ASPHALT BINDER

Section 2 – Asphalt Performance Grading

1

Grading of Asphalt Binder

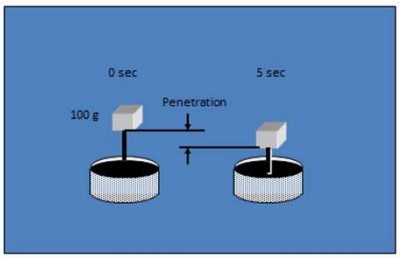
- Viscosity of original
- Viscosity of aged asphalt
- Penetration of original
- SHRP performance grading

2

Old Asphalt Testing Equipment

Penetration

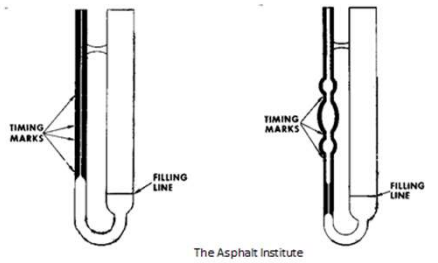
AASHTO T 49, ASTM D 5



3

Old Asphalt Testing Equipment

Absolute Viscosity



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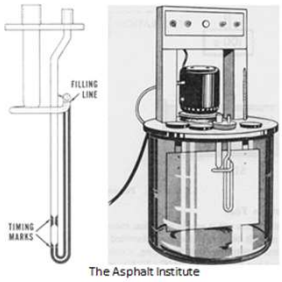
Section 2 - 4

4

Old Asphalt Testing Equipment

Kinematic Viscosity



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Section 2 - 5

5

Old Asphalt Testing Equipment

Cleveland Open Cup

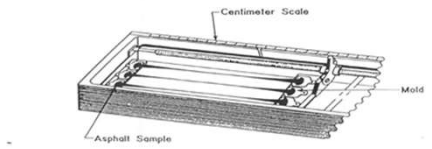
Section 2 - 6

6

Old Asphalt Testing Equipment

Ductility

AASHTO T 51, ASTM D 113



- Ability of the asphalt binder to deform without breaking
- 5 cm/s at 25°C
- Some interpret low ductility to indicate brittle asphalt binders

Section 2 - 7

7

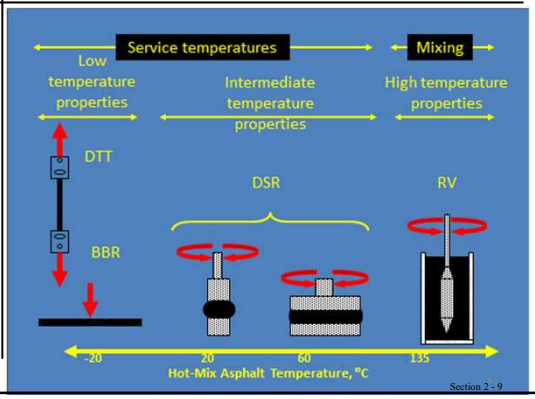
Performance Grading (PG) Asphalt Testing Equipment

Equipment	Purpose	Performance Property
Rotational Viscometer	Handling pumping	Flow
Rolling Thin Film Oven Test Pressure Aging Vessel	Simulate aging through Hot Plant Simulate long term aging	n/a
Dynamic Shear Rheometer	Measure properties @ high & intermediate temperature	Permanent deformation & fatigue cracking
Bending Beam Rheometer Direct Tension Tester	Measure properties @ low temperature	Low temperature cracking

Section 2 - 8

8

Asphalt Performance Grading (PG)



Section 2 - 9

9

PG Asphalt Tests (Aging)

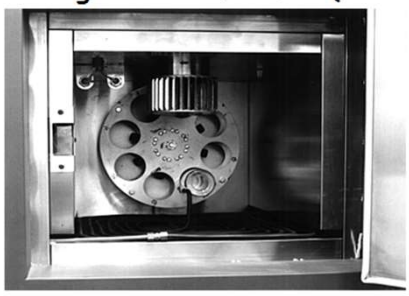
- **Rolling Thin Film Oven (RTFO): It simulates the condition of asphalt immediately after construction**
- **Pressure Aging Vessel (PAV): It simulates the aging of asphalt after years of being in service. PAV samples must be RTFO aged first**

