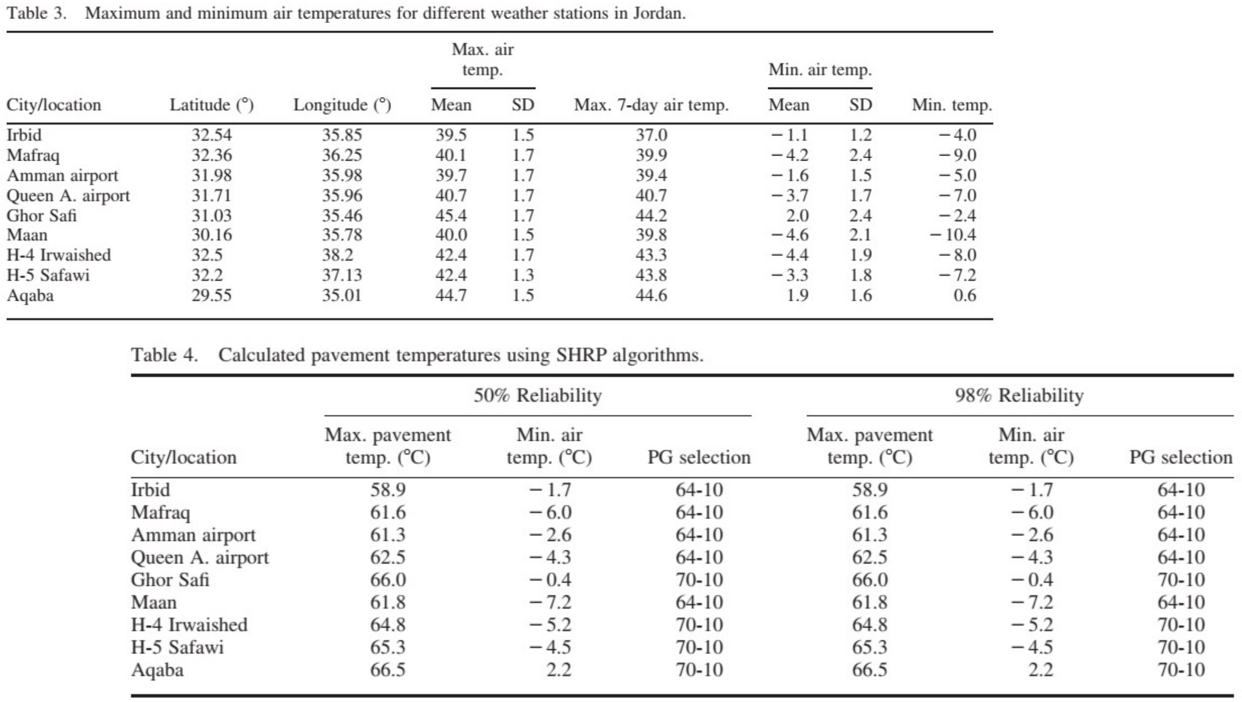


Table 3. Maximum and minimum air temperatures for different weather stations in Jordan.

City/location	Latitude (°)	Longitude (°)	Max. air temp. Mean	Max. air temp. SD	Max. 7-day air temp.	Min. air temp. Mean	Min. air temp. SD	Min. temp.
Irbid	32.54	35.85	39.5	1.5	37.0	− 1.1	1.2	− 4.0
Mafraq	32.36	36.25	40.1	1.7	39.9	− 4.2	2.4	− 9.0
Amman airport	31.98	35.98	39.7	1.7	39.4	− 1.6	1.5	− 5.0
Queen A. airport	31.71	35.96	40.7	1.7	40.7	− 3.7	1.7	− 7.0
Ghor Safi	31.03	35.46	45.4	1.7	44.2	2.0	2.4	− 2.4
Maan	30.16	35.78	40.0	1.5	39.8	− 4.6	2.1	− 10.4
H-4 Irwaished	32.5	38.2	42.4	1.7	43.3	− 4.4	1.9	− 8.0
H-5 Safawi	32.2	37.13	42.4	1.3	43.8	− 3.3	1.8	− 7.2
Aqaba	29.55	35.01	44.7	1.5	44.6	1.9	1.6	0.6

Table 4. Calculated pavement temperatures using SHRP algorithms.

