

# THE BASICS OF ASPHALT BINDERS

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2026 Spring Training

# What is Asphalt?

- A high molecular weight thermoplastic hydrocarbon found in crude petroleum oils
- Asphalt can occur naturally – Pitch Lake in Trinidad & Lake Bermudez in Venezuela
- Has been used for thousands of years – Mesopotamia & Ancient Egypt used as an adhesive and waterproofing
- First asphalt road in the U.S. – 1870 in New Jersey
- The “best glue in the world”

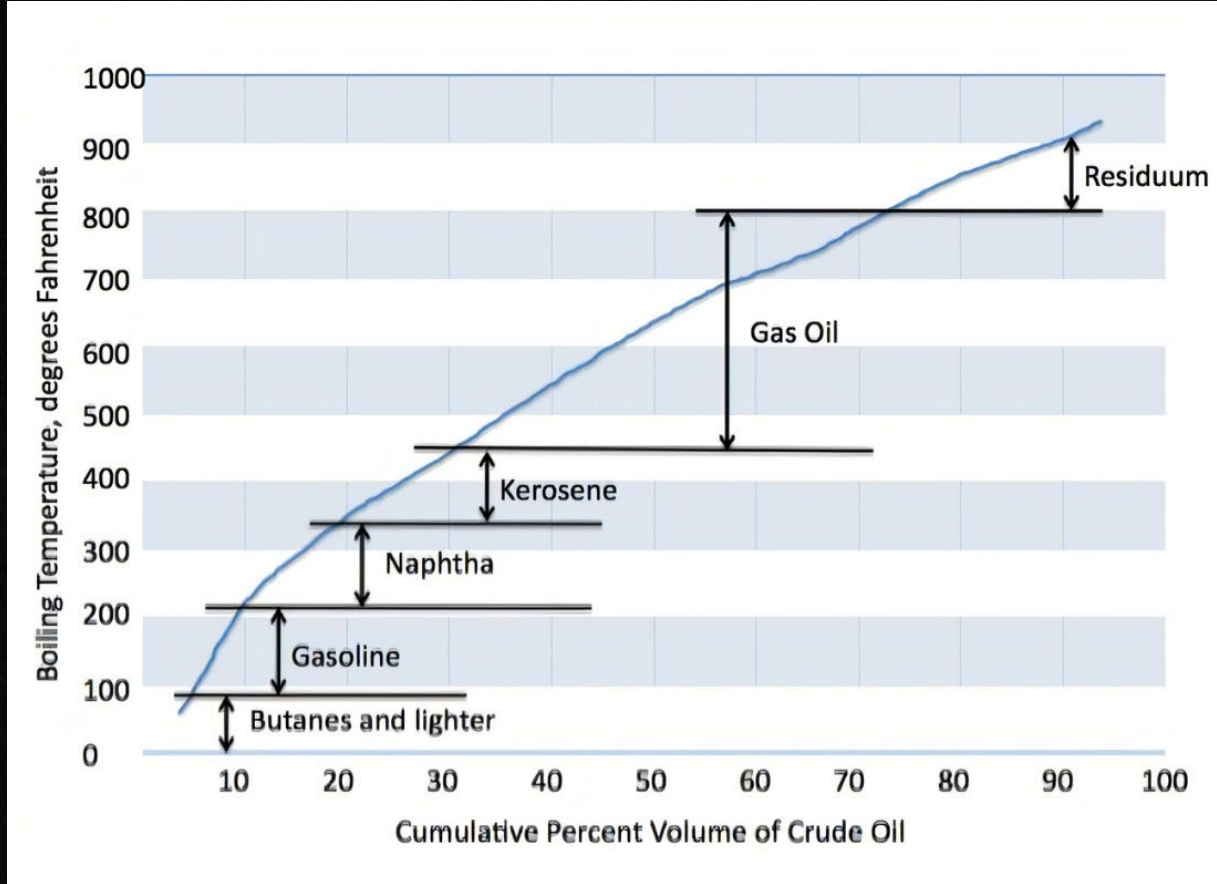


# Asphalt From Crude Oil



- Crude Oil was formed millions of years ago by the bacterial decomposition of organic matter, both plant and animal, buried under heavy layers of our earth's sediment.
- Asphalt Cement is NOT tar.

