Pavement Materials & Design

Asphalt Materials

4.4_Specifying asphalt binder and checking their quality

Dr. Hamza Alkuime

1

Laboratory tests and properties of asphalt

GENERAL

- The **purpose** of the laboratory tests performed on asphalt is to
  - *Define its characteristic properties, so as to ascertain its suitability and predict its behaviour during the service life of the pavement.*
- The term characteristic properties include all properties, such as
  - *Technological*
    - Technological properties are those defined by **empirical and not fundamental tests**, unlike the mechanical and rheological properties
  - *Mechanical*
  - *Rheological*
  - *Physical*
  - *Chemical*

2

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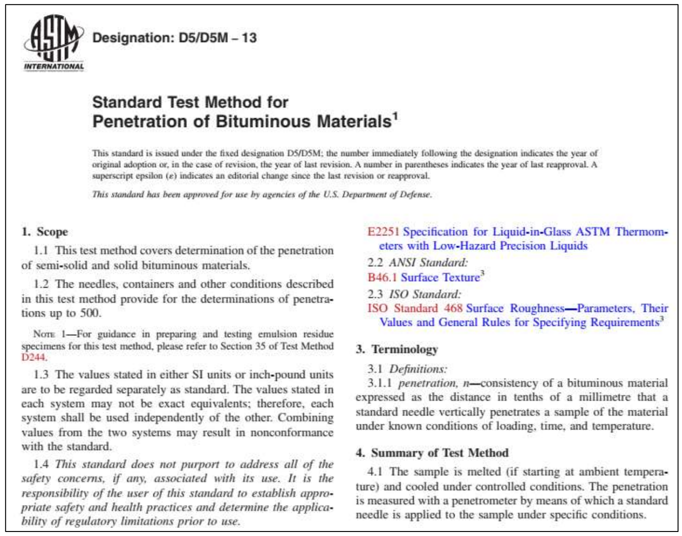
Laboratory tests and properties of asphalt

Testing Standards

- ASTM
  - Stand for the American Society for Testing and Materials
- AASHTO
  - Stand for American Association of State Highway and Transportation Officials



Designation: D5/D5M – 13

Standard Test Method for Penetration of Bituminous Materials[1]

This standard is issued under the fixed designation D5/D5M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 This test method covers determination of the penetration of semi-solid and solid bituminous materials.

1.2 The needles, containers and other conditions described in this test method provide for the determinations of penetrations up to 500.

NOTE 1—For guidance in preparing and testing emulsion residue specimens for this test method, please refer to Section 35 of Test Method D244.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

E2251 Specification for Liquid-in-Glass ASTM Thermometers with Low-Hazard Precision Liquids

2.2 *ANSI Standard:*

B46.1 Surface Texture[3]

2.3 *ISO Standard:*

ISO Standard 468 Surface Roughness—Parameters, Their Values and General Rules for Specifying Requirements[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *penetration, n*—consistency of a bituminous material expressed as the distance in tenths of a millimetre that a standard needle vertically penetrates a sample of the material under known conditions of loading, time, and temperature.

4. Summary of Test Method

4.1 The sample is melted (if starting at ambient temperature) and cooled under controlled conditions. The penetration is measured with a penetrometer by means of which a standard needle is applied to the sample under specific conditions.

Laboratory tests and properties of asphalt

- Consistency tests
  - *Penetration test (ASTM D5)*
  - *Softening point (ASTM D36)*
  - *Ductility test (ASTM D113)*
  - *Absolute (dynamic) viscosity (ASTM D2171, D4402)*
  - *Kinematic viscosity (ASTM D445 and D2170)*
- Durability tests
  - *Thin Film Oven test (ASTM D 1754)*
  - *Rolling Thin Film Oven Test (ASTM D 2872)*
  - *Distillation of Cutback Asphalt (ASTM D402)*
  - *Loss on heating (ASTM D6)*
- Purity tests
  - *Solubility in Trichloroethylene (ASTM D2042)*
  - *Presence of water (ASTM D95)*
  - *Water content (ASTM D95)*
- Safety tests
  - *Flash and fire point test (ASTM D1310)*
- Other tests
  - *Specific Gravity (S.G) (ASTM D70)*

Pavement Materials & Design

Asphalt Materials

1.12: ASTM D36 :Softening point

Dr. Hamza Alkuime

5

Softening point test

ASTM D36

- ASTM D36
  - *Standard Test Method for Softening Point of asphalt (Ring-and-Ball Apparatus)*
- Scope
  - *This test method covers the determination of the softening point of asphalt in the range from 30 to 157 °C using the ring-and-ball apparatus immersed in*
    - Distilled water (30 to 80°C)
    - USP glycerin (above 80 to 157 °C)
- Significance and use
  - *To determine the temperature at which a phase change occurs in the asphalt cement*
  - *It is used to measure the consistency of asphalt at elevated temperature empirically*

6

6

Softening point test

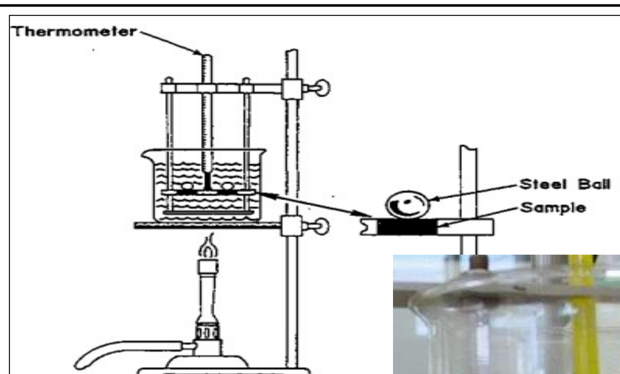
ASTM D36

- **Softening point test is defined as**
  - The temperature at which material under standardized test conditions attains a specific consistency
  - *It is the temperature at which an asphalt cement* ***cannot*** *support the weight of a steel ball and starts flowing*

7

Softening point test

ASTM D36



- **Summary of Test Method**
  - *The softening point is the mean of the temperatures at which the two discs soften enough to allow each ball, enveloped in bituminous binder, to fall a distance of 25.0 mm*

8

Softening point test

ASTM D36

Video source: https://www.youtube.com/watch?v=wBptuNTDs1g

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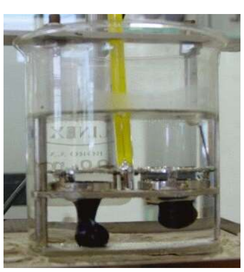
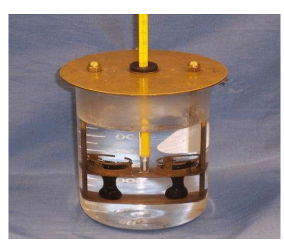
ASTM D5: Penetration test

Test Idea

Soft | Medium Soft | Medium Hard | Hard | Extra Hard





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Pavement Materials & Design

Asphalt Materials

1.13: ASTM D5 :Penetration test

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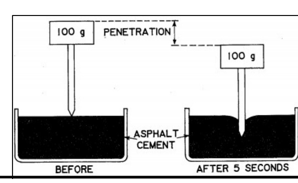
11

Penetration test

ASTM D5 :Standard Test Method for Penetration of Bituminous Materials

- **Scope**
  - *This test method covers determination of the penetration of semi-solid and solid bituminous materials*
- **Penetration is defined as**
  - *Consistency of a bituminous material **expressed as** the distance in tenths of a millimeter that a standard needle vertically penetrates a sample of the material under known conditions of loading, time, and temperature*
- **Significance and Use**
  - *The penetration test is used as a measure of consistency at intermediate service temperature*
  - *At 25 °C, there is not simple method to measure the consistency of asphalt binder*
    - This temperature a approximates the **average service temperature of the HMA pavements**
    - Thus, the penetration test is used to measure the consistency of asphalt binder at this temperature **empirically**
  - *Higher values of penetration indicate softer consistency.*



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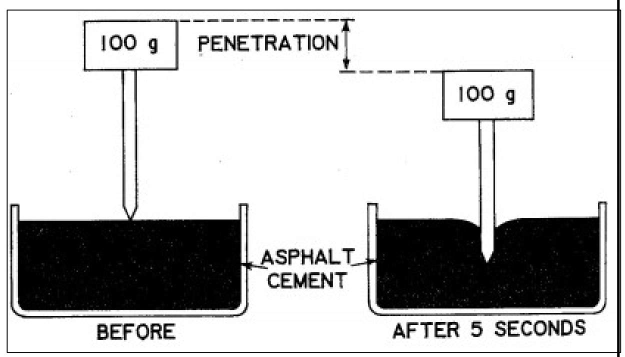
Penetration test

ASTM D5

- **Penetration measurement**
  - *The standardized needle first touches the surface of the asphalt binder specimen and then is allowed to penetrate into the mass of the specimen under the influence of its own weight and an additional mass so that the total load is 100 ± 0.1 g, for a period of 5 s.*
  - *After loading, the penetration depth of the needle is measured in 0.1 mm or decimillimetres (dmm).*
    - For example, if the needle penetrates 8 mm, the penetration of asphalt cement is 80
  - *This unit is also called 'pen'*
    - 1 pen = 0.1 mm



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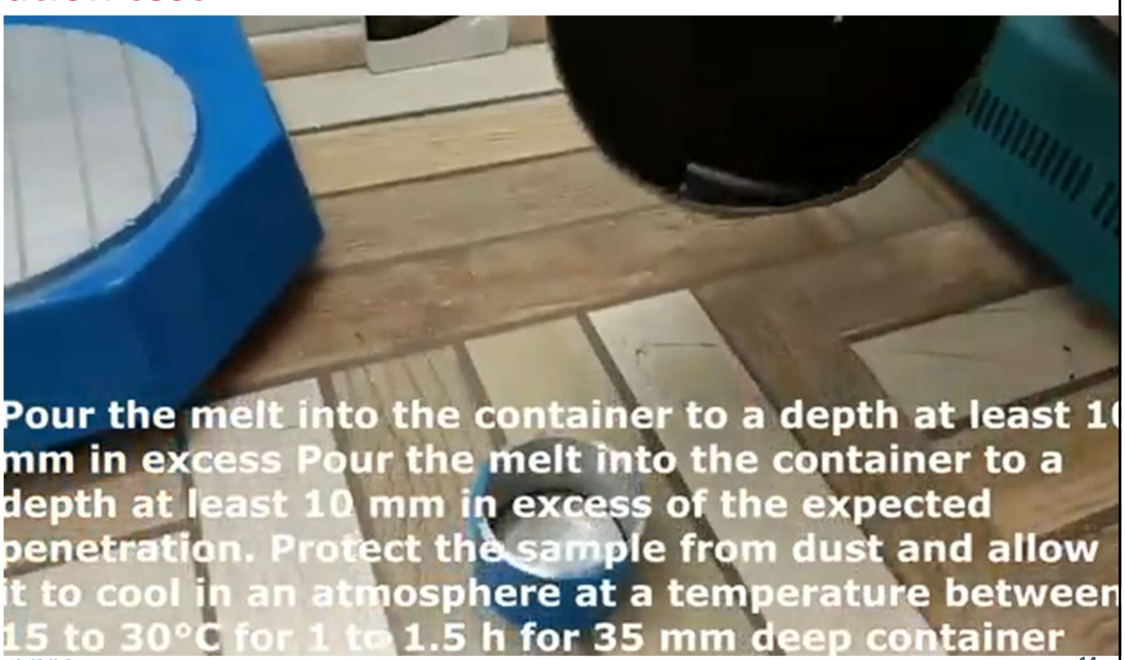
Penetration test

ASTM D5



Video source : https://www.youtube.com/watch?v=lGIFmQ3u-jE

14

14

Pavement Materials & Design

Asphalt Materials

1.14: ASTM D946 :Penetration Grading system

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15

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

16

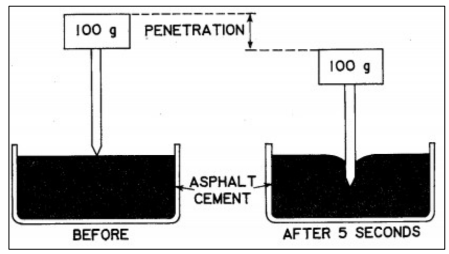
16

ASTM D5: Penetration test

Test Idea

Soft | Medium Soft | Medium Hard | Hard | Extra Hard

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



Penetration Grading system

ASTM D946

- The selection of the most suitable grade is based on
  - *The climatic*
  - ***And traffic conditions encountered.***
- The softest grade (200-300) is used in cold climate, while the hardest grade (40-50) is used in hot areas (WHY)
- The system also add specification for:
  - *Flash point test*
  - *Ductility*
  - *Solubility*
  - *Thin film oven aging*
    - Penetration
    - Ductility

Requirements for Penetration Graded Asphalt Cement

ASTM D946

	Penetration Grade									
	40–50		60–70		85–100		120–150		200–300	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Penetration at 25°C [77°F], 100 g, 5 s	40	50	60	70	85	100	120	150	200	300
Softening Point, °C [°F]	49 [120]		46 [115]		42 [108]		38 [100]		32 [90]	
Flash point, °C [°F], (Cleveland open cup)	230 [450]	...	230 [450]	...	230 [450]	...	220 [425]	...	175 [350]	...
Ductility at 25°C [77°F], 5 cm/min, cm	100	...	100	...	100	...	100	...	100[A]	...
Solubility in trichloroethylene, %	99.0	...	99.0	...	99.0	...	99.0	...	99.0	...
Retained penetration after thin-film oven test, %	55 +	...	52 +	...	47 +	...	42 +	...	37 +	...
Ductility at 25°C [77°F], 5 cm/min, cm after thin-film oven test test	...	...	50	...	75	...	100	...	100[A]	...

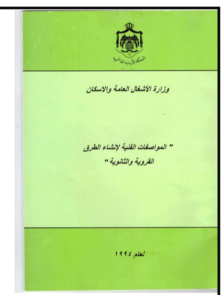
[A]If ductility at 25°C [77°F] is less than 100 cm, material will be accepted if ductility at 15°C [60°F] is 100 cm minimum at the pull rate of 5 cm/min.

19

19

Ministry of Public Works and Housing

Specifications for secondary and village roads construction



/ب- الخلطة الاسفلتية الساخنة (Hot Mix) :

أ- الخلطة الاسفلتية تكون من نوع (Hot Bituminous Concrete) ويكون الاسفلت المطلوب هو الاسفلت الجامد ١٠٠/٨٠ أو ٧٠/٦٠ وحسب طلب المهندس المشرف .

الرابط ـــــ

٦- يراعى استعمال :

- الاسفلت ١٠٠/٨٠ للمناطق الباردة .
- الاسفلت ٧٠/٦٠ للمناطق الحارة .

(يتم تحديد نوع الأسفلت المطلوب من قبل المهندس المشرف)

20

20

JORDAN PETROLEUM REFINERY CO. LTD

Specifications of Asphalt 60-70

S.N	Characteristics		Test Method	Control Limits
1	Ductility @ 25 °C, 5cm / min.	cm	ASTM D113	Min. 100
2	Flash Point	°C	ASTM D92	Min. 232
3	Penetration @ 25 °C, 100g, 5 sec.	0.1 mm	ASTM D5	60 - 70
4	Solubility in Trichloroethylene	Mass %	ASTM D2042	Min. 99.0
5	Performance after Thin-film Oven Test_ ASTM D1754			
5.1	Retained Penetration.	%	ASTM D5	Min. 52+
5.2	Ductility at 25°C, 5 cm/min.	cm	ASTM D113	Min. 50

[1] This specification is based on Jordanian Technical Regulation # JS 612:1989, and ASTM D946/D946M-15 for Asphalt- Penetration Graded Asphalt Cement for Use in Pavement Construction.

[2]The asphalt binder shall be homogeneous, free from water and foreign matter, and shall not foam when heated to 175°C.