	50% Reliability			98% Reliability		
City/location	Max. pavement temp. (°C)	Min. air temp. (°C)	PG selection	Max. pavement temp. (°C)	Min. air temp. (°C)	PG selection
Irbid	58.9	− 1.7	64-10	58.9	− 1.7	64-10
Mafraq	61.6	− 6.0	64-10	61.6	− 6.0	64-10
Amman airport	61.3	− 2.6	64-10	61.3	− 2.6	64-10
Queen A. airport	62.5	− 4.3	64-10	62.5	− 4.3	64-10
Ghor Safi	66.0	− 0.4	70-10	66.0	− 0.4	70-10
Maan	61.8	− 7.2	64-10	61.8	− 7.2	64-10
H-4 Irwaished	64.8	− 5.2	70-10	64.8	− 5.2	70-10
H-5 Safawi	65.3	− 4.5	70-10	65.3	− 4.5	70-10
Aqaba	66.5	2.2	70-10	66.5	2.2	70-10

Source: Khalid A. Ghuzlan &

SuperPave binder selection process

4. PG grade bumping

Texas Department of Transportation®

Superpave Binder Materials Selection Procedures

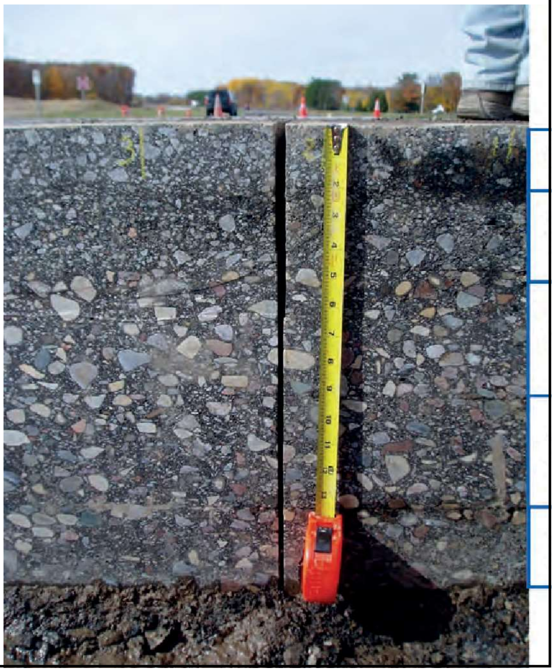
April 2023

Asphalt Binder Branch, Materials and Tests Division

SuperPave binder selection process

PG grade bumping

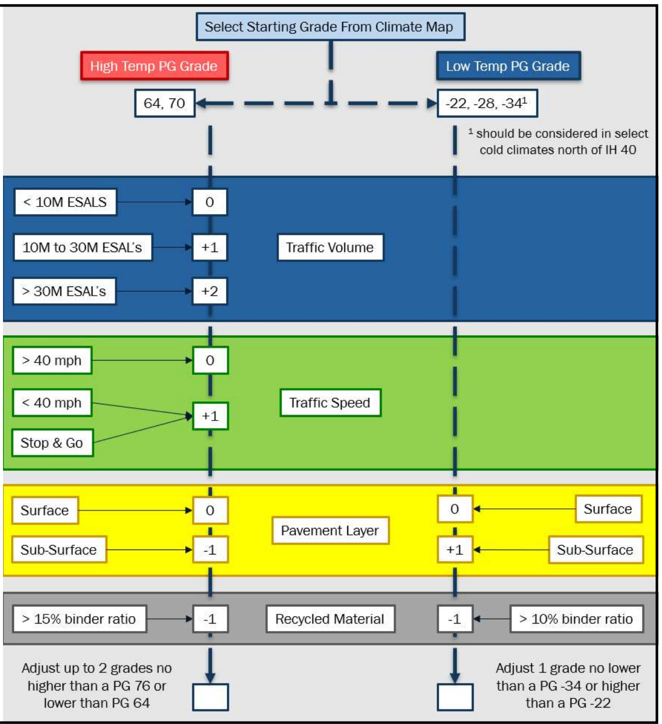
- ☐ The Superpave BASE PG binder is selected assuming the following conditions are met :
  - ➢ *Fast-loading rate, or fast-moving traffic*
  - ➢ *The binder for a surface layer (i.e., 20 mm below the surface)*
- ☐ PG grade bumping : Adjust the binder grade to consider the effect of
  1. *Traffic speed*
  2. *Traffic volume*
  3. *Layer location*
  4. *Using Recycled materials*



PG grade bumping

Traffic Volume

- ☐ Low-PG
  - ➢ *In theory, traffic volume has no affect on low temperature binder performance*
- ☐ High-PG
  - ➢ *If the design life of the pavement will see between 10 million and 30 million ESALs,*
    - ❖ consider increasing the high temperature designation by one grade,
  - ➢ *If the design life of the pavement will see more than 30 million ESALs,*
    - ❖ increase the high temperature designation by minimum one grade.
    - ❖ However, you may consider a two-grade increase in such cases.



