THE BASICS OF ASPHALT BINDERS

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2023 Black to Basics Training

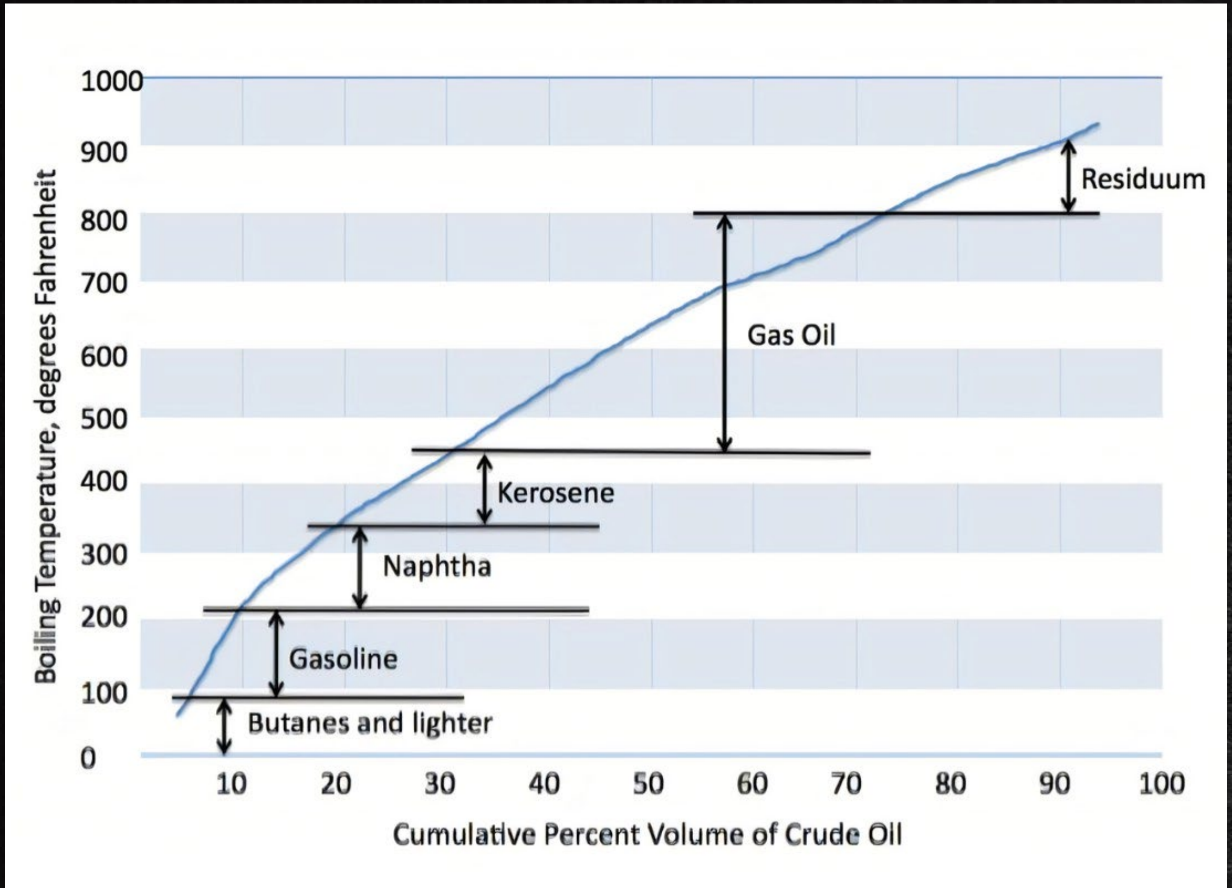
What is Asphalt?