JORDAN PETROLEUM REFINERY CO. LTD

Specifications of Asphalt 85-100

S.N	Characteristics		Test Method	Control Limits
1	Ductility @ 25 °C, 5cm / min.	cm	ASTM D-113	Min. 100
2	Penetration @ 25 °C, 100g, 5sec.	0.1 mm	ASTM D-5	85 - 100
3	Softening point	°C	ASTM D-36	Min. 42
4	Solubility in Trichloroethylene	Mass %	ASTM D-2042	Min. 99

[1] This specification is based on ASTM D – 946/946M – 15 Standard Specification for Penetration-Graded Asphalt Cement for Use in Pavement Construction

محاضرة علمية

- ❑ محاضرة علمية بعنوان | | الخلطات الاسفلتية | | (١)
- ❑ محاضرة علمية بعنوان | | الخلطات الاسفلتية | | (٢)

23

23

What do you think

محاضرة علمية بعنوان | | الخلطات الاسفلتية | | (١)

https://www.youtube.com/watch?v=rnyVkmspfsw&t=3243s

24

24

محاضرة علمية بعنوان || الخلطات الاسفلتية || (١)

- الخصائص المطلوبة للخلطة الإسفلتية

CONCLUSION

Maximizing All properties is Impossible

We have to make A COMPROMISE

Asphalt Mix Designs

https://www.youtube.com/watch?v=rnyVkmspfsw&t=3243s

26

26

Pavement Materials & Design

Asphalt Materials

1.16: Asphalt Viscosity

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32

Asphalt Consistency

Viscosity definition and type

33

33

Viscosity

Definition

- Viscosity is
  - *The measure of a fluid's resistance to flow*
  - *A fundamental characteristic property of asphalt*
    - Since it determines the way, it will behave in a specific temperature or at a range of temperatures

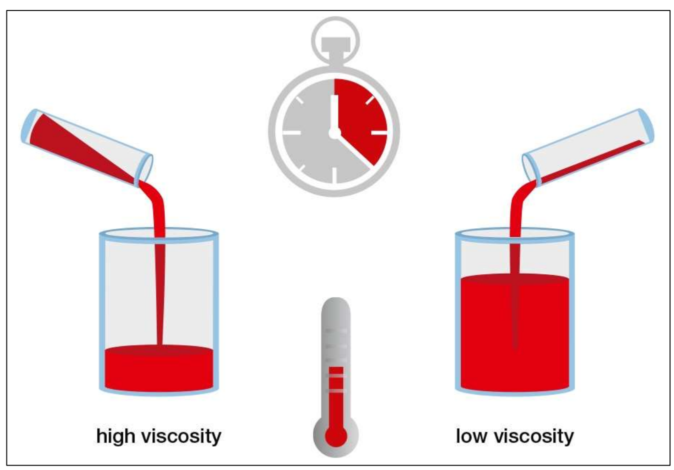

Image source: https://wiki.anton-paar.com/hu-hu/a-viszkozimetria-alapjai/

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Viscosity *Definition and types*

https://www.youtube.com/watch?v=VvDJyhYSJv8

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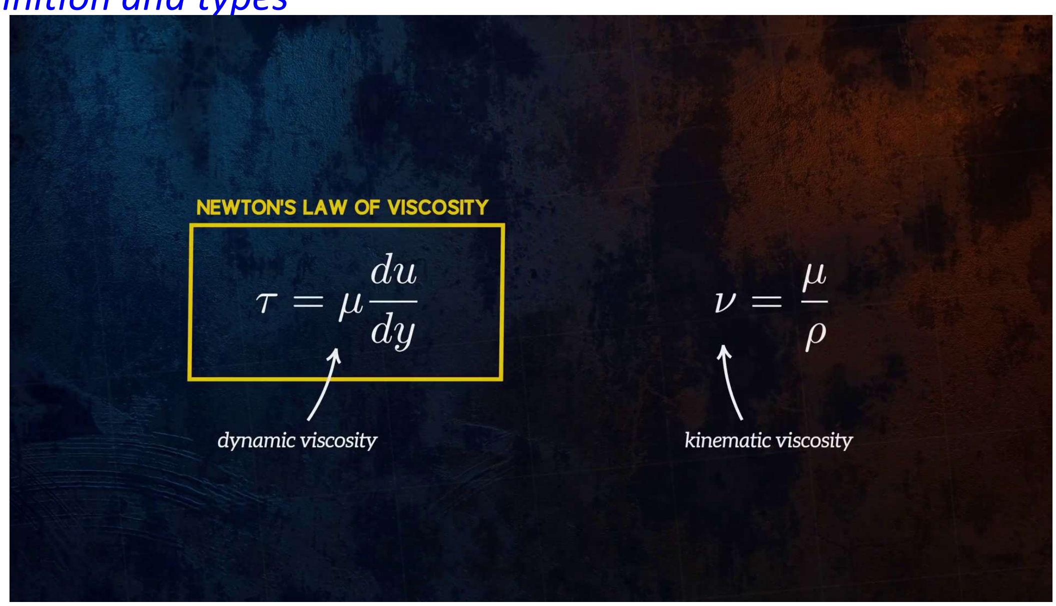
35

Viscosity

Definition and types



Understanding Viscosity - YouTube

36

36

Viscosity

Units

$$\mu = \frac{\tau}{\dot{\gamma}} \rightarrow [\mu] = \frac{F/L^2}{1/T} \rightarrow [\mu] = \mathrm{Pa \cdot s} \rightarrow [\mu] = \mathrm{Pa \cdot s}, \quad [\nu] = \mathrm{m^2 \cdot s^{-1}}$$

$$0.1\,\mathrm{Pa \cdot s} = 1\,\mathrm{P}$$ poise

$$0.0001\,\mathrm{m^2 \cdot s^{-1}} = 1\,\mathrm{St}$$ Stokes

centipoise

$$0.001\,\mathrm{Pa \cdot s} = 1\,\mathrm{cP}$$

$$0.000001\,\mathrm{m^2 \cdot s^{-1}} = 1\,\mathrm{cSt}$$

centistokes

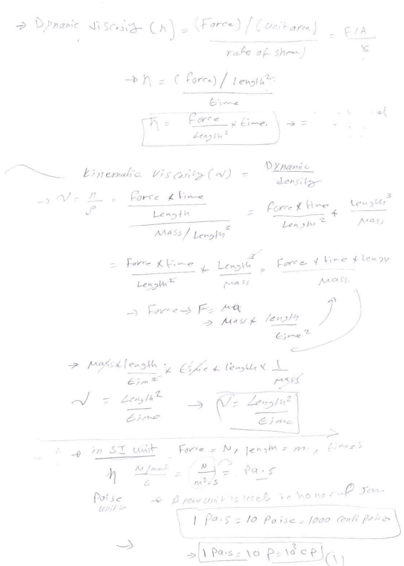
Understanding Viscosity - YouTube

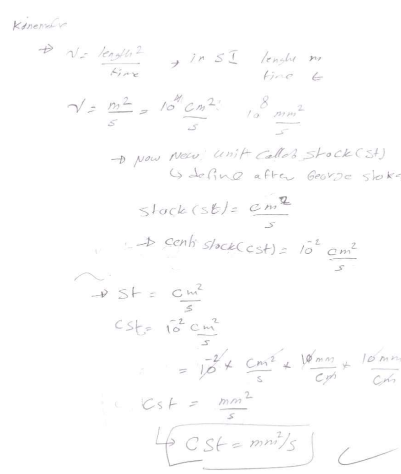
37

37

Relation between Kinematic and absolute viscosity

Units' derivation





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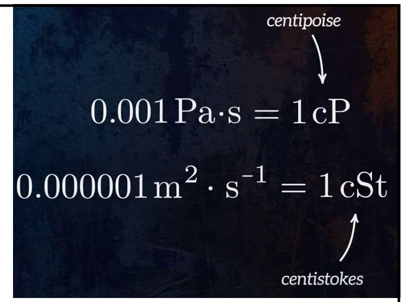
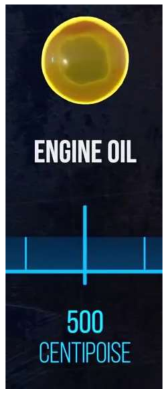
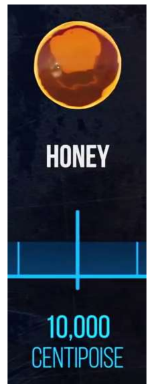
38

Viscosity





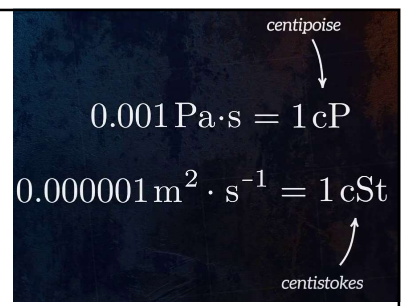


Understanding Viscosity - YouTube

39

39

Viscosity



https://www.youtube.com/watch?v=r06S127HM40

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40

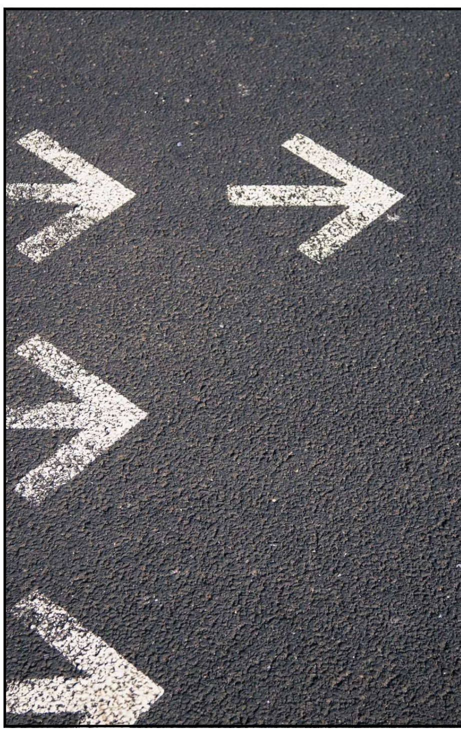
Pavement Materials & Design

Asphalt Materials

Why asphalt viscosity is important ?

Dr. Hamza Alkuime

41



What do you think ?

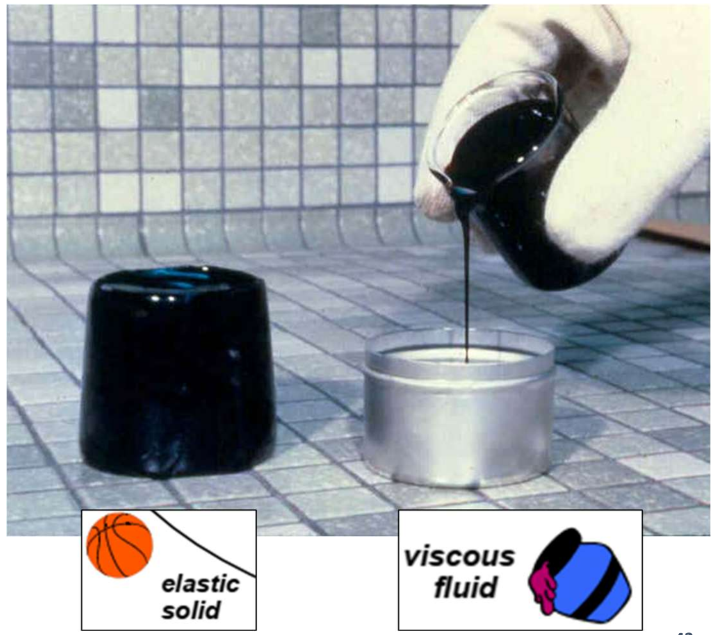
Why asphalt viscosity is important ?

42

42

Why asphalt viscosity is important ?

- Asphalt Processing
  1. *Storage and Handling*
  2. *Mixing*
  3. *Compaction*
  4. *Application (for liquid asphalt)*



43

43

Why asphalt viscosity is important ?

Mixing

Video source : https://www.youtube.com/watch?v=rzfAJtLA1d4&t=175s

44

44

Why asphalt viscosity is important ?

Laboratory Mix Compaction

Video source: https://www.youtube.com/watch?v=0rAUfFjx5BY

45

45

Why asphalt viscosity is important ?

Field Mix Compaction

https://www.youtube.com/watch?v=0nC6KgNbR8o&t=196s

46

46

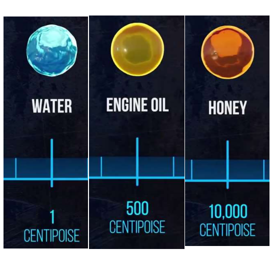
Conventional flexible pavement layers

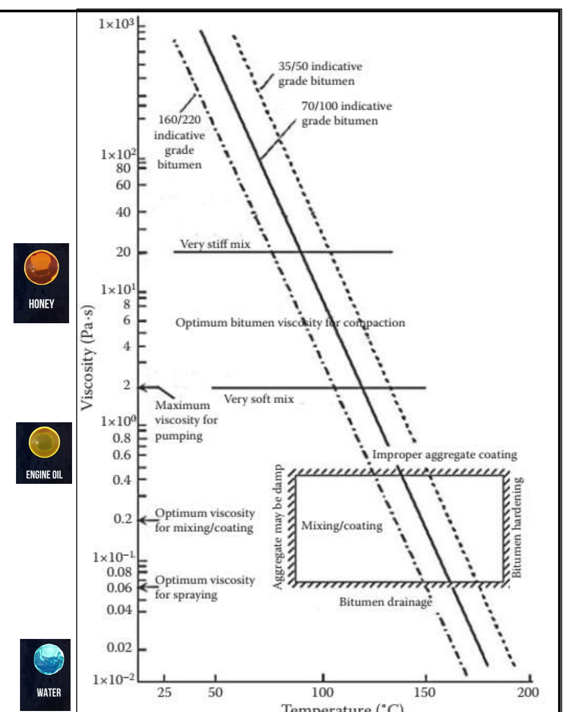
Application (for liquid asphalt) + Mix Compaction

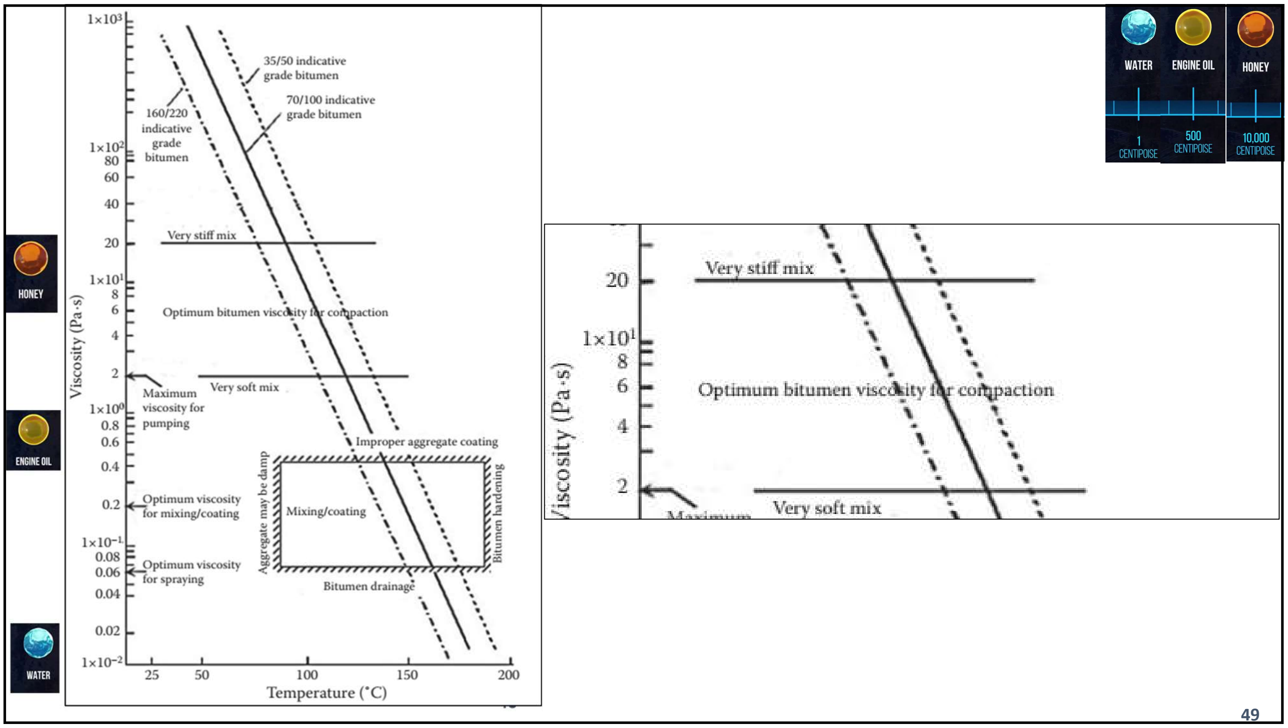
Video source:https://www.youtube.com/watch?v=aDe03CSITSU

47

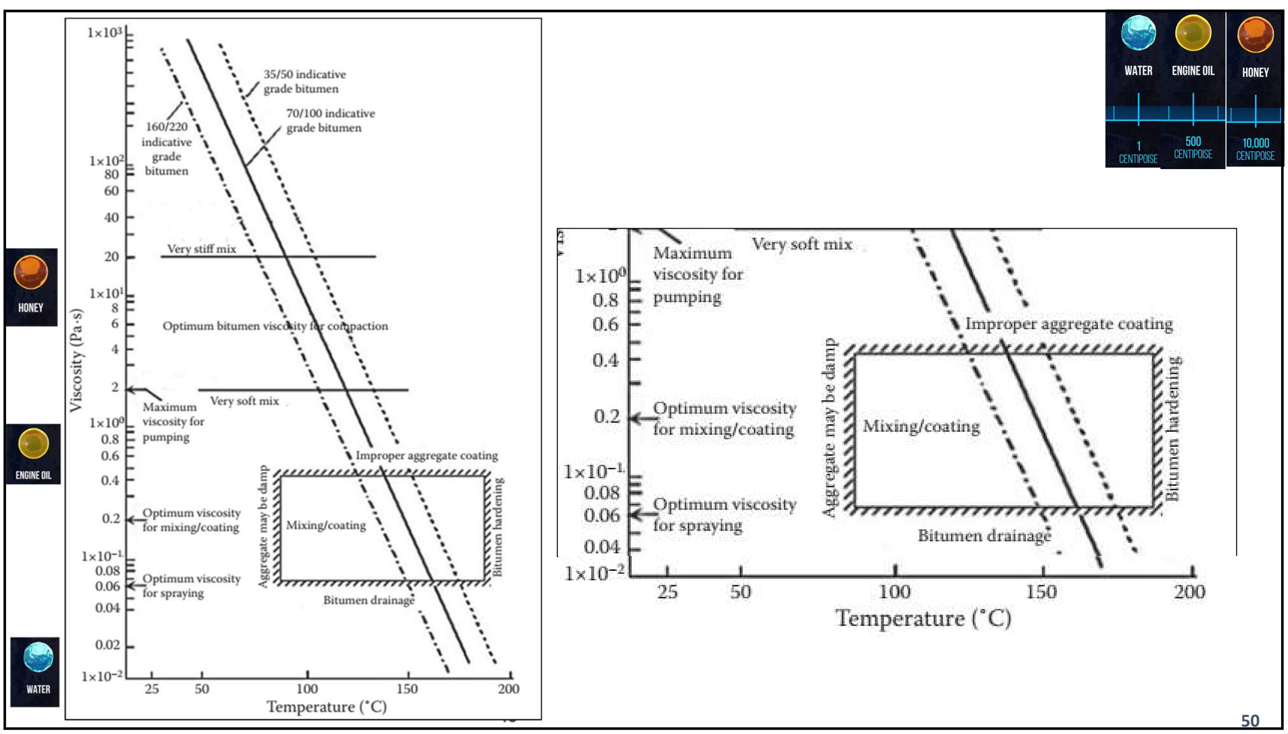
Relation between temperature and viscosity, at different stages of asphalt use