# Crude Oil Production - Fractional Distillation



- Propane
- Butane
- Gasoline
- Naphtha
- Kerosene
- Diesel
- Gas Oils
- Asphalt

## Crude Oil Breakdown

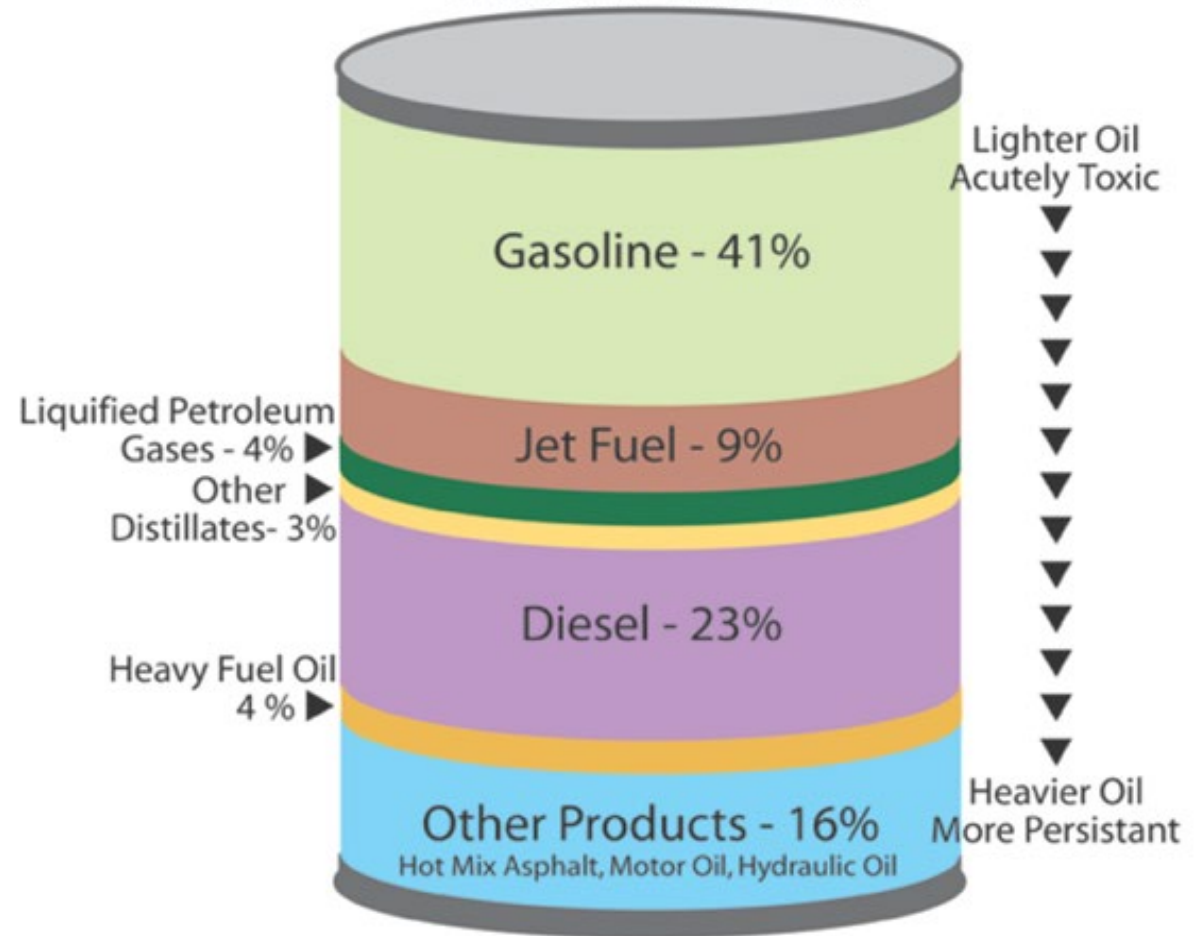
Asphalt Cement is the “bottom of the barrel.”