Select Starting Grade From Climate Map

High Temp PG Grade

Low Temp PG Grade

64, 70

-22, -28, -34[1]

[1] should be considered in select cold climates north of IH 40

Traffic Volume

< 10M ESALS → 0

10M to 30M ESAL's → +1

> 30M ESAL's → +2

Traffic Speed

> 40 mph → 0

< 40 mph → +1

Stop & Go → +1

Pavement Layer

Surface → 0

Sub-Surface → -1

Surface → 0

Sub-Surface → +1

Recycled Material

> 15% binder ratio → -1

> 10% binder ratio → -1

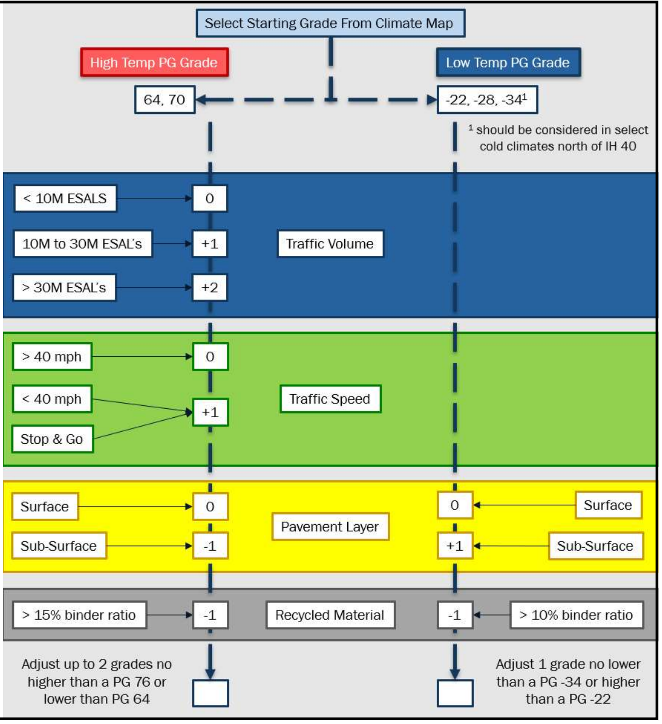
Adjust up to 2 grades no higher than a PG 76 or lower than PG 64

Adjust 1 grade no lower than a PG -34 or higher than a PG -22

PG grade bumping

Traffic speed factor

- ☐ Low-PG
  - *In theory, slow traffic has no affect on low temperature binder performance (resistance to thermal cracking)*
- ☐ High-PG
  - *Slow moving traffic (longer loading times)*
    - may warrant an increase of one temperature grade on the high side.
  - *Standing traffic (higher loading times)*
    - may warrant increasing the high temperature grade by two increments over the base climate grade