Section 2 - 10

10

PG Asphalt Testing Equipment

Rolling Thin Film Oven (RTFO)



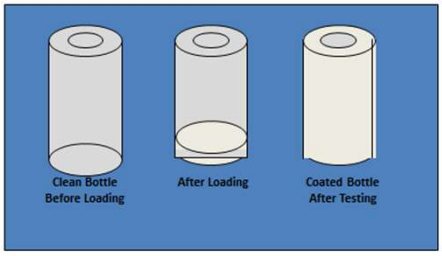
Section 2 - 11

11

PG Asphalt Testing Equipment

Rolling Thin Film Oven

Sample Bottles



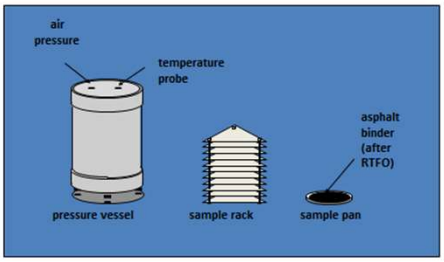
Section 2 - 12

12

PGAsphalt Testing Equipment

Pressure Aging Vessel (PAV)

AASHTO PP1



Section 2 - 13

13

PG Asphalt Testing Equipment

PAV

Section 2 - 14

14

PG Asphalt Tests (Rotational Viscometer)

- **RV measures the viscosity of asphalt or tank asphalt at 135°C**
- **RV is used to determine if the asphalt is fluid enough to handle**
- **RV is performed on unaged asphalt only**

Section 2 - 15

15

PG Asphalt Testing Equipment

Rotational Viscometer

Section 2 - 16

16

PG Asphalt Tests (Dynamic Shear Rheometer)

- DSR is performed to check rutting and fatigue cracking
- DSR is used to characterize the viscous and elastic behavior of asphalt
- DSR measures the complex shear modulus (G*) and phase angle (delta)
- DSR is performed on original, RTFO aged binder, and PAV aged binder

Section 2 - 17

17

PG Asphalt Testing Equipment

DSR

Section 2 - 18

18

PG Asphalt Tests (Bending Beam Rheometer)

- BBR is performed to check low temperature cracking
- BBR measures stiffness at very low temperatures
- BBR measures asphalt deflection under a constant load at a constant temperature. Parameters determined are stiffness (s) and slope (m)
- BBR is performed on PAV aged asphalt

Section 2 - 19

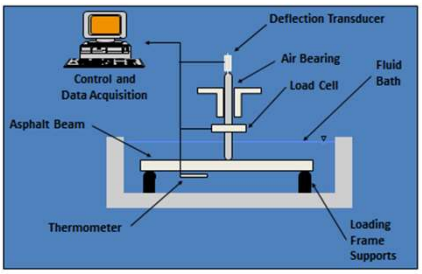
19

PG Asphalt Testing Equipment

Bending Beam Rheometer

AASHTO TP1

Evaluate low temperature creep stiffness of the asphalt binder

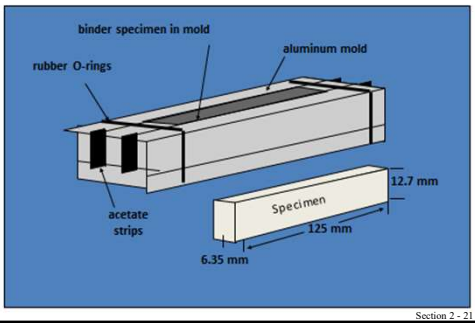


Section 2 - 20

20

PG Asphalt Testing Equipment

BBR Specimen Mold



Section 2 - 21

21

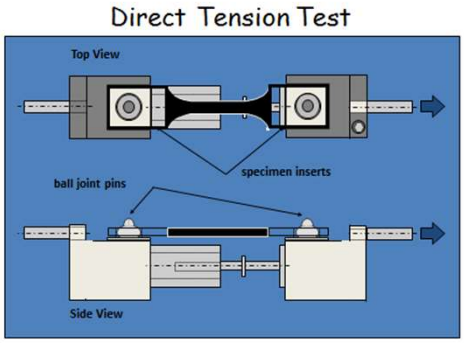
PG Asphalt Tests (Direct Tension Tester)