Crude oils vary, widely. As a generality:

1 Barrel = 42 gallons

## Percentage\* of Products Made from a Barrel of Crude Oil

\*General Statement - Distribution Varies



# SWEET CRUDE vs. SOUR CRUDE

- Sweet crude oil is considered “sweet” if it contains less than 0.5% sulfur. Early prospectors would taste oil to determine its quality – lower sulfur oil actually - tasted sweet.
- Sour crude oil contains impurity sulfur levels greater than 0.5%.
- Before sour crude oil can be refined into gasoline, impurities need to be removed, therefore increasing the cost of processing.
- Sweet crude is mainly found in the Appalachian Basin in Eastern North America, Western Texas, the Bakken Formation of North Dakota & Saskatchewan, the European North Sea, North Africa, Australia, and the Far East/Indonesia.
- Sour crude is more common in the Gulf of Mexico, Mexico, South America, and Canada. Crude produced by OPEC Member Nations also tends to be relatively sour, with an average sulfur content of around 2.0%.

# LIGHT vs. HEAVY CRUDE

- Difference between light & heavy oil - compares to the liquid density of water
- Light Crude Oil has a lower density – lighter than water - floats.
- Heavy Crude Oil has a higher density – heavier than water - sinks.
- Heavier crude oil is harder to refine. Heavy crude oil is also known as “tar sands” because of its high bitumen content.
- Light crude tends to trade at a premium because it is easier to refine and produces more gasoline and diesel fuel.
- Asphalt cement in the U.S. is from a combination of these sources based on the current economics

# Asphalt Nomenclature

- History of Asphalt Nomenclature
- Today's Performance Graded Asphalts
- Comparison of Performance Graded vs. MSCR

## History of AC Nomenclature



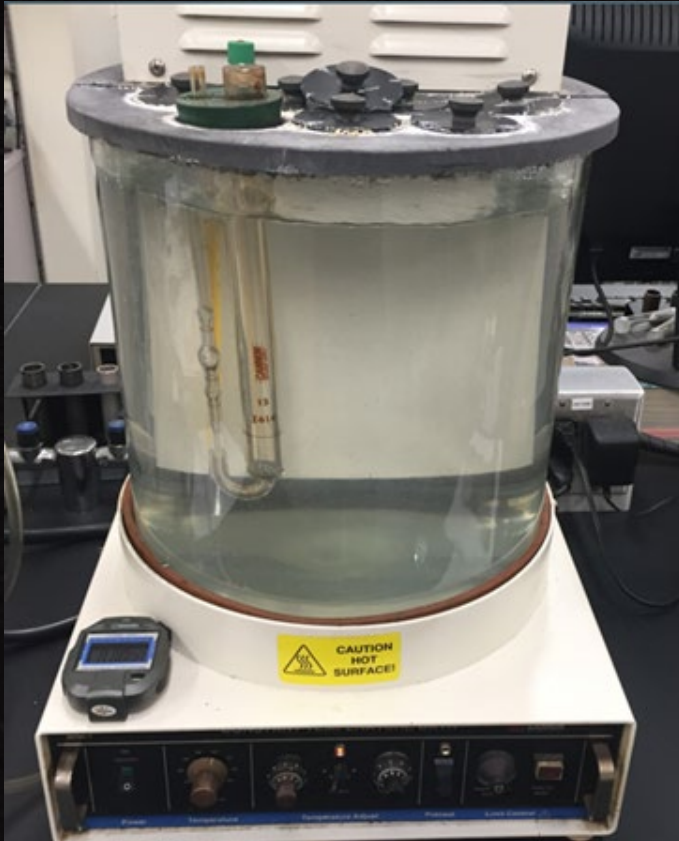
- Prior to 1970, asphalts were specified as penetration grades: 5/9, 50/60, 60/70, 85/100, 140/160, and >300 pen
- The penetration of an asphalt is determined by the depth that a free-falling weighted needle penetrates an asphalt sample, at a specified temperature, weight and time. The needle penetration, measured in mm/10, is the penetration of the asphalt. More commonly this is simply referred to as the “pen.”