Select Starting Grade From Climate Map

High Temp PG Grade

Low Temp PG Grade

64, 70

-22, -28, -34^1

^{1} should be considered in select cold climates north of IH 40

< 10M ESALS → 0

10M to 30M ESAL's → +1

> 30M ESAL's → +2

Traffic Volume

> 40 mph → 0

< 40 mph → +1

Stop & Go → +1

Traffic Speed

Surface → 0

Sub-Surface → -1

Pavement Layer

Surface → 0

Sub-Surface → +1

> 15% binder ratio → -1

Recycled Material

> 10% binder ratio → -1

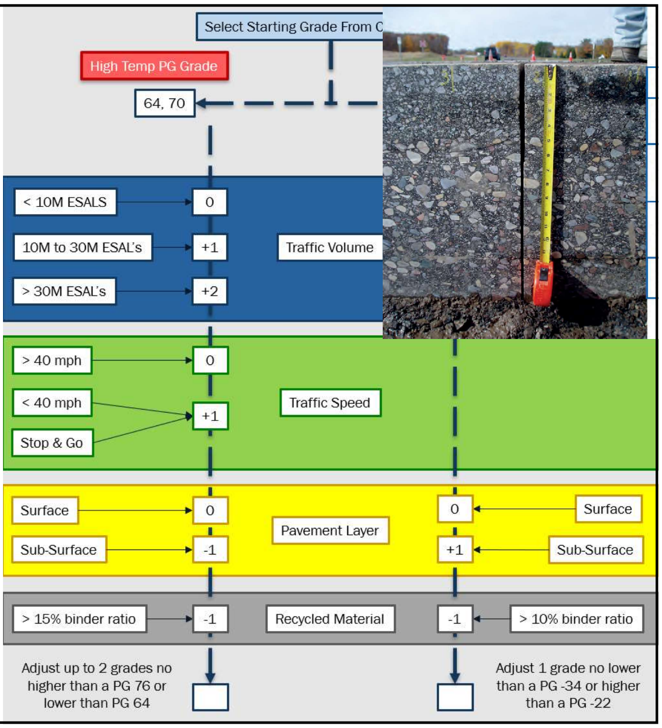
Adjust up to 2 grades no higher than a PG 76 or lower than PG 64

Adjust 1 grade no lower than a PG -34 or higher than a PG -22

PG grade bumping

Layer location

- ☐ The base PG selection process, assumes you are selecting the binder for a surface layer
- ☐ Deeper in the pavement structure the binder is not exposed to the same temperature extremes as the surface
  - *therefore, multi-layer paving projects can use less demanding binder grades in lower layers*



Select Starting Grade From C

High Temp PG Grade

64, 70

< 10M ESALS → 0

10M to 30M ESAL's → +1

> 30M ESAL's → +2

Traffic Volume

> 40 mph → 0

< 40 mph → +1

Stop & Go → +1

Traffic Speed

Surface → 0

Sub-Surface → -1

Pavement Layer

Surface → 0

Sub-Surface → +1

> 15% binder ratio → -1

Recycled Material

> 10% binder ratio → -1

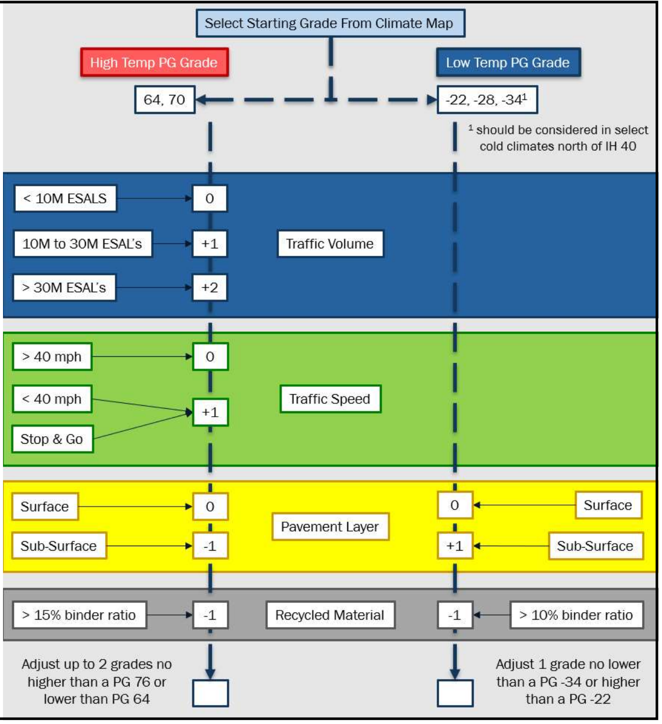
Adjust up to 2 grades no higher than a PG 76 or lower than PG 64

Adjust 1 grade no lower than a PG -34 or higher than a PG -22

PG grade bumping

Layer location on High PG

- ❑ High-PG
  - ➢ *Generally, do not need bump-ups for the high temperature grade*
  - ➢ *the further from the surface they are, they can use **lower** high temperature grade binders than the standard selection process indicates*
- ❑ For example:
  - ➢ *If you were building three layers and PG 64-22 is indicated as the standard climate grade and you are on high volume facility,*
  - ➢ *one might use*
    - ❖ PG 76- 22 for the surface
    - ❖ PG 64-22 for the middle and the lowest layers



Select Starting Grade From Climate Map

High Temp PG Grade

64, 70

Low Temp PG Grade

-22, -28, -34[1]