WATER
ENGINE OIL
HONEY
1 CENTIPOISE
500 CENTIPOISE
10,000 CENTIPOISE
35/50 indicative grade bitumen
70/100 indicative grade bitumen
160/220 indicative grade bitumen
Very stiff mix
Optimum bitumen viscosity for compaction
Very soft mix
Maximum viscosity for pumping
Improper aggregate coating
Optimum viscosity for mixing/coating
Mixing/coating
Aggregate may be damp
Bitumen hardening
Optimum viscosity for spraying
Bitumen drainage
Viscosity (Pa·s)
Temperature (°C)
49

49


WATER
ENGINE OIL
HONEY
1 CENTIPOISE
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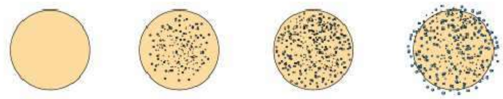
10,000 CENTIPOISE
35/50 indicative grade bitumen
70/100 indicative grade bitumen
160/220 indicative grade bitumen
Very stiff mix
Optimum bitumen viscosity for compaction
Very soft mix
Maximum viscosity for pumping
Improper aggregate coating
Optimum viscosity for mixing/coating
Mixing/coating
Aggregate may be damp
Bitumen hardening
Optimum viscosity for spraying
Bitumen drainage
Viscosity (Pa·s)
Temperature (°C)
50

50

51

52

52

State	Oven dry	Air dry	Saturated, surface dry	Damp or wet
				
Total Moisture	None	Less than potential absorption	Equal to potential absorption	Greater than absorption

Moisture conditions of aggregates

Granite aggregate at various moisture conditions

53

53

Pavement Materials & Design

Asphalt Materials

1.18: ASTM D3381:Asphalt Viscosity Grading system

Dr. Hamza Alkuime

65

Viscosity Grading system based on original asphalt cement (AC system)

ASTM D3381

- This specification covers asphalt cements graded by viscosity of original sphalt cement at 60 °C for use in pavement construction.
- Six penetration grades are specified

Grade	Dynamic Viscosity, 60 °C , Pa·s
AC-2.5	25 ± 5
AC-5	50 ± 10
AC-10	100 ± 20
AC-20	200 ± 40
AC-30	300 ± 60
AC-40	400 ± 80

66

66

Pavement Materials & Design

Asphalt Materials

ASTM D1754:Thin Film Oven test (TFO)

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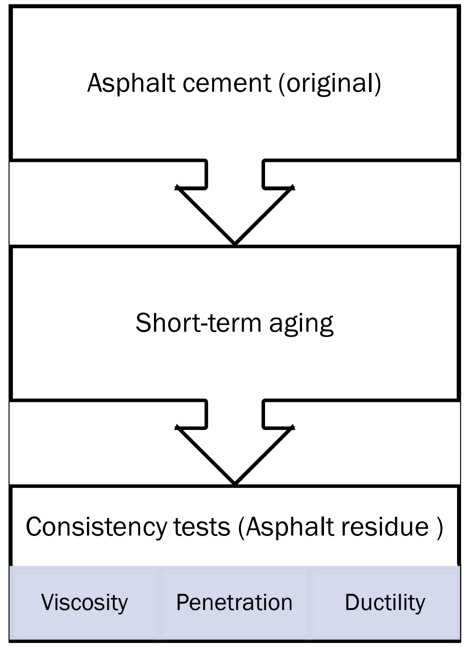
75

Thin Film Oven test (TFO)

ASTM D1754:

- TFO test measures the combined effects of heat and air on a film of asphalt or bituminous binder
  - *Which simulate hardening (durability) characteristic of asphalt binder during mix production and construction (Short-term ageing)*
- The consistency of the material is determined before and after the TFO procedure using either the penetration test or a viscosity test to estimate the amount of hardening that will take place in the material when used to produce plant hot-mix asphalt.
- The specimen shall have a
  - *minimum percentage retained penetration*
  - *or maximum viscosity*

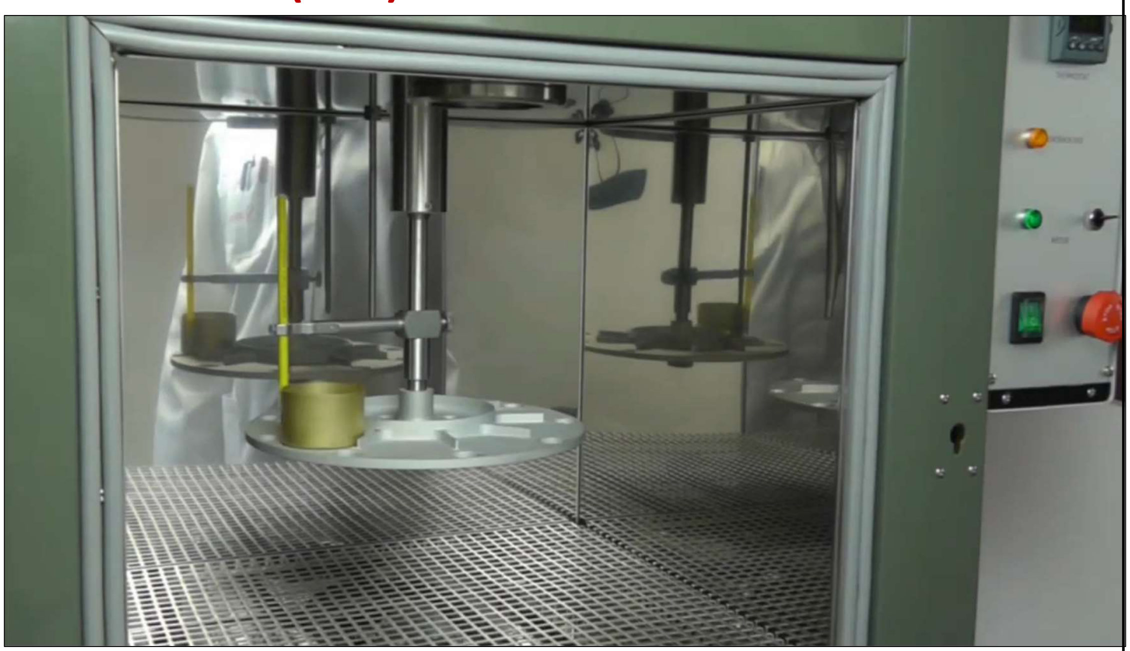


76

76

Thin Film Oven test (TFO)

ASTM D1754



Video source : https://www.youtube.com/watch?v=VSg0EXqbNak

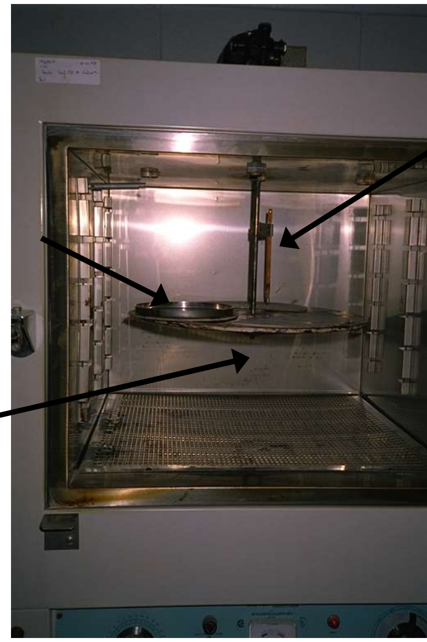
77

77

Thin Film Oven test (TFO)

ASTM D1754

Outside of Oven



78

78

Laboratory tests and properties of asphalt

- **Consistency tests**
  - *Absolute (dynamic) viscosity (ASTM D2171, D4402)*
  - *Kinematic viscosity (ASTM D445 and D2170)*
  - *Penetration test (ASTM D5)*
  - *Softening point (ASTM D36)*
  - *Ductility test (ASTM D113)*
- **Durability tests**
  - *Thin Film Oven test (ASTM D 1754)*
  - *Rolling Thin Film Oven Test (ASTM D 2872)*
  - *Distillation of Cutback Asphalt (ASTM D402)*
  - *Loss on heating (ASTM D6)*
- **Purity tests**
  - *Solubility in Trichloroethylene (ASTM D2042)*
  - *Presence of water (ASTM D95)*
  - *Water content (ASTM D95)*
- **Safety tests**
  - *Flash and fire point test (ASTM D1310)*
- **Other tests**
  - *Specific Gravity (S.G) (ASTM D70)*

79

79

Rolling Thin Film Oven Test

ASTM D2872

Video source : https://www.youtube.com/watch?v=3SwRYEg1FCQ

80

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Laboratory tests and properties of asphalt

- **Consistency tests**
  - *Absolute (dynamic) viscosity (ASTM D2171, D4402)*
  - *Kinematic viscosity (ASTM D445 and D2170)*
  - *Penetration test (ASTM D5)*
  - *Softening point (ASTM D36)*
  - *Ductility test (ASTM D113)*
- **Durability tests**
  - *Thin Film Oven test (ASTM D 1754)*
  - *Rolling Thin Film Oven Test (ASTM D 2872)*
  - *Distillation of Cutback Asphalt (ASTM D402)*
  - *Loss on heating (ASTM D6)*
- **Purity tests**
  - *Solubility in Trichloroethylene (ASTM D2042)*
  - *Presence of water (ASTM D95)*
  - *Water content (ASTM D95)*
- **Safety tests**
  - *Flash and fire point test (ASTM D1310)*
- **Other tests**
  - *Specific Gravity (S.G) (ASTM D70)*

81

81

Flash and fire point test

ASTM D1310

- ASTM D1310
  - *Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester*
- Scope
  - *This test method describes the determination of the flash point and fire point of petroleum products by a manual Cleveland open cup apparatus or an automated Cleveland open cup apparatus.*
- Flash point is defined as
  - *The lowest temperature corrected to a barometric pressure of 101.3 kPa ,at which application of an ignition source causes the vapors of a specimen of the sample to ignite under specified conditions of test*
- Fire point is defined as
  - *The lowest temperature corrected to a barometric pressure of 101.3 kPa at which application of an ignition source causes the vapors of a test specimen of the sample to ignite and sustain burning for a minimum of 5 seconds under specified conditions of test.*

82

82

Flash and fire point test

Why it is Necessary?

- Explosion of asphalt tanks due to excessive temperature

https://www.youtube.com/watch?v=y-vm0ZopQoc

85

85

Pavement Materials & Design

Asphalt Materials

1.19: ASTM D70:Specific Gravity (S.G)

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90

Specific Gravity (S.G)

ASTM D70

- ASTM D70
  - *Standard Test Method for Density of Semi-Solid Bituminous Materials (Pycnometer Method*
- Scope
  - *This test method covers the determination of the relative density and density of semi-solid bituminous materials, asphalt cements, and soft tar pitches by use of a pycnometer*
- Significance and Use
  - *The asphalt cement expands on heating, therefore, a specific gravity determination is useful for*
    - Making temperature-volume corrections
    - Determining the weight per unit volume of asphalt cement heated to its application temperature.

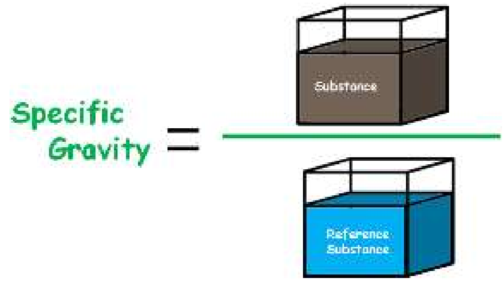
91

91

Specific Gravity (S.G)

ASTM D70

- Specific gravity is defined as
  - *The ratio of the mass of the material at a given temperature to the mass of an equal volume of water at the same temperature.*
- The specific gravity of pure bitumen is in the range of 0.97 to 1.02.
- The specific gravity of tar is approximately 1.20.



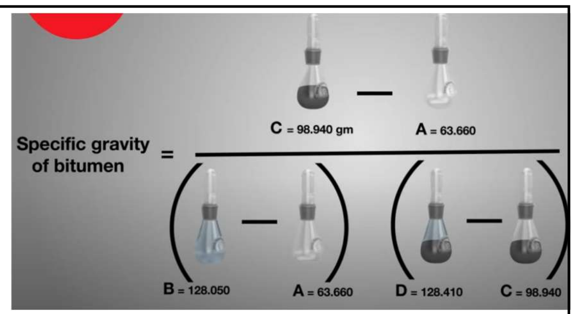
https://elementaryengineeringlibrary.com/civil-engineering/soil-mechanics/specific-gravity-of-solids

92

92

Specific Gravity (S.G)

ASTM D70



- Calculate the S.G. as indicated in the following equ:
  - $S.G = \frac{(C-A)}{[(B-A)-(D-C)]}$
    - Where
      - A = mass of pycnometer (plus stopper),
      - B = mass of pycnometer filled with water,
      - C = mass of pycnometer partially filled with asphalt
      - D = mass of pycnometer plus asphalt plus water.
  - $Density = S.G \times \gamma_w$, *Where*
    - γ_w = density of water at the test temperature (At 25°C, γ_w = 997.0 kg/m^3)
- The results reported the S.G at a given temperature for both asphalt and water
  - *For example, S.G of 1.02 at 15.6 ℃/15.6 ℃*
  - *Means that the asphalt cement specific gravity is 1.02 when both the asphalt and water has temperature of 15.6 °C*

94

94

Pavement Materials & Design

Asphalt Materials

Binder Grading

Vs. Binder verification

Vs. Binder Selection

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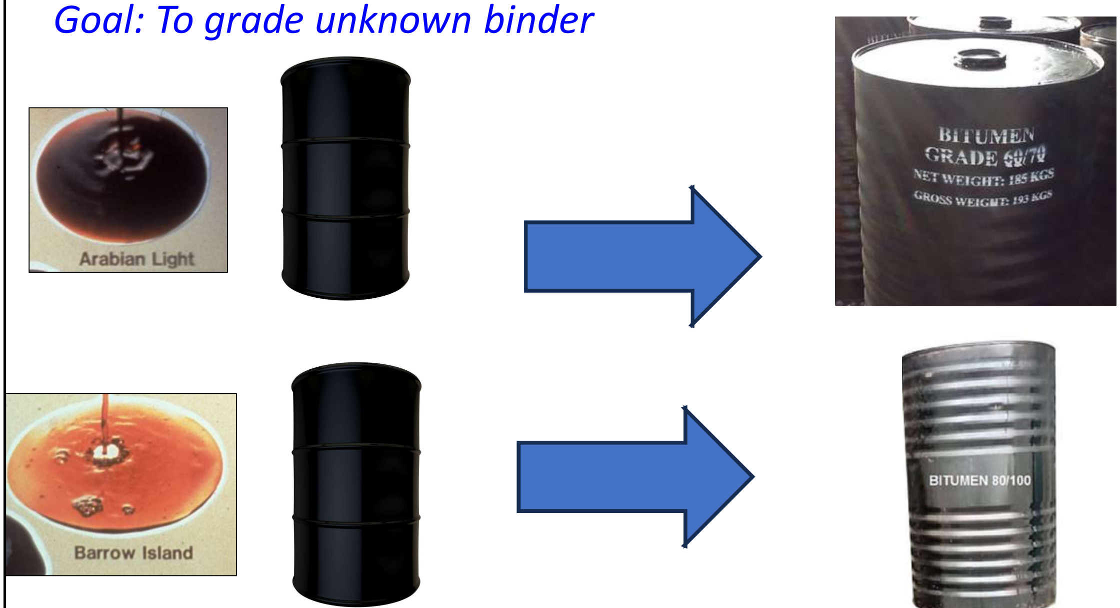
95

Binder Grading

Goal: To grade unknown binder



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96

Binder Verification

Goal: To verify the grade of binder

Penetration = 60-70

Refinery, Storage Tank

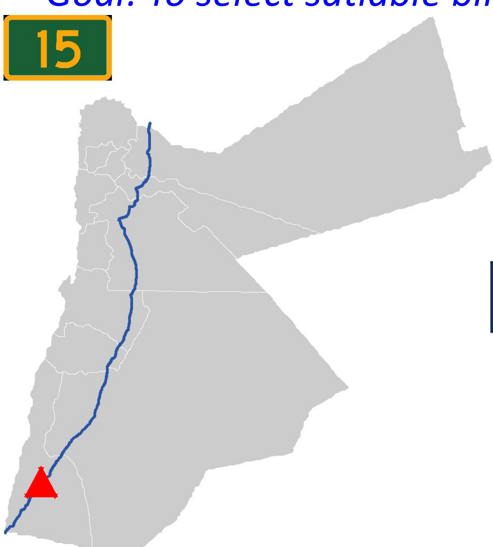
Penetration = ?????