Asphalt.

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## History of AC Nomenclature



- Beginning in 1970, asphalts were specified as viscosity grades. AC-5, AC-10, AC-20, AC-30 and AC-40
- Testing performed in Absolute Viscometer. Measuring flow of material through a calibrated capillary tube under set temperature and vacuum. *What did the 30 in AC-30 mean? Multiply  $30 \times 100 = 3000$ . This was the middle of the acceptable viscosity range for the AC-30 specification.*
- *Lower the ending number, the thinner/softer the oil was.*

# Performance Grades – PG Asphalt

- In the 1990's State DOTs began to specify SHRP (Strategic Highway Research Program) or Performance Grades of Asphalts: PG 58-28, PG 64-22, PG 70-22, PG 76-22, etc.
- Thought process of SHRP – Performance Grades were created at the same time as Super Pave HMA processes. Transitioning the industry toward where we are today.
- PG Binder Criteria:
  - Designed to utilize Rheological testing, at different desired climatical temperatures, at different points of binders “life cycle”
  - Rheology – *“the science of deformation and flow within a material”*

# Performance Grades – PG Asphalt

- PG Binder types are selected geographically, based off that regions 100-year climate history.
- PG Binder nomenclature:  
 Max Design Temperature, °C  
 Min. Design Temperature, °C

Ex.) PG58-28, PG64-22

Performance Grades																																				
Max. Design Temp.	PG 46				PG 52				PG 58				PG 64				PG 70				PG 76				PG 82											
Min. Design Temp.	-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	-10	-16	-22	-28	-34	-10	-16	-22	-28	-34
<b>Original</b>																																				
≥230 °C	<b>Flash Point</b>																																			
≤ 3 Pa-s @ 135 °C	<b>Rotational Viscosity</b>																																			
≥ 1.00 kPa	<b>DSR G*/sin δ (Dynamic Shear Rheometer)</b>																																			
	46	52				58				64				70				76				82														
<b>(Rolling Thin Film Oven) RTFO, Mass Change ≤ 1.00%</b>																																				
≥ 2.20 kPa	<b>DSR G*/sin δ (Dynamic Shear Rheometer)</b>																																			
	46	52				58				64				70				76				82														
<b>(Pressure Aging Vessel) PAV</b>																																				
20 hours, 2.10 MPa	90	90				100				100				100(110)				100(110)				100(110)														
≤ 5000 kPa	<b>DSR G*·sin δ (Dynamic Shear Rheometer)</b> <span style="float:right">Intermediate Temp. = [(Max. + Min.)/2] + 4</span>																																			
	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	31
S ≤ 300 MPa m ≥ 0.300	<b>BBR S (creep stiffness) &amp; m-value (Bending Beam Rheometer)</b>																																			
	-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	-18
If BBR m-value ≥ 0.300 and creep stiffness is between 300 and 600, the Direct Tension failure strain requirement can be used in lieu of the creep stiffness requirement.																																				
ε <sub>t</sub> ≥ 1.00%	<b>DTT (Direct Tension Tester)</b>																																			
	-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	-18

# Performance Grades

Max. Design Temp.	PG 46			PG 52				PG 58				PG 64				PG 70				PG 76				PG 82													
Min. Design Temp.	-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	-28	-34

## Original

$\geq 230$ °C	<b>Flash Point</b>																											
$\leq 3$ Pa-s @ 135 °C	<b>Rotational Viscosity</b>																											
$\geq 1.00$ kPa	<b>DSR G*/sin <math>\delta</math></b> (Dynamic Shear Rheometer)																											
	46	52				58				64				70				76				82						