[1] should be considered in select cold climates north of IH 40

Traffic Volume

< 10M ESALS → 0

10M to 30M ESAL's → +1

> 30M ESAL's → +2

Traffic Speed

> 40 mph → 0

< 40 mph → +1

Stop & Go → +1

Pavement Layer

Surface → 0

Sub-Surface → -1

Surface → 0

Sub-Surface → +1

Recycled Material

> 15% binder ratio → -1

> 10% binder ratio → -1

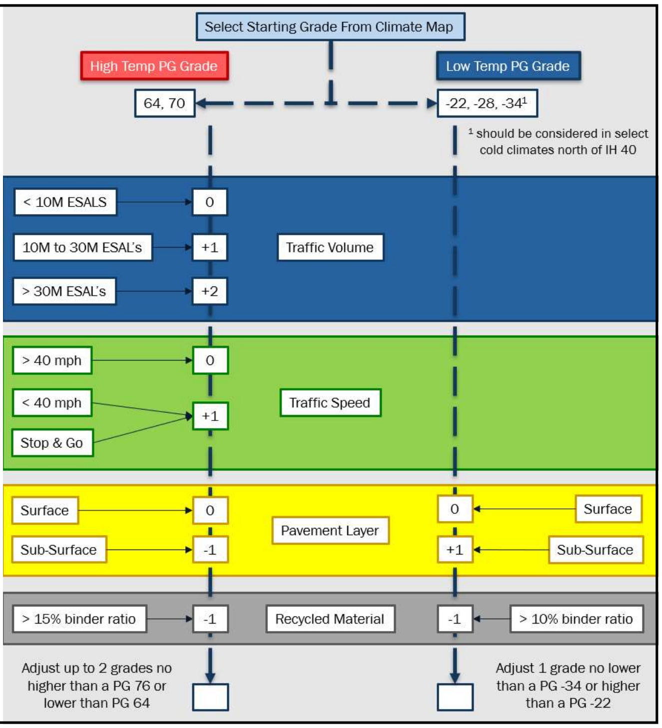
Adjust up to 2 grades no higher than a PG 76 or lower than PG 64

Adjust 1 grade no lower than a PG -34 or higher than a PG -22

PG grade bumping

Layer location on Low PG

- ❑ Low-PG
  - ➢ *Less pavement support means more deflection under traffic.*
  - ➢ *One possibility to address this is to "bump" the low temperature grade down,*
- ❑ For instance, from a -22 to - 28.
  - ❖ This gives more cracking protection from temperature extremes but also makes the binder more fatigue resistant



Select Starting Grade From Climate Map

High Temp PG Grade

64, 70

Low Temp PG Grade

-22, -28, -34[1]

[1] should be considered in select cold climates north of IH 40

Traffic Volume

< 10M ESALS → 0

10M to 30M ESAL's → +1

> 30M ESAL's → +2

Traffic Speed

> 40 mph → 0

< 40 mph → +1

Stop & Go → +1

Pavement Layer

Surface → 0

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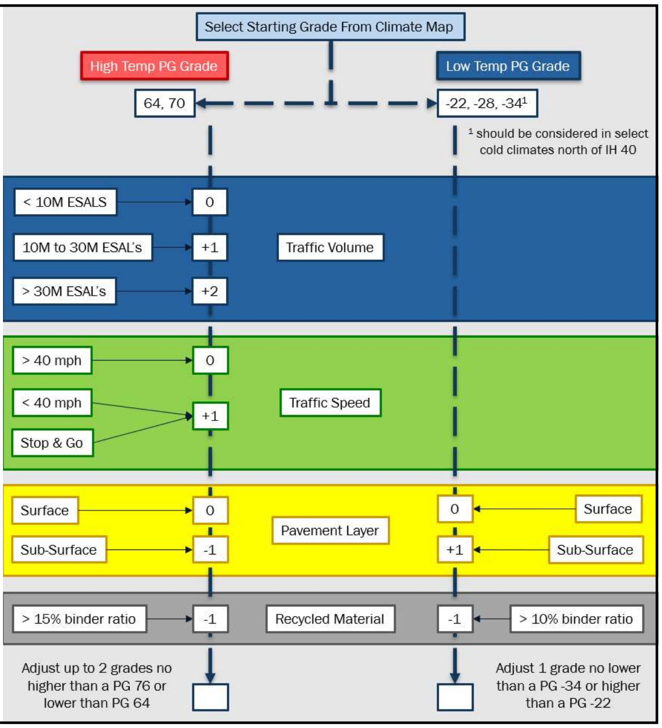
Adjust 1 grade no lower than a PG -34 or higher than a PG -22