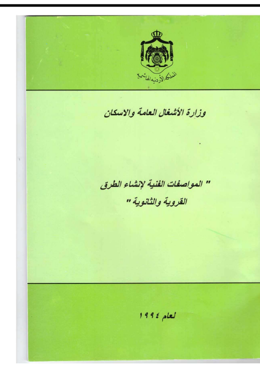
97

97

Binder Selection

Goal: To select satiable binder for specific project





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 ?

98

98

Pavement Materials & Design

Asphalt Materials

Asphalt Grading Systems

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99

Asphalt binder grading systems

Available systems

- ❑ Grading By Chewing
- ❑ Penetration Grading system (ASTM D946)
- ❑ Viscosity Grading system based on original asphalt cement (AC system)
- ❑ Viscosity Grading system based on aged asphalt cement (AR system)
- ❑ Superpave Performance Grade (PG) system (AASHTO M320)
- ❑ (PG) plus tests

100

100

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

101

101

Viscosity Grading system based on original asphalt cement (AC system)

ASTM D3381

- This specification covers asphalt cements graded by viscosity of original sphalt cement at 60 °C for use in pavement construction.
- Six penetration grades are specified

Grade	Viscosity, 60 ° C , Pa·s
AC-2.5	25 ± 5
AC-5	50 ± 10
AC-10	100 ± 20
AC-20	200 ± 40
AC-30	300 ± 60
AC-40	400 ± 80

107

107

Viscosity Grading system based on aged asphalt cement (AR system)

ASTM D3381

- This specification covers asphalt cements graded by viscosity of **aged** asphalt cement at 60 °C for use in pavement construction.
  - *Tests are performed on Residue from Rolling Thin-Film Oven*
- Six penetration grades are specified

Grade	Viscosity, 60 °C, Pa·s
AR-1000	100 ± 25
AR-2000	200 ± 50
AR-4000	400 ± 100
AR-8000	200 ± 40
AR-16000	1600 ± 400

111

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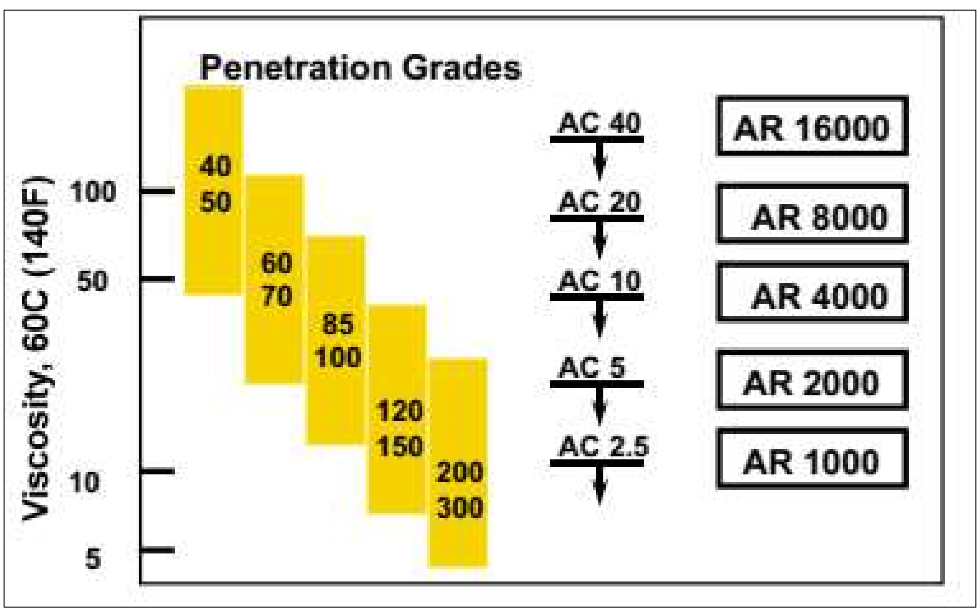
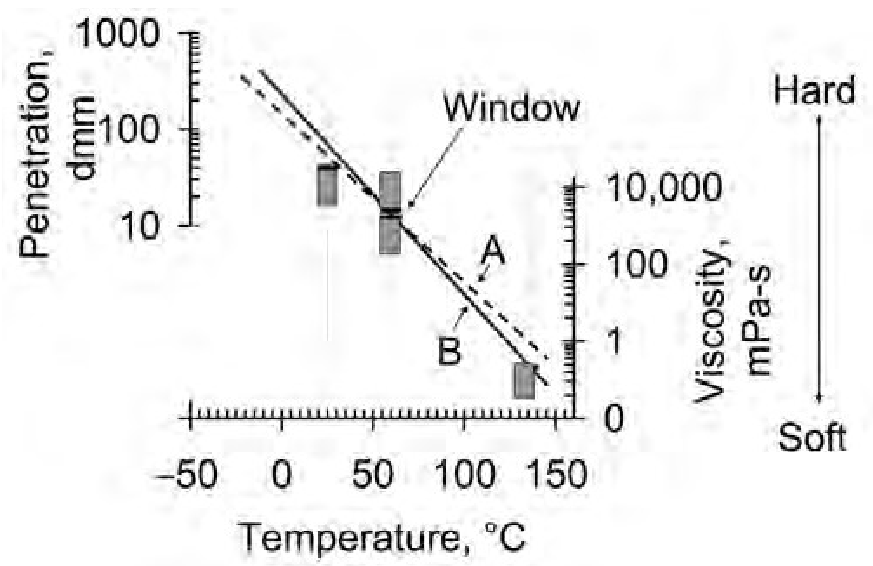
Relation between different grading systems



115

115

Relation between different grading systems



116

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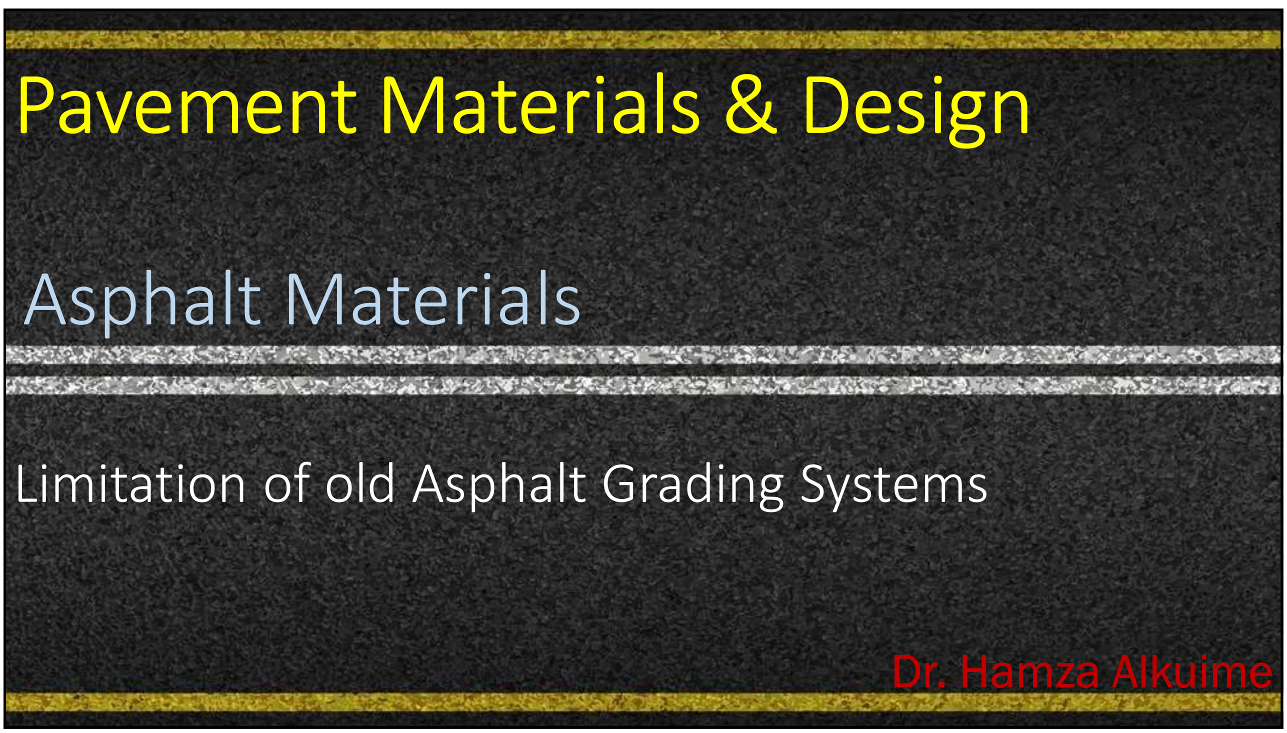
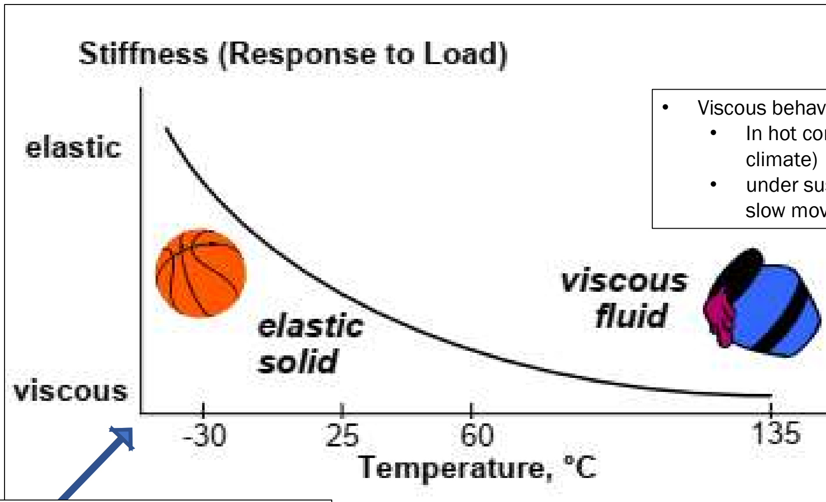


117

How Asphalt Behaves

Temperature Dependency



- Viscous behavior
  - In hot conditions (e.g., desert climate)
  - under sustained loads (e.g., slow moving trucks)

- Elastic behavior
  - In cold climates (e.g., winter days)
  - Under rapid loading (e.g., fast moving trucks)

118

118

What **laboratory** performance assessment tests are missing ?

WHAT DO YOU THINK ?

119

119

Temperature susceptibility

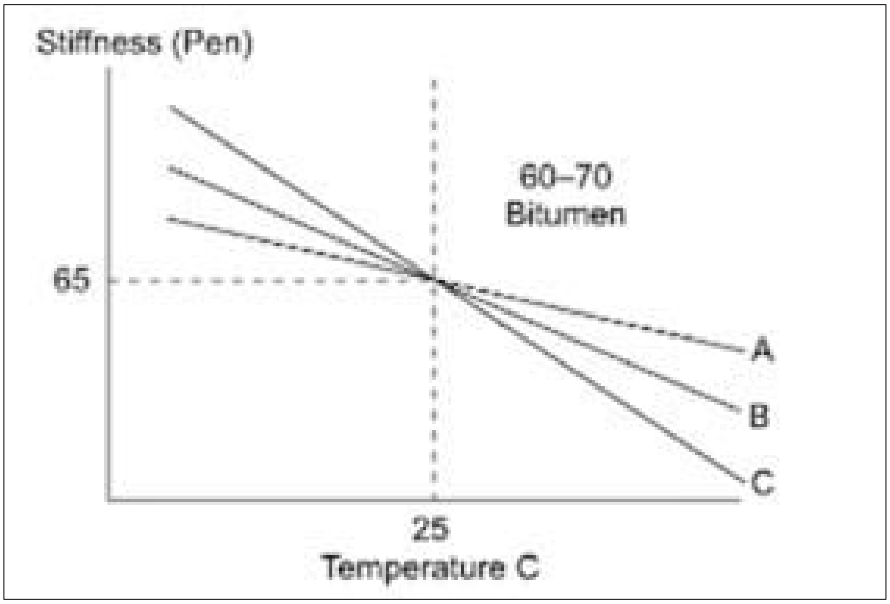


Image source: https://theconstructor.org/transportation/grading-of-bitumen-methods/15949/

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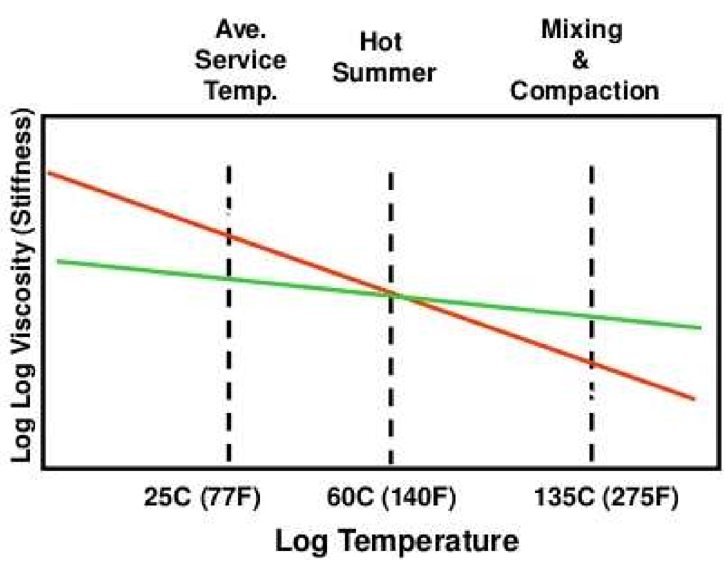
120

Temperature Susceptibility

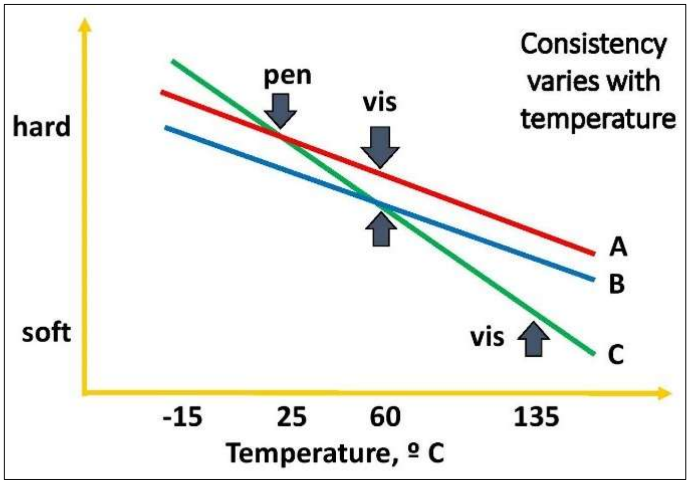
- Defined as the rate of change of viscosity (or other measure of asphalt consistency) with temperature



121

121

Temperature Susceptibility



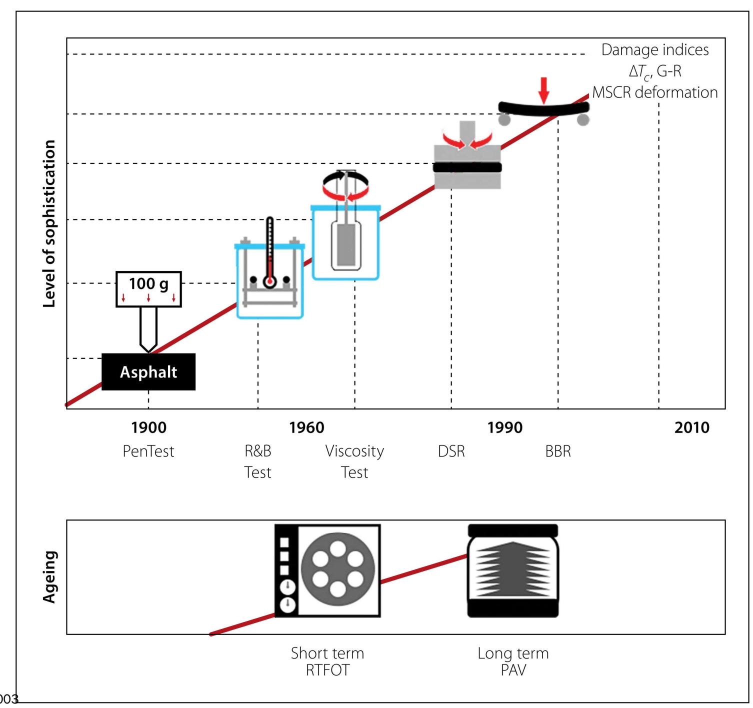
The penetration and viscosity asphalt specifications can classify different asphalts with the same grading, when in fact these asphalts may have very different temperature and performance characteristics