- DTT is performed to check low temperature cracking
- DTT supplements the BBR
- DTT is not used in specification compliance
- DTT is performed on PAV aged asphalt

Section 2 - 22

22

PG Asphalt Testing Equipment



Section 2 - 23

23

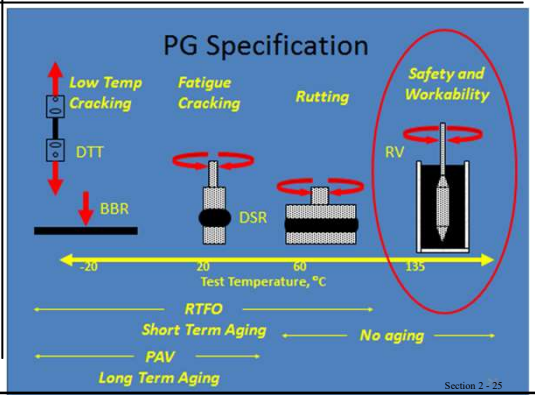
Asphalt Performance Grading (PG)

- The main objective of PG is to improve field performance by limiting the potential of asphalt to contribute toward rutting, fatigue cracking, and low temperature cracking
- Physical properties are constant but the testing temperatures are different

Section 2 - 24

24

Asphalt Performance Grading (PG)



25

Asphalt Performance Grading (PG)

- The required PG grading for a specific location can be determined based on high and low pavement temperature
- High pavement temperature is calculated at a .8" (20 mm) depth based on seven-day average high air temperature and the geographic latitude of the project
- Low pavement surface temperature is determined based on the one-day minimum air temperature

Section 2 - 26

26

Asphalt Performance Grading (PG)

- The reliability concept is used to determine a degree of design risk to high and low temperatures
- Reliability levels range from 50 to 98 percent
- Current SHRP recommendations are to use 98% for the high traffic end and 50% for the low traffic end
- Air temperatures are available for thousands of weather stations nationwide

Section 2 - 27

27

Asphalt Performance Grading (PG)

- Seven grades are available based on high temperature (46, 52, 58, 64, 70, 76, and 82°C)
- Up to seven grades are available based on low pavement temperature [-10, -16, -22, -28, -34, -40, and -46°C]
- Examples: PG 52-22, PG 64-28
- Not all low temperatures are available with some high temperatures
- Deeper pavement layers may have lower grades

28

Performance Grade Table

Performance Grade	PG 46			PG 52						
	-34	-40	-46	-10	-16	-22	-28	-34	-40	-46
Average 7-day maximum Pavement Design temperature,°C	<46			<52						
Minimum Pavement Design temperature,°C	>-34	>-40	>-46	>-10	>-16	>-22	>-28	>-34	>-40	>-46
Original Binder										
Flash Point Temp, T48: Minimum °C	230									
Viscosity, ASTM D 4402: Maximum, 3 Pas (3000cP), Test, °C	135									
Dynamic Shear, TP5: G*/sinδ, Minimum, 1.00 kPa Test Temperature @ 10rad/s, °C,	46			52						
Rolline Thin Film Oven (T 240) or Thin Film Oven (T 179) Residue										
Mass Loss, maximum , %	1.00									
Dynamic Shear, TP5: G*sinδ, Maximum, 2.20 kPa Test Temp @ 10rad/sec, °C,	46			52						
Pressure Aging Vessel Residue (PP1)										
PAV Aging Temperature, °C	90			90						
Dynamic Shear, TP5: G*sinδ, Maximum, 5000 kPa Test Temp @ 10rad/sec, °C	10	7	4	25	22	19	16	13	10	7
Report										
Creep Stiffness, TP1: S, Maximum, 300 MPa m-value, Minimum, 0.300 Test Temp, @ 60 sec, °C	-24	-30	-36	0	-6	-12	-18	-24	-30	-36
Direct Tension, TP3: Failure Strain, Minimum, 1.00% Test Temp @ 1.0 mm/min,°C	-24	-30	-36	0	-6	-12	-18	-24	-30	-36