PG grade bumping

Recycled Materials usage

Composite RAP is reprocessed (i.e. crushed, screened, stockpiled and QC tested)



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64, 70

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Pavement Layer

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Recycled Material

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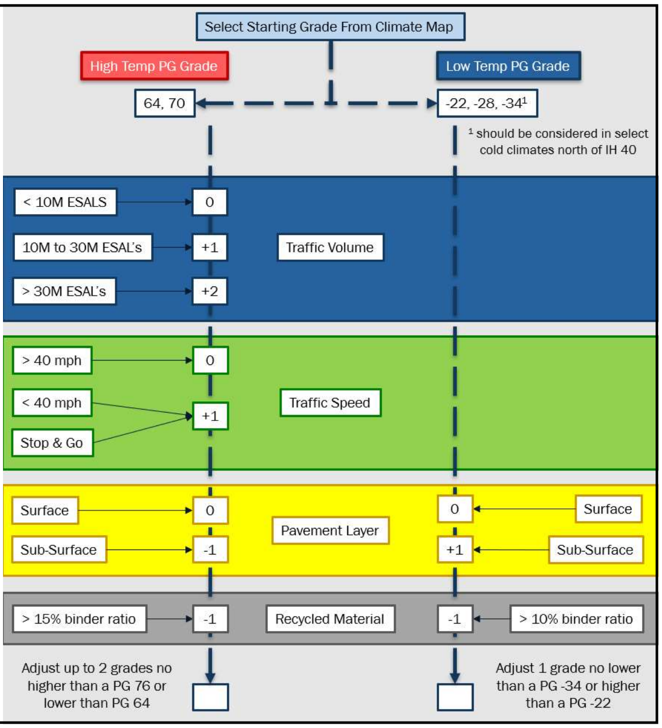
Adjust 1 grade no lower than a PG -34 or higher than a PG -22

PG grade bumping

Engineering Judgment

- ☐ Use judgment in the number of high-temperature grade "bump-ups."
- ☐ One could come up with a scenario in which a base climate grade of PG 64-22 **is bumped** three or four times resulting in a PG 82-22 to be specified for a project.
  - ➢ *This would probably be overkill and would result in a very expensive binder,*
  - ➢ *which also may be difficult to place.*
- ☐ Therefore, limits should be used
  - ➢ *A maximum two-grade increase*
  - ➢ *to no higher than a PG 76 is usually sufficient in all but the most extreme conditions.*



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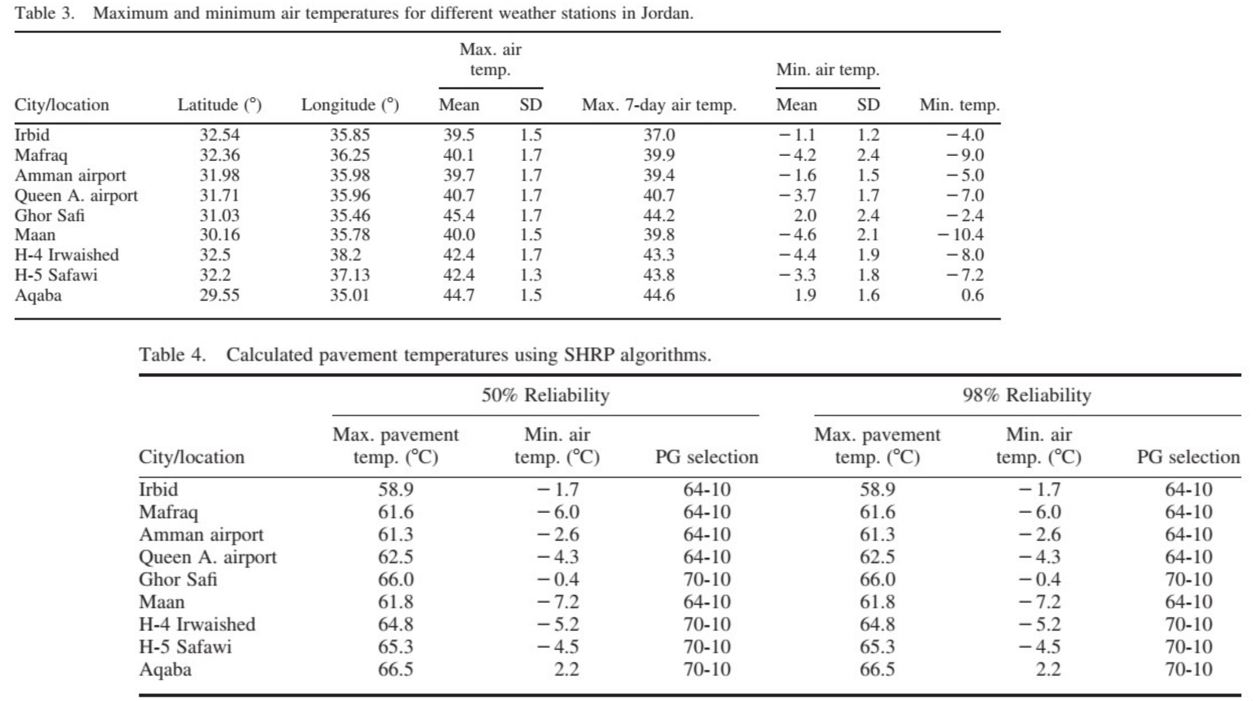