Image source: https://rheofalt.com/pen-corrector/empirical-pavement-design

123

123

Evolution of rheological test methods



Implementation of a performance-grade bitumen specification in South Africa

http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S1021-20192019000300003

124

Pavement Materials & Design

Asphalt Materials

SuperPave Physical Tests For Asphalt Binders

Dr. Hamza Alkuime

125

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*

126

126

Performance Graded(PG) system philosophy

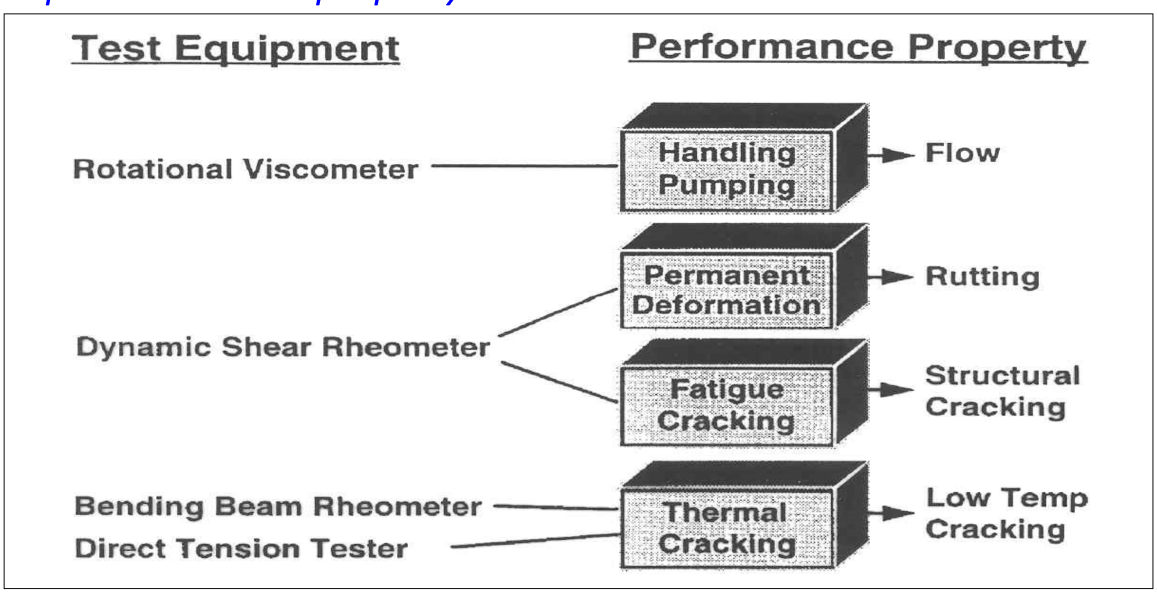
- With the advent of the Performance Graded (PG) system, specifying a single temperature for a particular test became obsolete.
- Rather than specifying a test temperature for a physical property,
  - *a desired property parameter was set*
  - *the temperature that **achieved** this desired value was 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*

128

128

SuperPave: The Future of Asphalt

SuperPave binder property measurements

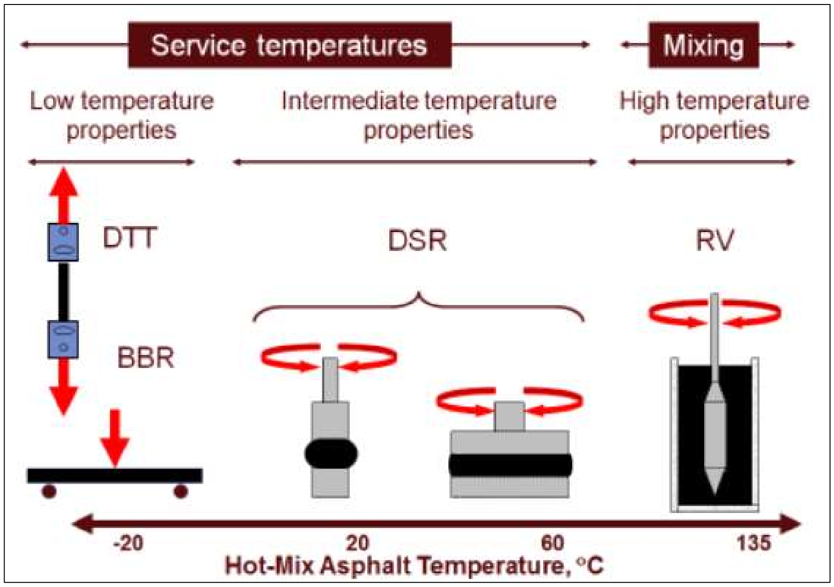


129

129

SuperPave: The Future of Asphalt

SuperPave binder property measurements

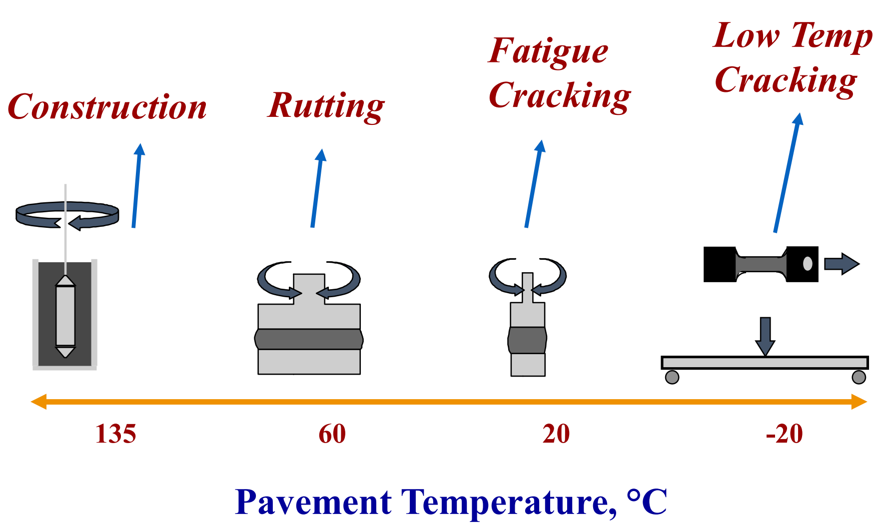


130

130

SuperPave: The Future of Asphalt

SuperPave binder property measurements

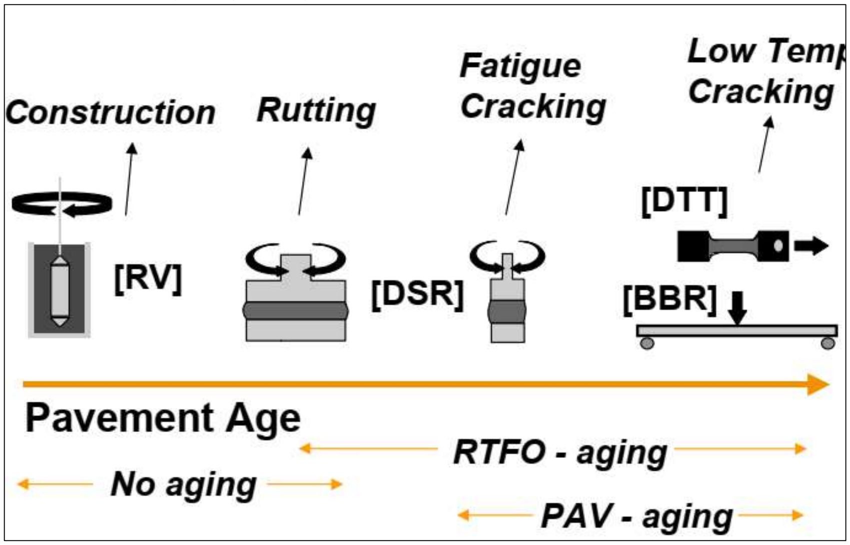


131

131

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

133

133

Superpave: The Future of Asphalt

Superpave binder property measurements

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

134

134

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

135

135

Pressure Ageing vessel

https://www.youtube.com/watch?v=FVQ455_KIYQ

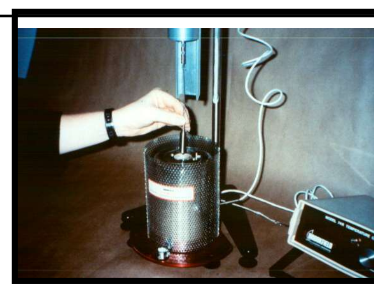
136

136

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



137

137

Absolute (dynamic) viscosity test

ASTM D4402

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

138

138

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

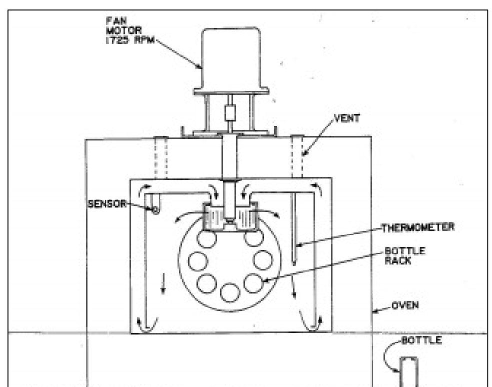


Figure 2–18. Rolling Thin Film Oven Test

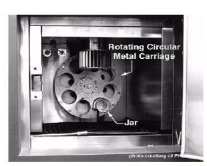


Figure : Rolling Thin-Film Oven Test

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

139

139

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)

140

140

Dynamic Shear Rheometer (DSR)

AASHTO T 315

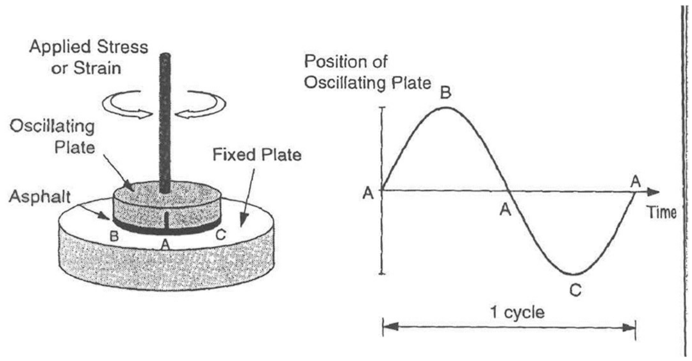
https://www.youtube.com/watch?v=Rv6eA_p9Mpw

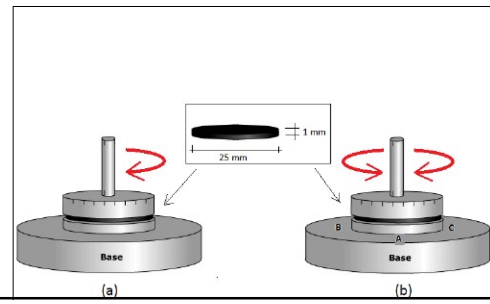
141

141

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)

142

Dynamic Shear Rheometer (DSR)

AASHTO T

Lecture 23
Asphalt Binders and Asphalt Mixtures (3)

Congrui Grace Jin

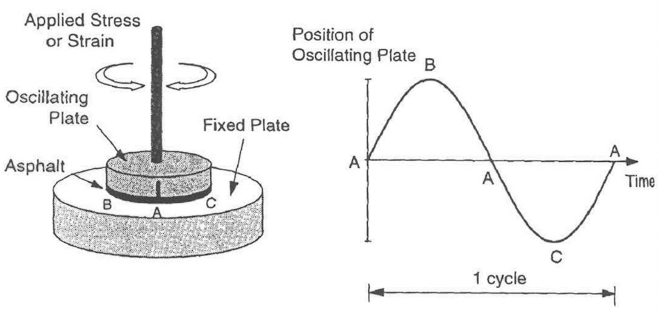
Apr 22, 2020

Rotation speed = 10 rad/sec

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

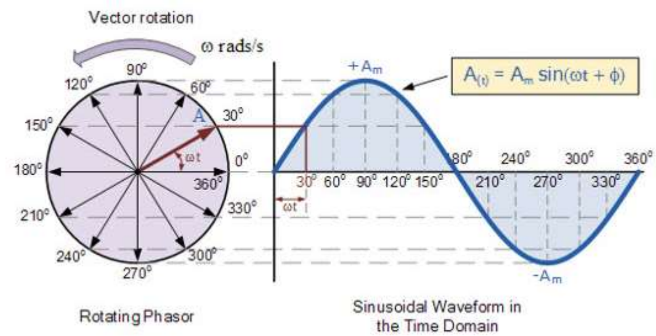
143

143



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

Δt = time lag → δ



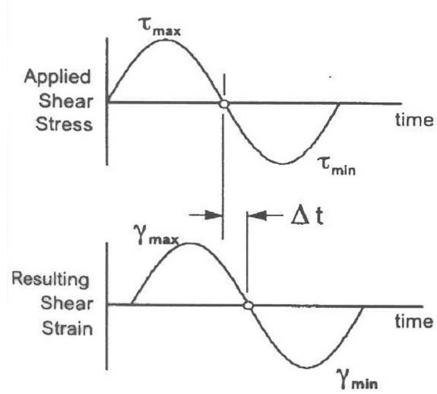
144

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: $0 < \delta < 90°$



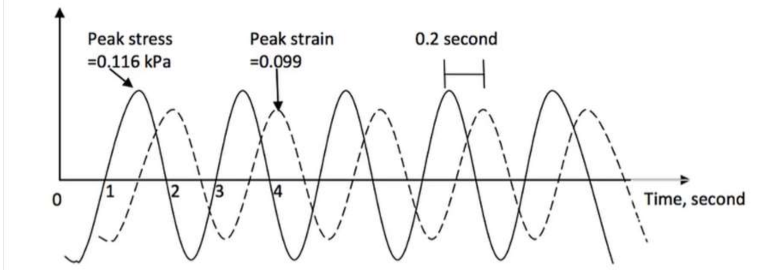
$$G^* = \frac{\tau_{max} - \tau_{min}}{\gamma_{max} - \gamma_{min}}$$

Δt = time lag → δ

145

145

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.

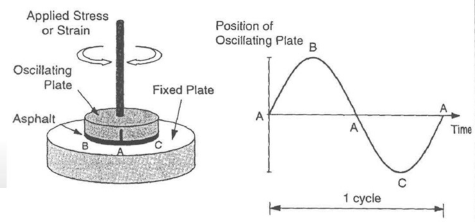


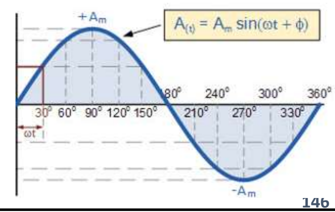
(1) Determine the complex modulus (G*) and phase angle (δ) of this RTFO-aged asphalt binder.

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

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

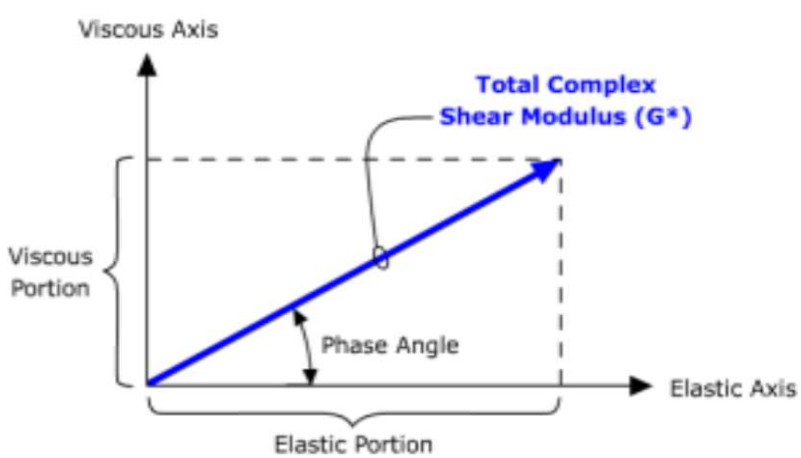
Δt = time lag → δ

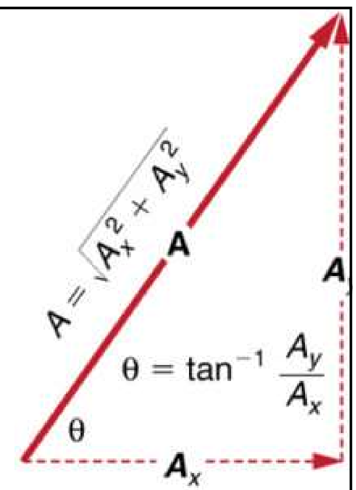




146

146



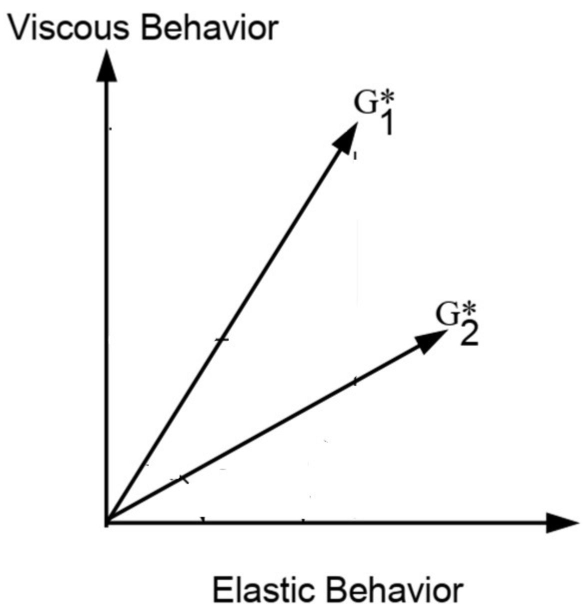


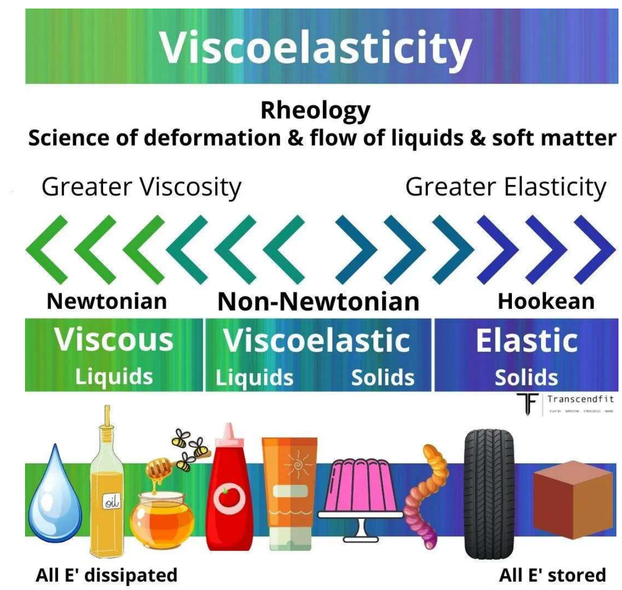
- *G* : measures the total resistance of the asphalt to deformation*
- *δ indicates the relative amounts of recoverable and non-recoverable deformation*