29

Performance Grade Table

Performance Grade	PG 58					PG 64					
	-16	-22	-28	-34	-40	-10	-16	-22	-28	-34	-40
Average 7-day maximum Pavement Design temperature,°C	<58					<64					
Minimum Pavement Design temperature,°C	>16	>22	>28	>34	>40	>10	>16	>22	>28	>34	>40
Original Binder											
Flash Point Temp, T48: Minimum °C	230										
Viscosity, ASTM D 4402: Maximum, 3 Pas (3000cP), Test, °C	135										
Dynamic Shear, TP5: G*/sinδ, Minimum, 1.00 kPa Test Temperature @ 10rad/s, °C,	58					64					
Rolline Thin Film Oven (T 240) or Thin Film Oven (T 179) Residue											
Mass Loss, maximum , %	1.00										
Dynamic Shear, TP5: G*sinδ, Maximum, 2.20 kPa Test Temp @ 10rad/sec, °C,	58					64					
Pressure Aging Vessel Residue (PP1)											
PAV Aging Temperature, °C	100					100					
Dynamic Shear, TP5: G*sinδ, Maximum, 5000 kPa Test Temp @ 10rad/sec, °C	25	22	19	16	13	31	28	25	22	19	16
Physical Hardening	Report										
Creep Stiffness, TP1: S, Maximum, 300 MPa m-value, Minimum, 0.300 Test Temp, @ 60 sec, °C	-6	-12	-18	-24	-30	0	-6	-12	-18	-24	-30
Direct Tension, TP3: Failure Strain, Minimum, 1.00% Test Temp @ 1.0 mm/min,°C	-6	-12	-18	-24	-30	0	-6	-12	-18	-24	-30

30

Performance Grade Table

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 maximum Pavement Design temperature,°C	<70						<76					<82				
Minimum Pavement Design temperature,°C	> -10	> -16	> -22	> -28	> -34	> -40	> -10	> -16	> -22	> -28	> -34	> -10	> -16	> -22	> -28	> -34
Original Binder																
Flash Point Temp, T48: Minimum °C	230															
Viscosity, ASTM D 4402: Maximum, 3 Pas (3000cP), Test, °C	135															
Dynamic Shear, TP5: G*/sinδ, Minimum, 1.00 kPa Test Temperature @ 10rad/s, °C,	70						76					82				
Rolling Thin Film Oven (T 240) or Thin Film Oven (T179) residue																
Mass Loss ,Minimum , %	1.00															
Dynamic Shear, TP5: G*/sinδ, Minimum, 2.20 kPa Test Temp @ 10rad/sec, °C	70						76					82				
Pressure Aging Vessel Residue (PAV)																
PAV Aging Temperature, °C	100(110)						100(110)					100(110)				
Dynamic Shear, TP5: G*sinδ, Maximum, 5000 kPa Test Temp @ 10rad/sec, °C	34	31	28	25	22	19	34	31	28	25	22	34	31	28	25	22
Physical Hardening	Report															
Creep Stiffness, TP1: S, Maximum, 300 MPa m-value, Minimum, 0.300 Test Temp. @ 60 sec. °C:	0	-6	-12	-18	-24	-30	0	-6	-12	-18	-24	0	-6	-12	-18	-24
Direct Tension, TP3: Failure Strain, Minimum, 1.00% Test Temp @ 1.0 mm/min,°C	0	-6	-12	-18	-24	-30	0	-6	-12	-18	-24	0	-6	-12	-18	-24

Section 2 - 31

31

Table: Asphalt Binder Grades and Reliability for Selected Cities (Asphalt Institute)

ST	Station	Latitude	Min 50% Grade	Actual Reliability High	Actual Reliability Low	Min 98% Grade	Actual Reliability High	Actual Reliability Low
FL	Miami WSCOMO AP	25.80	PG 58-10	99	99.9	PG 58-10	99	99.9
WY	Cheyenne WSFO AP	41.15	PG 52-22	68	55	PG 58-28	99.9	98.9
TX	Houston FAA AP	29.65	PG 64-10	99.9	99.3	PG 64-10	99.99	99.3
NY	New York Inter AP	40.65	PG 52-16	61	97.1	PG 58-16	99.9	97.1
CO	Denver WSFO AP	39.77	PG 58-22	99.9	78	PG 58-28	99.9	99
CA	Los Angles WSO AP	33.93	PG 52-10	66	99.9	PG 58-10	99.9	99.9