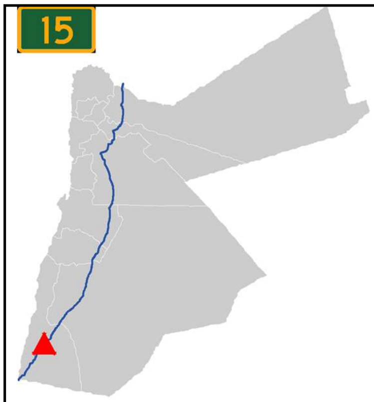
Table 3. Maximum and minimum air temperatures for different weather stations in Jordan.

City/location	Latitude (°)	Longitude (°)	Max. air temp. Mean	Max. air temp. SD	Max. 7-day air temp.	Min. air temp. Mean	Min. air temp. SD	Min. temp.
Irbid	32.54	35.85	39.5	1.5	37.0	− 1.1	1.2	− 4.0
Mafraq	32.36	36.25	40.1	1.7	39.9	− 4.2	2.4	− 9.0
Amman airport	31.98	35.98	39.7	1.7	39.4	− 1.6	1.5	− 5.0
Queen A. airport	31.71	35.96	40.7	1.7	40.7	− 3.7	1.7	− 7.0
Ghor Safi	31.03	35.46	45.4	1.7	44.2	2.0	2.4	− 2.4
Maan	30.16	35.78	40.0	1.5	39.8	− 4.6	2.1	− 10.4
H-4 Irwaished	32.5	38.2	42.4	1.7	43.3	− 4.4	1.9	− 8.0
H-5 Safawi	32.2	37.13	42.4	1.3	43.8	− 3.3	1.8	− 7.2
Aqaba	29.55	35.01	44.7	1.5	44.6	1.9	1.6	0.6

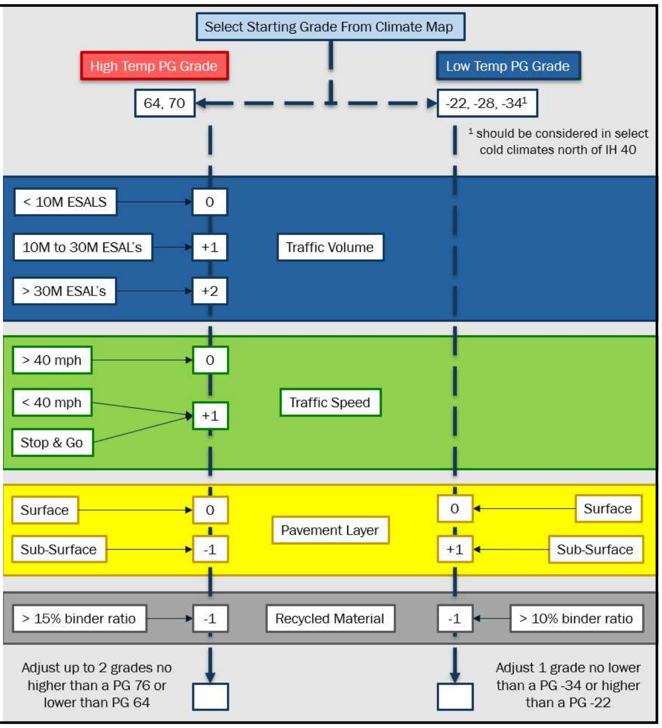
Table 4. Calculated pavement temperatures using SHRP algorithms.