## (Rolling Thin Film Oven) RTFO, Mass Change $\leq 1.00\%$

$\geq 2.20$ kPa	<b>DSR G*/sin <math>\delta</math></b> (Dynamic Shear Rheometer)																											
	46	52				58				64				70				76				82						

## (Pressure Aging Vessel) PAV

20 hours, 2.10 MPa	90	90				100				100				100(110)				100(110)				100(110)															
$\leq 5000$ kPa	<b>DSR G* sin <math>\delta</math></b> (Dynamic Shear Rheometer) <span style="float: right;">Intermediate Temp. = [(Max. + Min.)/2] + 4</span>																																				
	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	31	28
$S \leq 300$ MPa $m \geq 0.300$	<b>BBR S (creep stiffness) &amp; m-value</b> (Bending Beam Rheometer)																																				
	-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	-18	-24

If BBR m-value  $\geq 0.300$  and creep stiffness is between 300 and 600, the Direct Tension failure strain requirement can be used in lieu of the creep stiffness requirement.

$\epsilon_f \geq 1.00\%$	<b>DTT</b> (Direct Tension Tester)																																			
	-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	-18



# Performance Grades – PG Asphalt

- *“Different Points of Binders Life Cycle”* – How is that possible?
- Dynamic Shear Rheometer (DSR) Minimum value @ test temperature of original binder.
- Rolling Thin Film Oven (RTFO) Simulation of aging experienced in a hot-mix plant. Maximum mass loss specification. Also, a minimum requirement on the DSR after the RTFO to prevent permanent deformation.
- Pressure Aging Vessel (PAV) - Simulation of five to seven years of aging on the road. DSR maximum specification to prevent fatigue cracking.
- Bending Beam Rheometer (BBR) - Simulation of the low temperature specification to ensure that the binder will not thermally crack.

# Performance Grades – PG Asphalt



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# Performance Grades – PG Asphalt

- PG stands for “*Performance Grade*”

PG(58)(-28)

- 58 is *58 degrees Celsius*
- -28 is *negative 28 degrees Celsius*
- PG58-28 is expected to meet performance expectations with pavement temperatures between 58C (136° Fahrenheit) and -28C (-18° Fahrenheit) with light volumes of fast-moving traffic.
- PG64-22 should perform best at temperatures between 64°C (147°F) and -22°C (-8°F).

# PG Grades

- Main grades used in this region are
  - PG58-28
  - PG64-22
  - Also referred to as “Neat AC” or “Straight Run”
- Polymer Modified Asphalt Cements
  - PG64-28
  - PG70-22
  - PG76-22
  - PG70-28

Rule of 92: Max Design Temp – Min Design Temp. =  $\geq 92^{\circ}$   
Means that binder has been modified.

# MSCR Introduced

- Multiple Stress Creep Recovery Test added to existing PG Grade specifications/testing - MODOT ~ 2010.
- MSCR was designed to designate traffic load counts to standard climate grades for a certain region. Also, to do away with Elastic Recovery testing requirements, would be done utilizing DSR now.
- Traffic count is part of the equation
  - S – Standard Traffic (Ex: PG64S-22.)
  - H – Heavy Traffic (Ex: PG64H-22.)
  - V – Very Heavy Traffic (Ex: PG64V-22.)
  - E – Extremely Heavy Traffic (Ex: PG64E-22.)

# Multiple Stress Creep Recovery (MSCR)

- Standard Designation “S” in most typical situations will be for traffic levels fewer than 10 million Equivalent Single Axle Loads (ESALs) and more than the standard traffic speed (>70 km/h) 64S-22
- High Designation “H” in most situations will be for traffic levels of 10 to 30 million ESALs or slow-moving traffic (20 to 70 km/h) 64H-22
- Very High Designation “V” in most situations will be for traffic levels of greater than 30 million ESALs or standing traffic (<20 km/h) 64V-22
- Extremely High Designation “E” in most situations will be for traffic levels of greater than 30 million ESALs and standing traffic (<20 km/h) such as toll plazas or port facilities 64E-22

# Multiple Stress Creep Recovery (MSCR)

- Essentially here's what it means:
  - 64S-22 = 64-22
  - 64H-22 = 70-22
  - 64V-22 = 76-22
  - 64E-22 = 82-22
- Dependent upon if full MSCR specification is being followed.