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

148

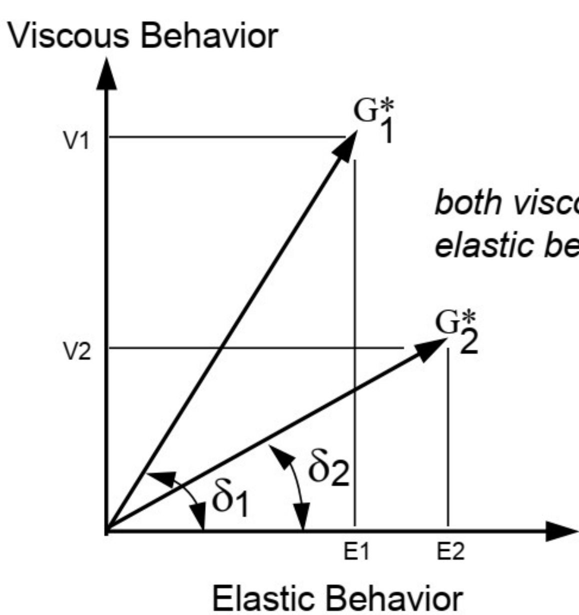
148



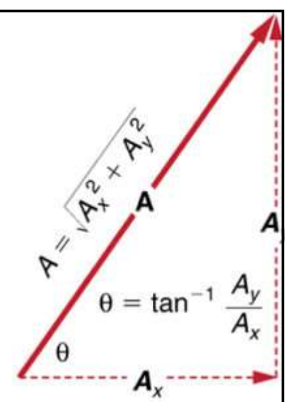


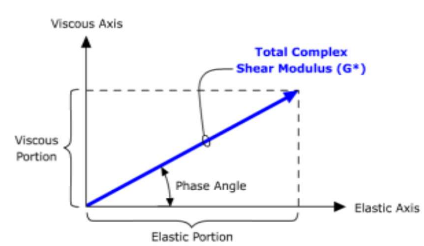
150

150



both viscous and elastic behavior





151

151

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

152

152

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

153

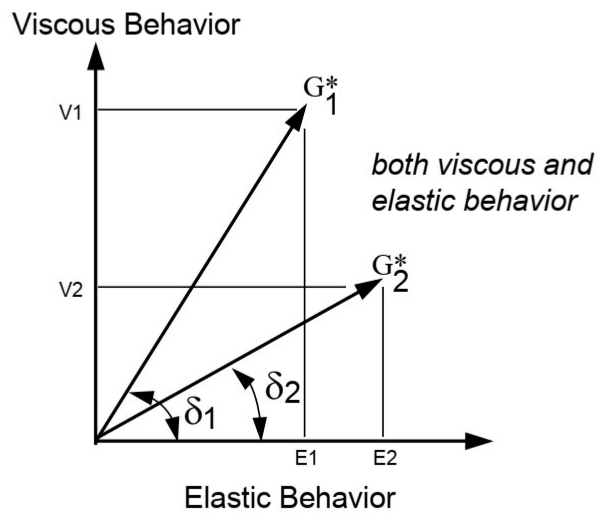
153

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*



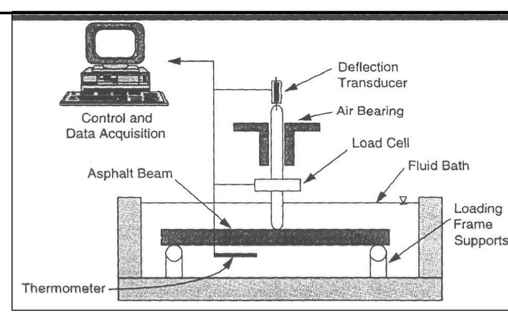
154

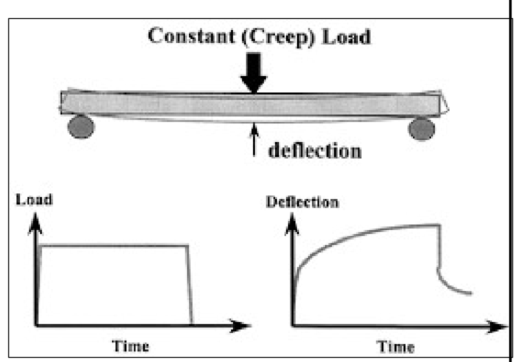
154

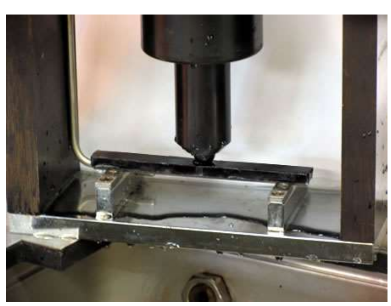
Bending Beam Rheometer (BBR)

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)







156

156

Bending Beam Rheometer (BBR)

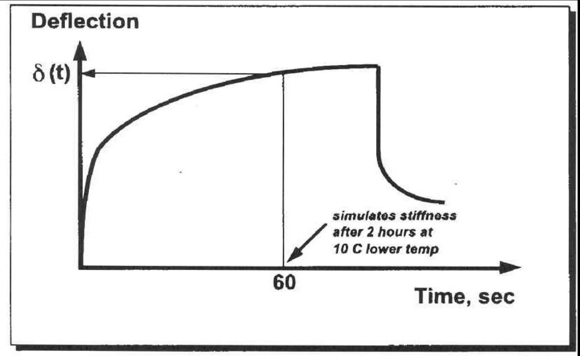
AASHTO T 321

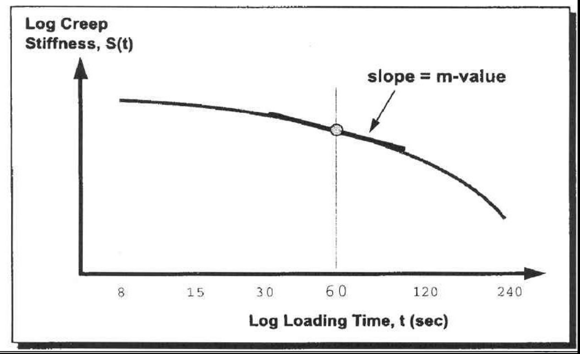
- Low temperature cracking
  - *Creep Stiffness (S) @ 60s < = 300 Mpa*
  - *S is between 300 to 600 MPa the Direct Tension test may be used in lieu of the creep stiffness requirement*
  - *m-value (m) @ 60s > = .3*

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

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.





157

Bending Beam R

AASHTO T 321

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

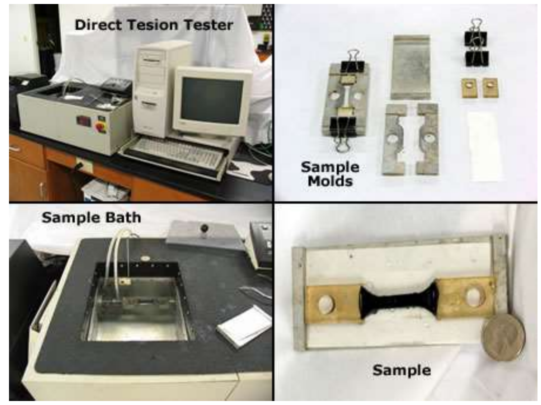
158

158

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



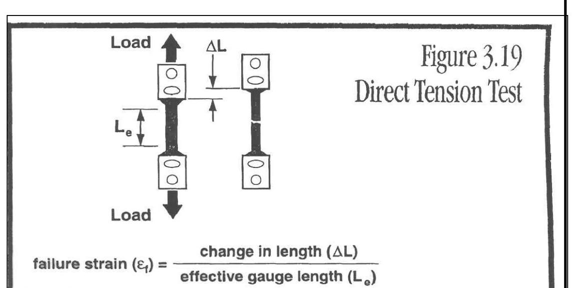
159

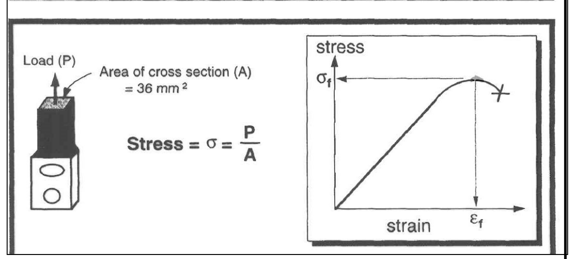
159

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*





160

160

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%

161

SuperPave Performance Grading

Grading system

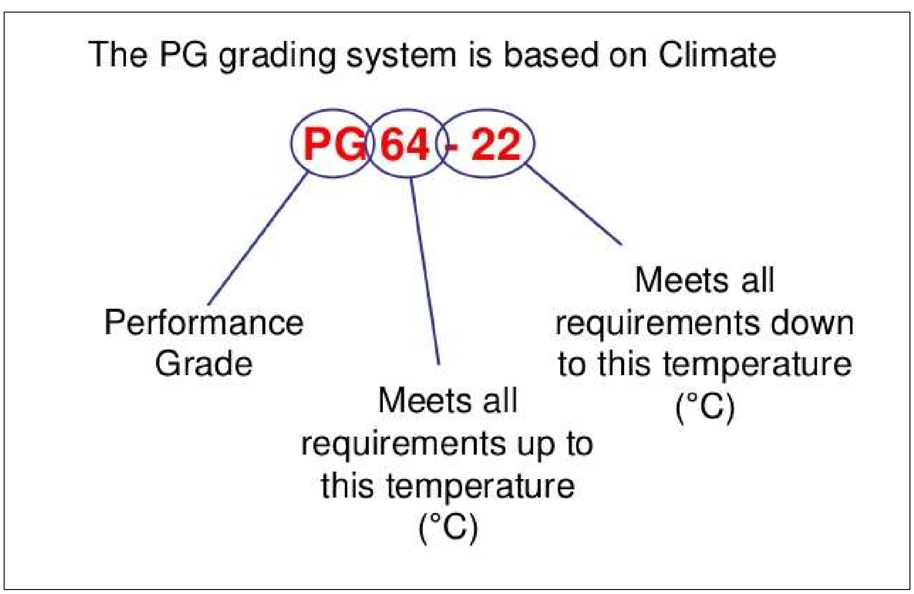


Image source: https://www.slideshare.net/CaliforniaAsphalt/asphalt-binders-101

162

SuperPave Performance Grading

Grading system

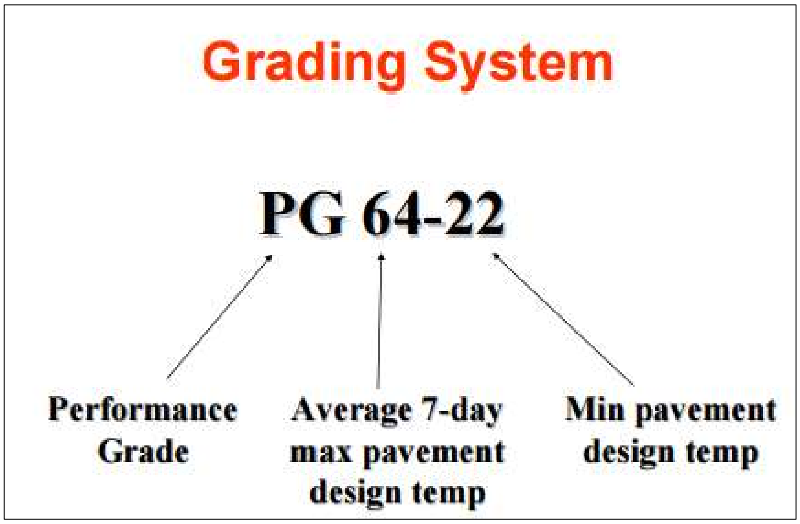


Image source: http://rahabitumen.com/performance-grade-pg-bitumen/

163

163

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

164

164

SuperPave Performance Grading

Grading system

High Temperature, °C

Low 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

165

165

Pavement Materials & Design

Asphalt Materials

1.20_ SuperPave Grading procedures

Dr. Hamza Alkuime

166

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

167

167

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%

168

168

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

169

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

170

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

171

171

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

172

172

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

173

173

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

176

176

Material 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

177

177

Pavement Materials & Design

Asphalt Materials

Binder Selection process

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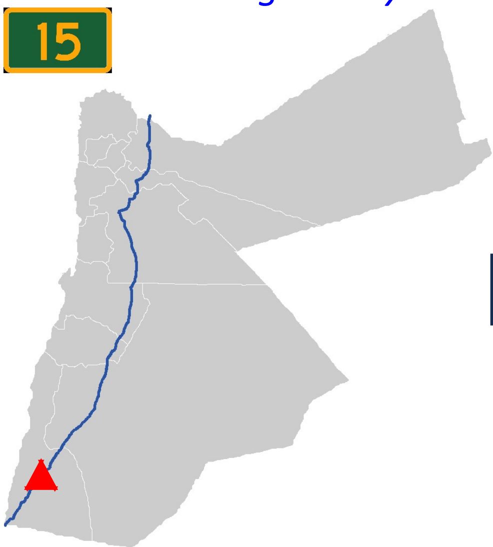
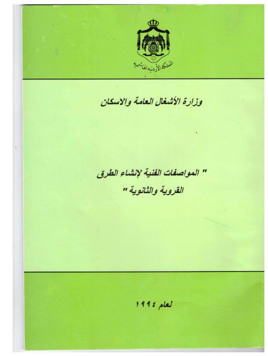
178

Binder Selection

Penetration grade system





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 ?

179

179

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 :

- الاسفلت ٨٠/١٠٠ للمناطق الباردة .
- 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

180

180

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)

181

181

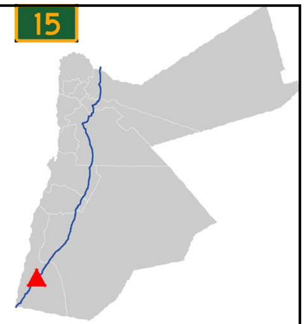
SuperPave binder selection process

1. Climate analysis

182

182

SuperPave binder selection process



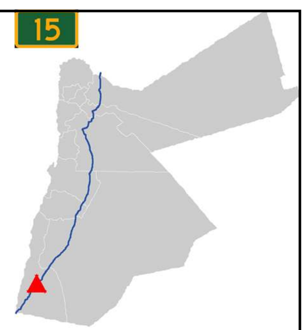
1. Climate analysis :

- ❑ 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*

183

183

1. Climate analysis :



By Pavement Temperature:

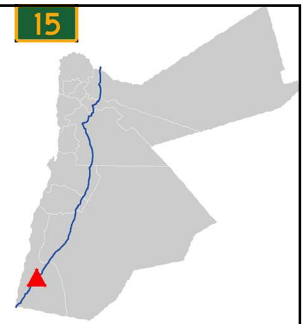
- ❑ The designer would need to know design pavement temperature.

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

184

184

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.

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

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

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City/location	Latitude (°)	Longitude (°)	Max. air temp.		Max. 7-day air temp.	Min. air temp.		Min. temp.
			Mean	SD		Mean	SD	
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
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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
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Aqaba	29.55	35.01	44.7	1.5	44.6	1.9	1.6	0.6

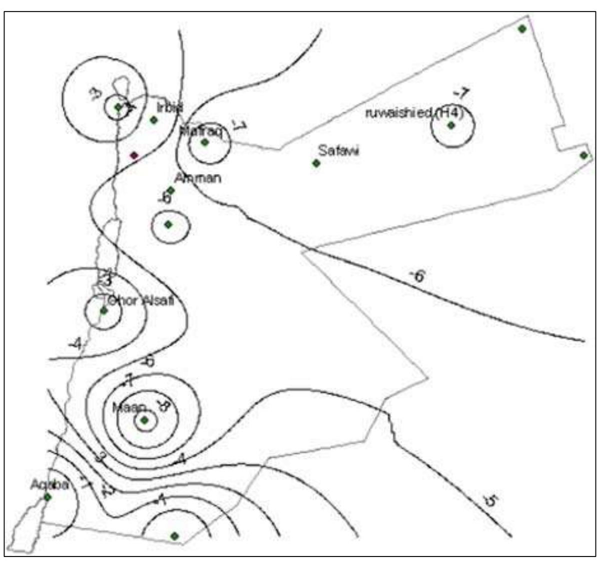
Table 4. Calculated pavement temperatures using SHRP algorithms.