	50% Reliability			98% Reliability		
City/location	Max. pavement temp. (°C)	Min. air temp. (°C)	PG selection	Max. pavement temp. (°C)	Min. air temp. (°C)	PG selection
Irbid	58.9	− 1.7	64-10	58.9	− 1.7	64-10
Mafraq	61.6	− 6.0	64-10	61.6	− 6.0	64-10
Amman airport	61.3	− 2.6	64-10	61.3	− 2.6	64-10
Queen A. airport	62.5	− 4.3	64-10	62.5	− 4.3	64-10
Ghor Safi	66.0	− 0.4	70-10	66.0	− 0.4	70-10
Maan	61.8	− 7.2	64-10	61.8	− 7.2	64-10
H-4 Irwaished	64.8	− 5.2	70-10	64.8	− 5.2	70-10
H-5 Safawi	65.3	− 4.5	70-10	65.3	− 4.5	70-10
Aqaba	66.5	2.2	70-10	66.5	2.2	70-10

Source: Khalid A. Ghuzlan &



High Temperature Grades (°C)	Low Temperature Grades (°C)
PG 46	−34, −40, −46
PG 52	−10, −16, −22, −28, −34, −40, −46
PG 58	−16, −22, −28, −34, −40
PG 64	−10, −16, −22, −28, −34, −40
PG 70	−10, −16, −22, −28, −34, −40
PG 76	−10, −16, −22, −28, −34
PG 82	−10, −16, −22, −28, −34



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Recycled Material

-1 ← > 10% binder ratio

Adjust up to 2 grades no higher than a PG 76 or lower than PG 64

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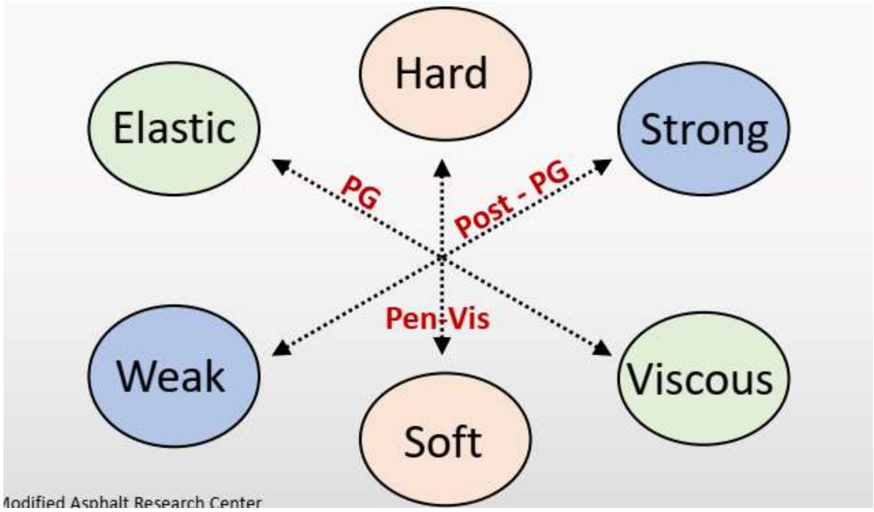
Superpave Performance Grading

Evolution of Asphalt Specifications



https://www.ndltap.org/events/asphalt/downloads/2019-binder-selection-process.pdf

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SuperPave + Performance Grading (PG +)

Multiple-Stress Creep-Recovery (MSCR) Grading for Traffic Levels

☐ Standard (S)
  - *Softer binder with lower truck traffic roads*
  - *PG 64S-22 (lower traffic levels and truck loads) "A"*

☐ High (H)
  - *Slightly harder binder for use with more trucks*
  - *PG 64H-22 (moderate traffic levels and truck loads) “*

☐ Very (H)
  - *Stiffer binder for use with heavy loads*

☐ Extremely High (E)
  - *Stiffest binder for use with extremely heavy truck traffic*
  - *PG 64E-22 (high traffic levels and truck loads) "E" Requires polymer modification*