Section 2 - 32

32

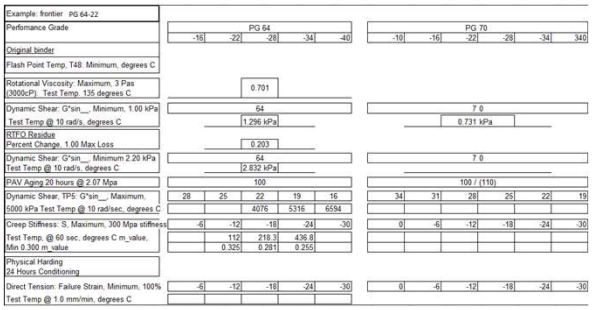
Asphalt Performance Grading (PG)

- **Cheyenne, Wyoming PG 52-22 @ 50 percent reliability**
- **Cheyenne, Wyoming PG 58-28 @ 98 percent reliability**
- **Miami Florida PG 58-10 @ 50 percent reliability**
- **Miami Florida PG 58-10 @ 98 percent reliability**
- **WYDOT uses LTPP-Bind for determination of appropriate grade for any particular layer.**

Section 2 - 33

33

Example: Frontier PG64-22



Example: frontier PG 64-22	PG 64					PG 70					
Performance Grade	-16	-22	-28	-34	-40	-10	-16	-22	-28	-34	340
Original binder											
Flash Point Temp, T48: Minimum, degrees C											
Rotational Viscosity: Maximum, 3 Pas (3000cP), Test Temp, 135 degrees C			0.701								
Dynamic Shear: G*sin__, Minimum, 1.00 kPa			64					7.0			
Test Temp @ 10 rad/s, degrees C			1.296 kPa					0.731 kPa			
RTFO Residue											
Percent Change, 1.00 Max Loss			0.203								
Dynamic Shear: G*sin__, Minimum 2.20 kPa			64					7.0			
Test Temp @ 10 rad/s, degrees C			2.832 kPa								
PAV Aging 20 hours @ 2.07 Mpa			100					100 / (110)			
Dynamic Shear, TP5: G*sin__, Maximum,	28	25	22	19	16	34	31	28	25	22	19
5000 kPa Test Temp @ 10 rad/sec, degrees C			4076	5316	6594						
Creep Stiffness: S, Maximum, 300 Mpa stiffness	-6	-12	-18	-24	-30	0	-6	-12	-18	-24	-30
Test Temp, @ 60 sec, degrees C m_value,		112	218.3	436.8							
Min 0.300 m_value		0.325	0.281	0.255							
Physical Harding											
24 Hours Conditioning											
Direct Tension: Failure Strain, Minimum, 100%	-6	-12	-18	-24	-30	0	-6	-12	-18	-24	-30
Test Temp @ 1.0 mm/min, degrees C											

34

Asphalt Performance Grading (Example)

- Frontier PG 64-22
- Tested at the Materials office: PG 64-22
- Is it good for Cheyenne at 50% reliability?
- Is it good for Cheyenne at 98% reliability?

35

PG Asphalt Grade Adjustment

	Traffic speed		
ESALs (million)	>70Km/h	20-70 Km/h	<20 Km/h
<0.3	-	-	-
0.3 to <3	-	1	2
3 to <10	-	1	2
10 to <30	-	1	2
>= 30	1	1	2

NOT USED ANYMORE

70 Km/h =43.5 MPH; 20 Km/h = 12.5 MPH

36

WYDOT MSCR PGAB Specifications

Section 2 - 37

37

WYDOT MSCR PGAB Spec

- Current Spec (AASHTO M320)
- MSCR Spec (AASHTO M332)
  - Background
  - Differences
  - State Implementation
- WYDOT Special Provision
  - Changes
  - Summary
  - Timeline

38

38

WYDOT MSCR PGAB Spec

Current Spec (AASHTO M320)

- Used since mid-1990's
- Improvement over pen & viscosity grading (AC's)
- 1st 'performance-based' spec for neat binders
  - Research basis

    (fundamental materials science -SHRP $150M, 5 yrs 1987-92;not anecdotal or empirical)
- 'Workarounds' for Modified binders
  - Uses 'grade-bumping' (58→64, 64→70, 70→76)

39

39

WYDOT MSCR PGAB Spec

MSCR Spec (AASHTO M332) -*Background*

- **Multiple Stress Creep Recovery (MSCR)**
  - **Research**
    - **NCHRP 9-10 project (Report 459, August 2001)**
  - **Data Collection *(WYDOT)***
    - **2009-present**