# MSCR – Why Fix What's Not Broken?

- Speed of testing – much faster now
- Better predictor of rutting
- Modifier neutral- Better indicator of quality of modification
- Same equipment
- Tested at climate conditions

# MODOT – Current Practices

How does this presentation apply to current MODOT specifications.

# MODOT – As Is Today

<b>State:</b> Missouri		<b>Materials:</b> Re: Section 1015 – Bituminous Material
<b>Date Last Reviewed:</b> 9/1/22		<b>Web Address:</b> <a href="http://www.modot.org">www.modot.org</a>
<b>Materials Engineer:</b> David Ahlvers		<b>Contact Info:</b> <a href="mailto:david.ahlvers@modot.mo.gov">david.ahlvers@modot.mo.gov</a>
<b>Asphalt Binder</b>		
Section 1015	<b>Highlights</b>	MODOT continues to specify M 320 graded binders but allows the substitution of M 332 (MSCR) graded binders as follows: PG 64V-22 in lieu of PG 76-22; PG 64H-22 in lieu of PG 70-22; PG 64S-22 in lieu of PG 64-22. There are no elastic recovery requirements for M 332 graded binders.
	<b>PMA Notes</b>	See elastic recovery below for M320 graded binders. Ground tire rubber (GTR) with 4.5% transpolyoctenamer rubber (TOR) may be used for modification.
	<b>Exclusions and Limits</b>	None stated.

# MODOT Binder Grades + HMA Recycle

- During HMA Design – recycled materials such as RAP (Recycled Asphalt Pavement) and RAS (Recycled Asphalt Shingles) are incorporated back into the mixture to supplement some of the virgin aggregate and virgin oil that is needed to design that mixture.
- Cheaper prices of the recycled materials = cheaper prices of the finished mixture.
- This leads to MODOT allowing Extracted Binder Gradings of the HMA Mixture.

## MODOT Binder Grades + HMA Recycle

- With MODOT virtually allowing unlimited amounts of Recycle to be allowed. Binder replacement charts (MODOT Sec. 401) have been put into place in specification.
- Chemical Extraction and Grading has become a major part of our specifications.

Binder	Percent Effective Virgin Binder Replacement		
	RAP	RAS	RAP and RAS combination
Contract Grade Virgin Binder shall be used	0 - 20	0 - 10	$RAP + (2 * RAS) \leq 20$
Virgin Binder shall be Softened One Grade <sup>a</sup>	21 - 40	11 - 20	$20 < RAP + (2 * RAS) \leq 40$
Blend Chart <sup>b</sup>	0 - 100	N/A	N/A
Extraction and Grading of Binder from final Mixture <sup>c</sup>	0 - 100		

# Chemical Extraction and PG Grading

- The HMA Mixture is designed and constructed during the laboratory design process. The final mixture of that HMA is “extracted” to reclaim all asphalt out of the mixture.
- Including virgin asphalt, and any asphalt incorporated by the RAP or RAS.
- Chemical Extraction uses solvents to strip the asphalt from the HMA mixture.
- Utilizing a series of High-Speed Centrifuges, and distillation processes. We are able to reclaim all asphalt from the HMA. Being able to successfully test it for SHRP (PG) Specifications.

# Chemical Extraction and PG Grading



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# Chemical Extraction and PG Grading

- Recycled materials are heavily oxidized and generally very stiff.
- Blending these materials into HMA, requires us to use softer PG Grades. To essentially “meet in the middle” at the desired Contract Grade, set by MODOT.

EX.) 40% RAP (PG94-10) + 80% PG46-34 = ??????

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