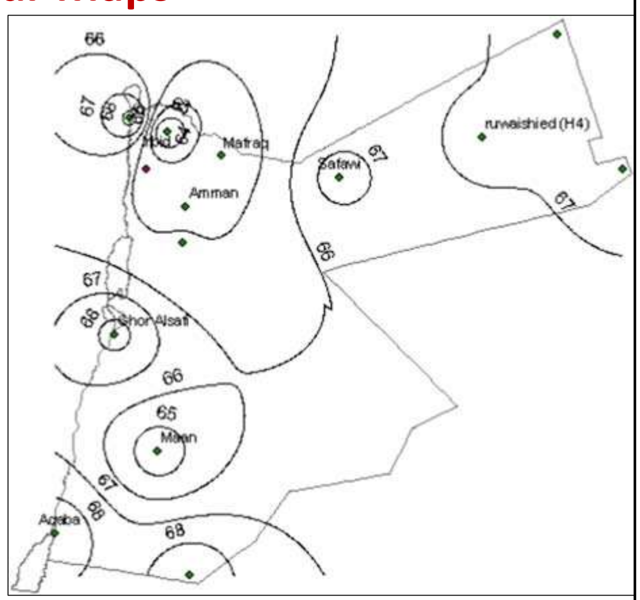
City/location	50% Reliability			98% Reliability		
	Max. pavement temp. (°C)	Min. air temp. (°C)	PG selection	Max. pavement temp. (°C)	Min. air temp. (°C)	PG selection
Irbid	58.9	−1.7	64-10	58.9	−1.7	64-10
Mafraq	61.6	−6.0	64-10	61.6	−6.0	64-10
Amman airport	61.3	−2.6	64-10	61.3	−2.6	64-10
Queen A. airport	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 &

187

Pavement temperature contour Maps





Minimum pavement temperature

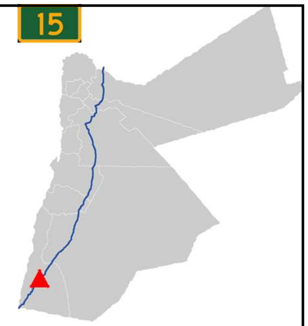
Maximum pavement temperature

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

188

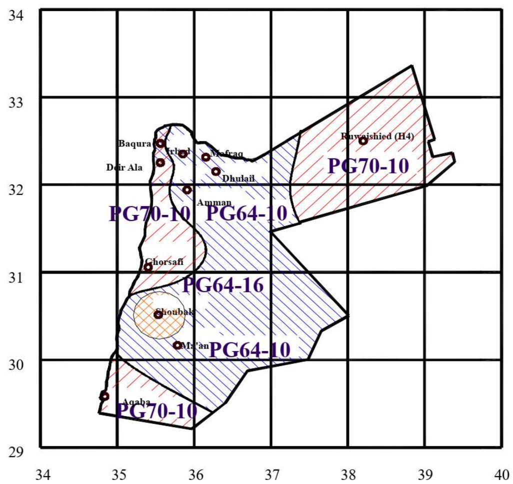
188

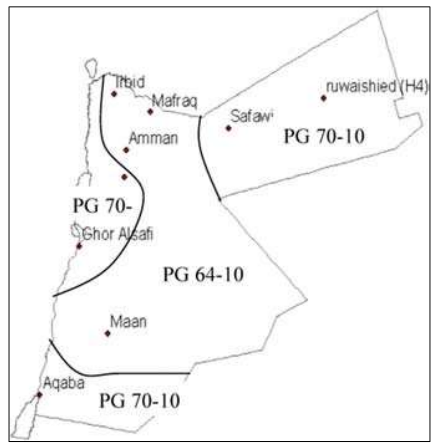
1. Climate analysis :



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



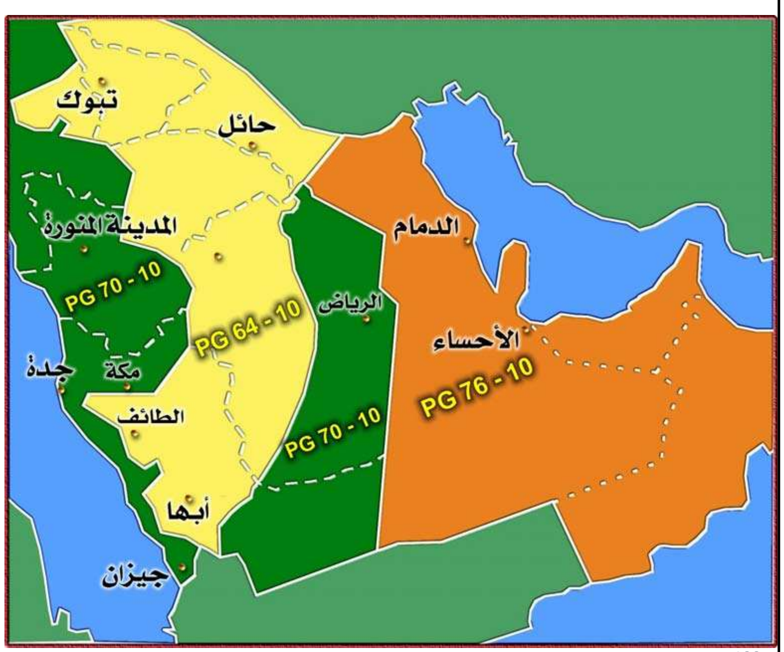


189

189

Base Binder selection

Application in Saudi Arabia



190

190

Asphalt Binder Selection in Jordan

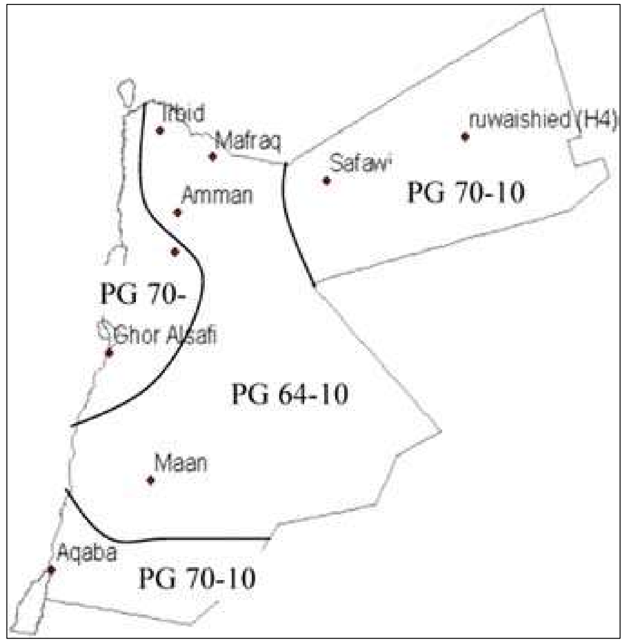
٦- يراعى استعمال :

- 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

191

191

SuperPave binder selection process

2. Reliability analysis

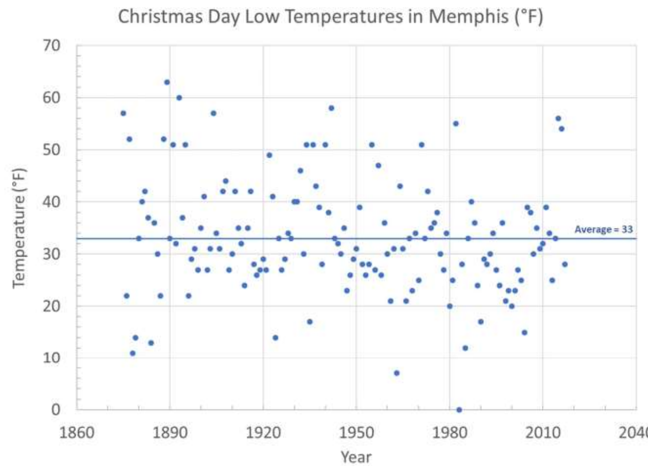
192

192

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.

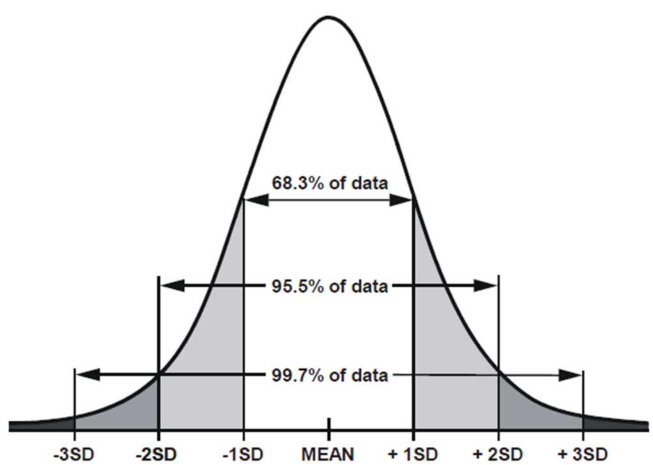


193

193

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.*



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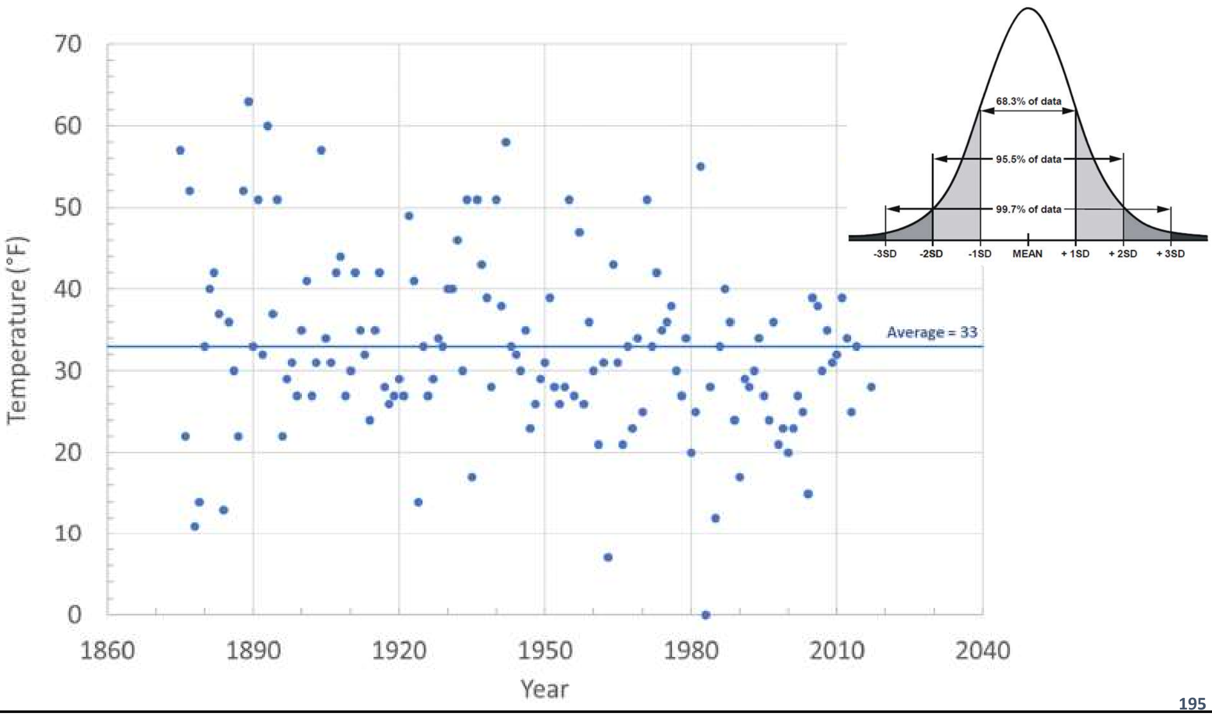


195

195

2. Reliability analysis

Importance

City/location	Min. air temp. 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

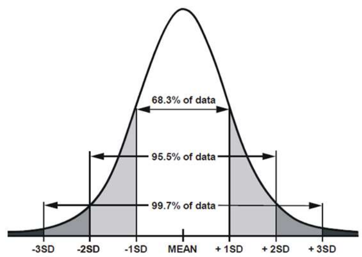
196

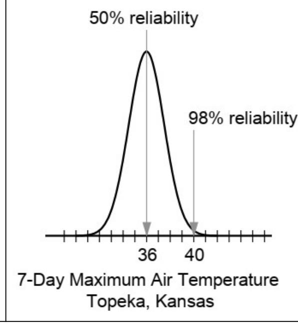
196

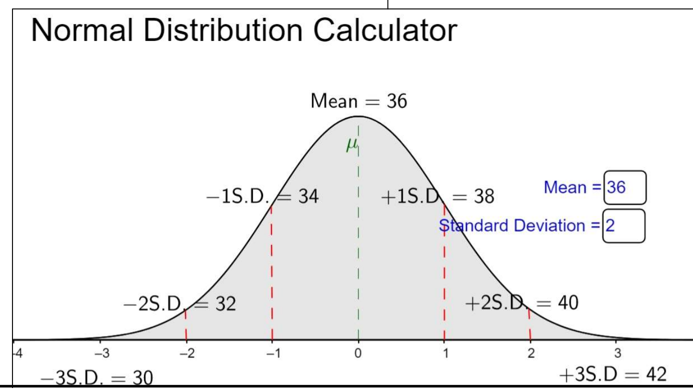
SuperPave binder selection process

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

198

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

199

199

SuperPave binder selection process

3. Base PG grade selection

200

200

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%)*

201

201

Example : Select the base grade

Given the following information select a base PG grade

In a normal summer,

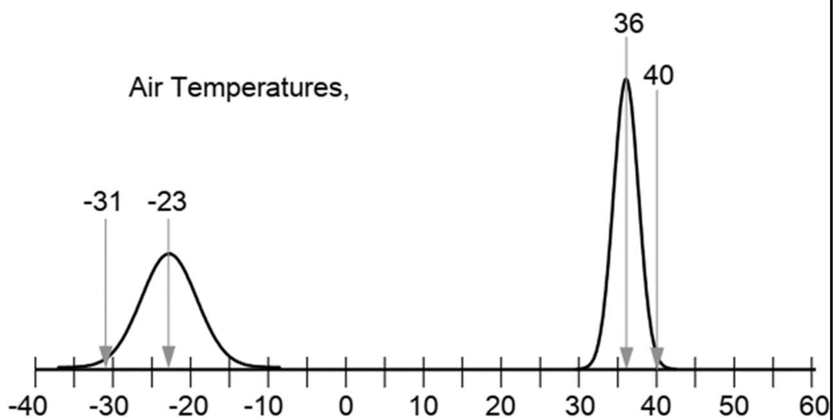
- *the average seven-day maximum **air** temperature is 36°C with*
- *a standard deviation of 2°C.*

❑ 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%*

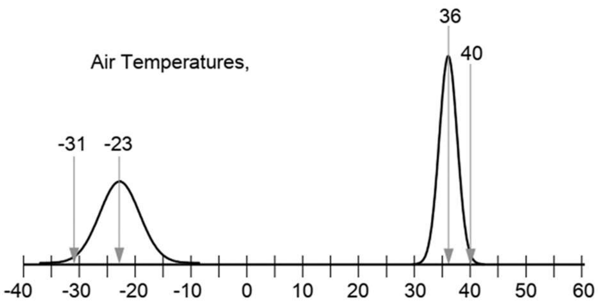


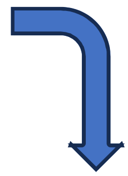
202

Example : Select the base grade

Solution

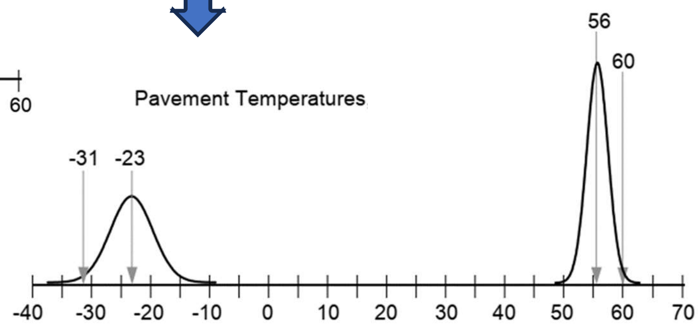
- Convert Air to Pavement Temperature





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

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.