40

40

WYDOT MSCR PGAB Spec

MSCR Spec (AASHTO M332) -*Differences*

- **Measures performance of neat & modified PGAB**
  - **Rutting (pavement mix; binder & aggregate)**
  - **Differentiate modifiers (quantity, system synergy)**
    - **Replaces 'SHRP+' tests with % Recovery**
- **Eliminates 'grade-bumping' (64~~→70~~,...)**
- **Includes temperature *and traffic***
  - **Climate (LTPPBind; 7900+ stations, US & Canada)**
  - **Traffic loading (ESAL's & speed)**

41

41

WYDOT MSCR PGAB Spec

MSCR Spec (AASHTO M332) –*State Implementation*

- **Implemented by States (26 as of 2023)**
  - **2013 (FL, RI)**
  - **2014 (CT, MD, ME, NY, PA)**
  - **2016-2018**
    (DE, GA, HI, IA, KY, LA, MA, MN, MO, NE, ND, NJ, OK, TN, VA, WA, WI, WV)
  - **2023 (MT)**
  - **2024 (WY)**

42

42

WYDOT MSCR PGAB Spec

WYDOT Special Provision -Changes

- MSCR test ($J_{nr3.2}$, $R_{3.2}$) replaces elastic recovery
- No 'grade-bumping' (PG64 max; 70 & 76's N/A)
- Adds 'traffic loading designation' (S, H, V, E)
  - Million ESAL's (equivalent single axle load)
    - <10, 10 - 30, > 30 (for 20 yr design service life)
  - Traffic speed
    - >40 mph (fast), 12-40 mph (slow), <12 mph (standing)

43

43

Typical Grades

Neat Binders	Typical Grades	Other Grades
PG 58S-28	PG 58S-34	PG 64H-34
PG 64S-22	PG58H-34	PG 64V-34
	PG58V-34	
	PG 64S-28	
	PG64H-28	
	PG64V-28	

44

44

According to FHWA Tech Brief

Table 1: The MSCR gradings reflect the current grade bumping limits.

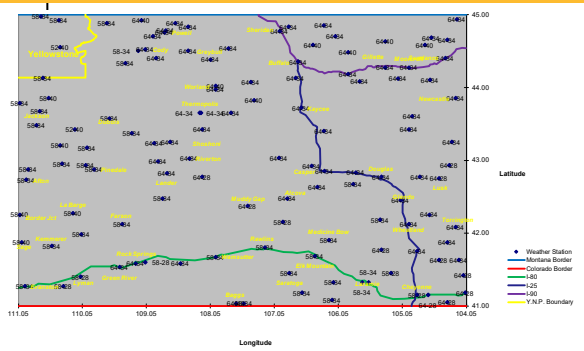
Standard S grade	Standard Traffic Loading (<10 million ESAL's & High Traffic Speed (>70 km/h)) traffic < 3 million ESAL's
Heavy H grade	Heavy Traffic Loading (10 million ESAL's - 30 million ESAL's or Slow Traffic Speed (20-70 km/h)) traffic > 3 million ESAL's
Very Heavy V grade	Very Heavy Traffic Loading (>30 million ESAL's or standing traffic (<20 km/h)) traffic > 10 million ESAL's
Extreme E grade	Extremely Heavy Traffic Loading (>30 million ESAL's & standing traffic (<20 km/h)) traffic > 30 million ESAL's

45

45

WYDOT MSCR PGAB Spec

WYDOT Special Provision -Changes



46

46

WYDOT MSCR PGAB Spec

WYDOT Special Provision –Timeline

- **Short term (2024) -**
  - **Add to all plans starting with Oct' 2023 letting**
- **Long term (after 2026?) –**
  - **Move SP to Supplemental Specs then Standard Spec**

47

47

Changing Grade of Binder

- **The grade of asphalt will be specified.**
- **The contractor may use a different grade according with the following (WYDOT 401.2.1)**
  - **The upper temperature may be increased.**
  - **The lower temperature may be decreased.**
  - **The DOT should be notified in writing of any changes before mix production begins.**
  - **Repeated changing of grades will not be allowed.**

Section 2 - 48

48