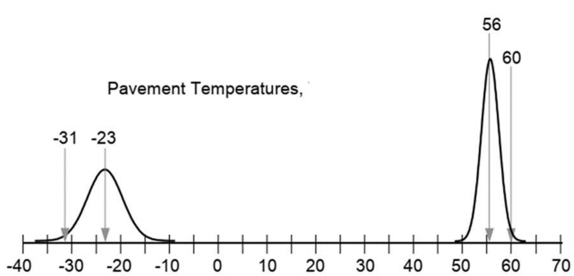
203

203

Example : Select the base grade

Reliability analysis for 50 % reliability

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



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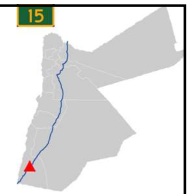
PG 58	−16, −22, −28, −34, −40
PG 64	−10, −16, −22, −28, −34, −40
PG 70	−10, −16, −22, −28, −34, −40
PG 76	−10, −16, −22, −28, −34
PG 82	−10, −16, −22, −28, −34

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

204

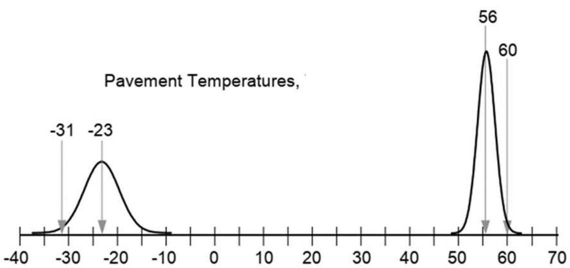
204

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



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PG 70	−10, −16, −22, −28, −34, −40
PG 76	−10, −16, −22, −28, −34
PG 82	−10, −16, −22, −28, −34

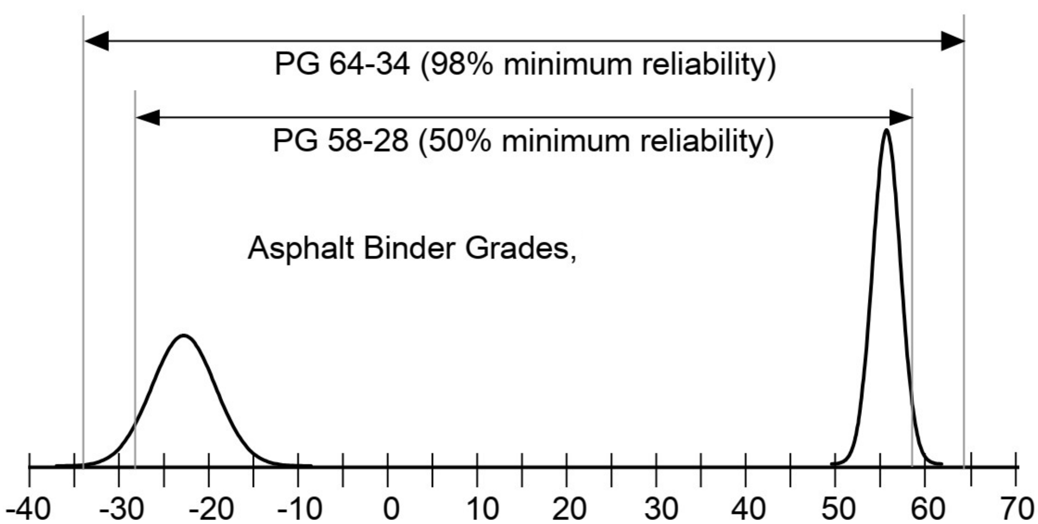
The closest standard PG asphalt binder grade that satisfies the two temperature grades is PG 64–34

205

205

Example : Select the base grade

Reliability analysis for 98 % reliability



206

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 &

208

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

210

210

SuperPave binder selection process

PG grade bumping

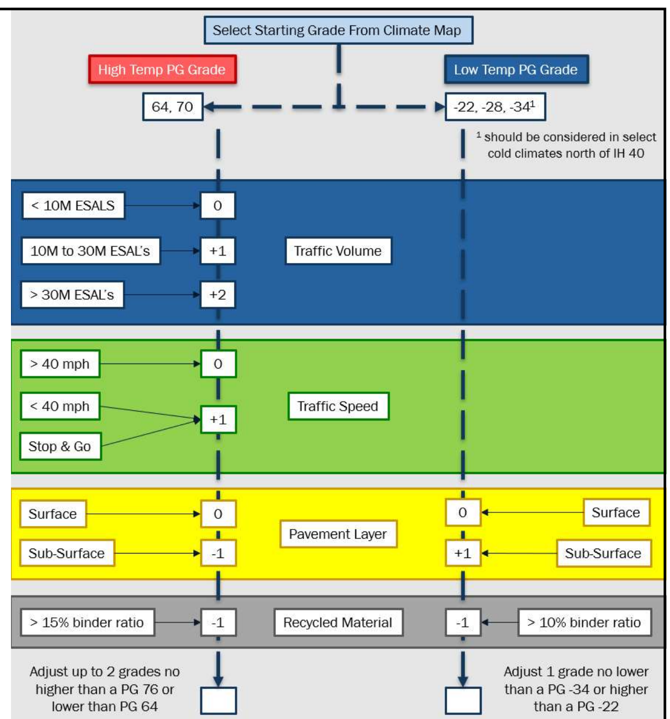
- The Superpave BASE PG binder is selected assuming the following conditions are met :
  - *Fast-loading rate, or fast-moving traffic*
  - *The binder for a surface layer (i.e., 20 mm below the surface)*
- PG grade bumping : Adjust the binder grade to consider the effect of
  1. *Traffic speed*
  2.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

211

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.

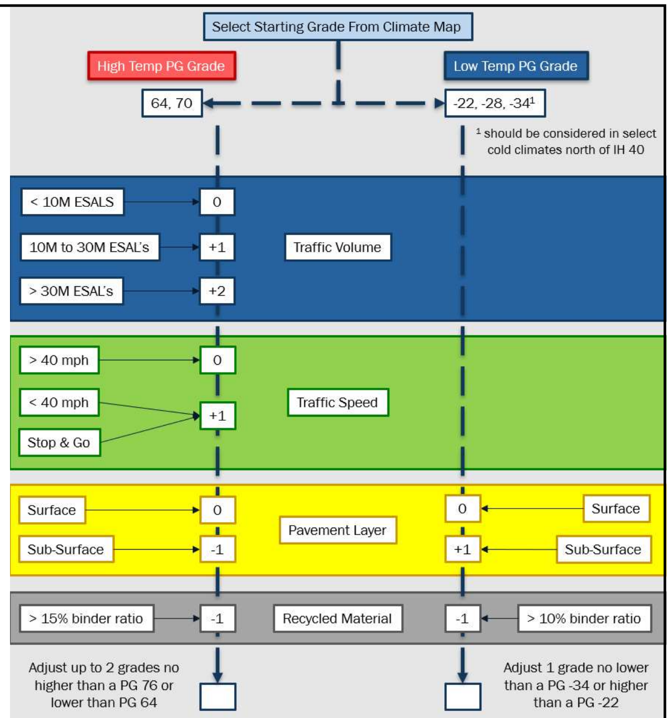


212

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

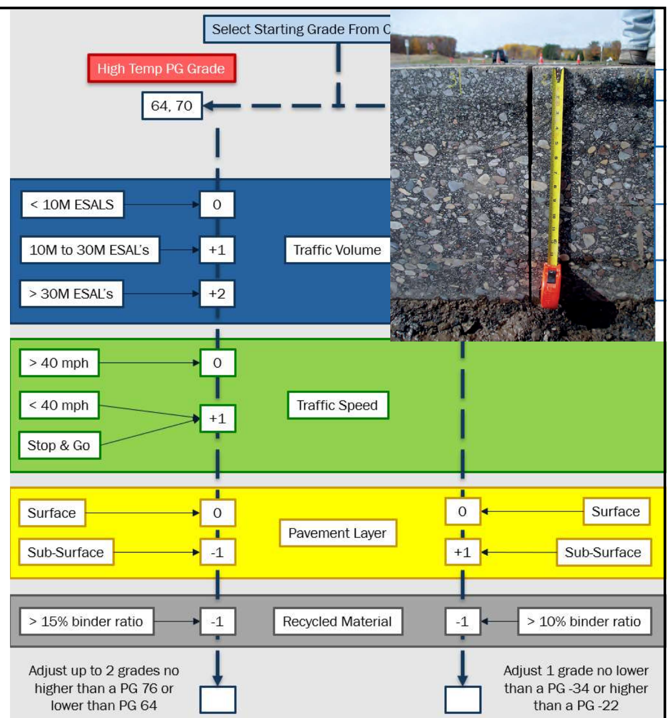


213

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*

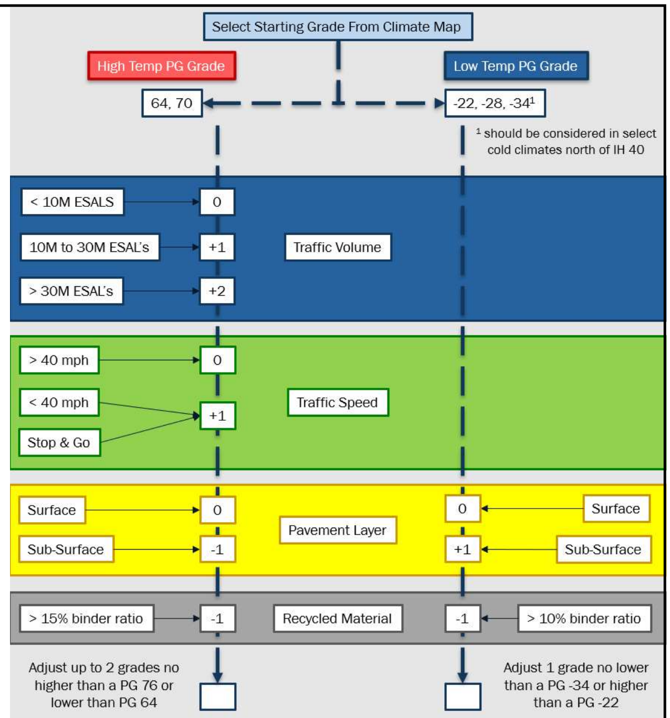


214

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

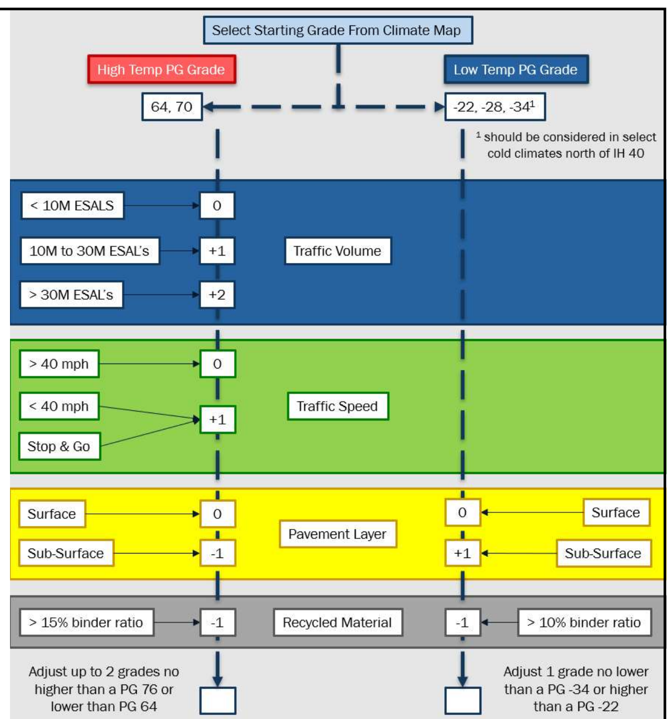


215

PG grade bumping

Layer location on Low PG

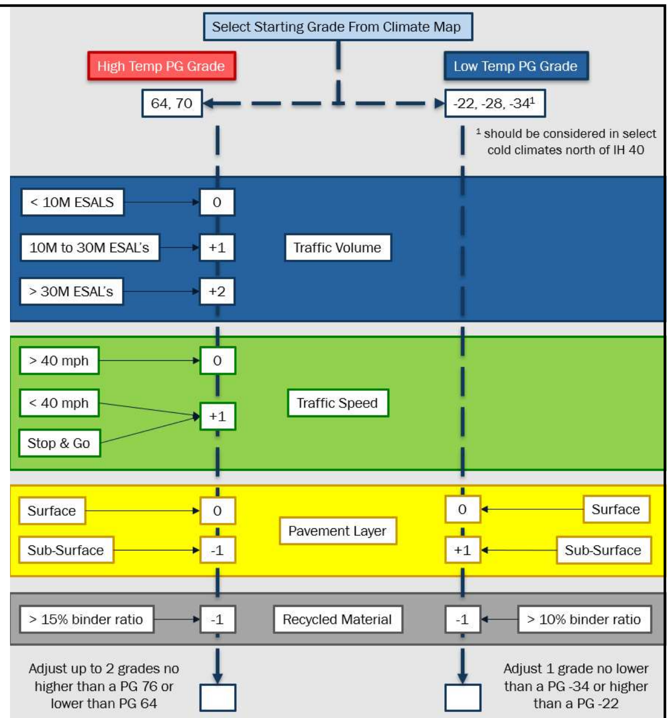
- Low-PG
  - Less pavement support means more deflection under traffic.
  - One possibility to address this is to "bump" the low temperature grade down,
- For instance, from a -22 to - 28.
  - This gives more cracking protection from temperature extremes but also makes the binder more fatigue resistant



216

PG grade bumping

Recycled Materials usage

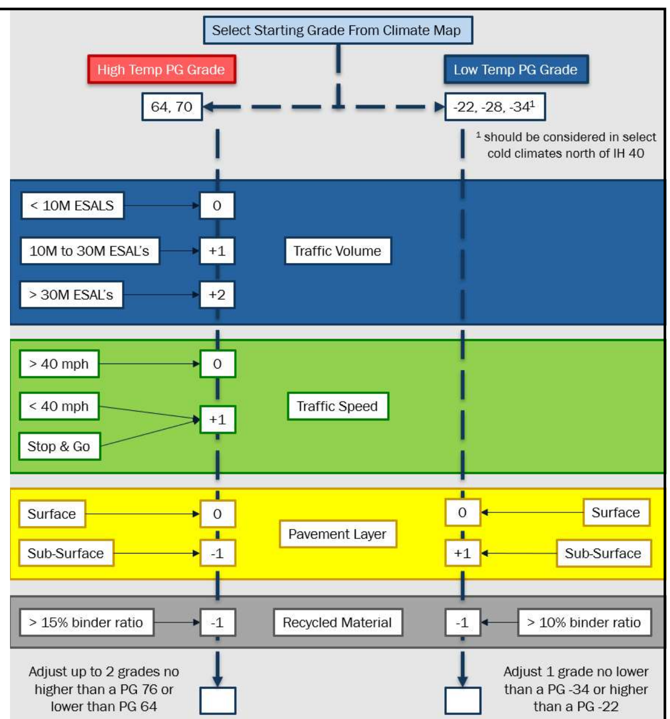


217

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.*



218

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

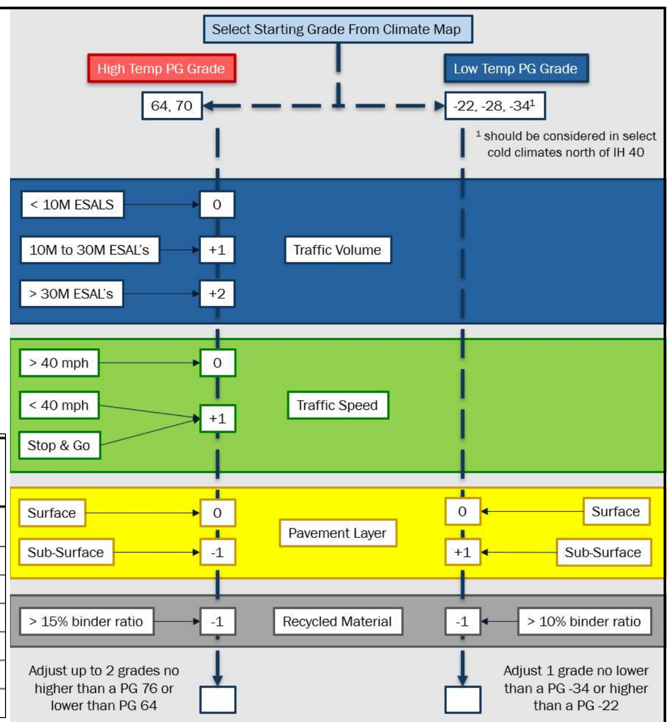
Table 4. Calculated pavement temperatures using SHRP algorithms.

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 &

219

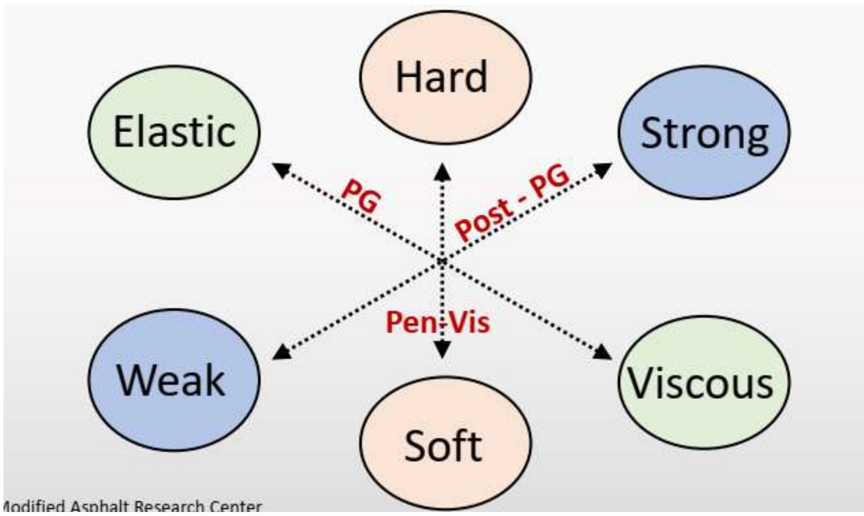
High Temperature Grades (°C)	Low Temperature Grades (°C)
PG 46	−34, −40, −46
PG 52	−10, −16, −22, −28, −34, −40, −46
PG 58	−16, −22, −28, −34, −40
PG 64	−10, −16, −22, −28, −34, −40
PG 70	−10, −16, −22, −28, −34, −40
PG 76	−10, −16, −22, −28, −34
PG 82	−10, −16, −22, −28, −34



220

Superpave Performance Grading

Evolution of Asphalt Specifications



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

224

224

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*

225

225