- 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



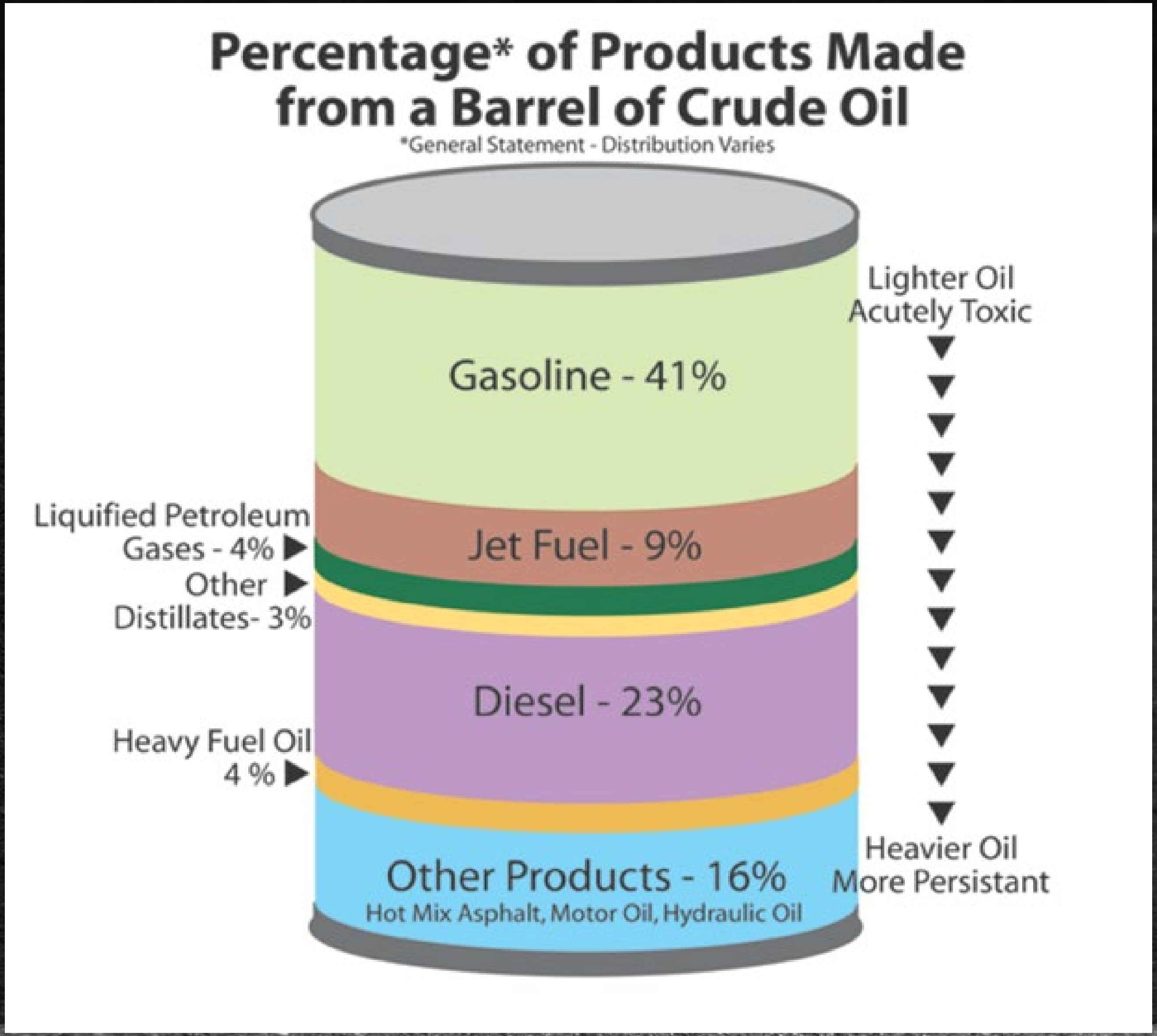
- Propane
- Butane
- Gasoline
- Naphtha
- Kerosene
- Diesel
- Gas Oils
- Asphalt

Crude Oil Breakdown

Asphalt Cement is the "bottom of the barrel."

Crude oils vary, widely. As a generality:

1 Barrel = 42 gallons



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
  - When gas prices are high, refineries want to get more gas out of each barrel of oil – may use a "Coker" to extract more, leaving less asphalt and lower quality asphalt.

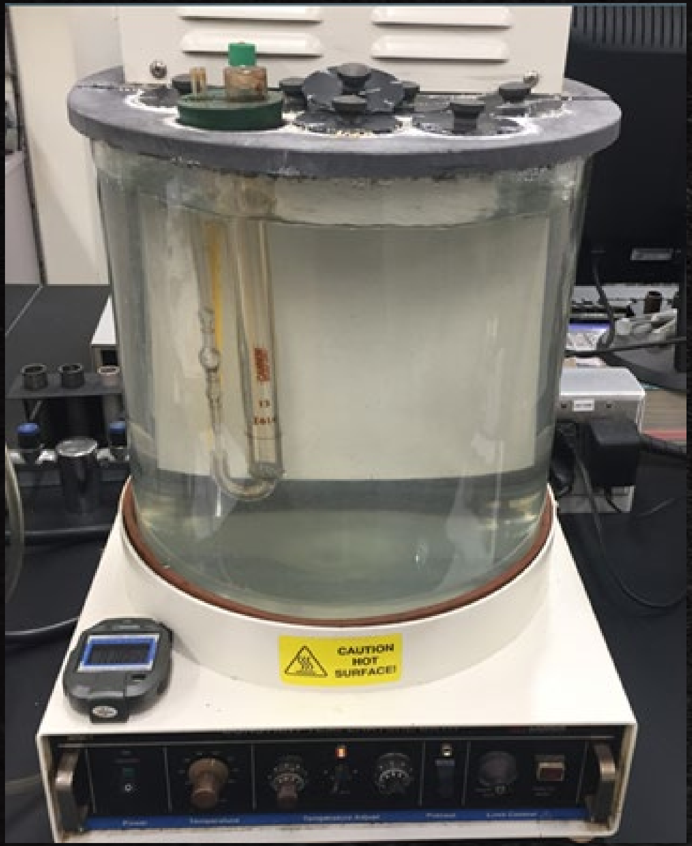
Asphalt Nomenclature

- History of Asphalt Nomenclature
- Todays 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."

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 30x100=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	-40	-10	-16	-22	-28	-34	-10	-16	-22	-28	-34
Original																																					
≥230 °C	**Flash Point**																																				
≤ 3 Pa-s @ 135 °C	**Rotational Viscosity**																																				
≥ 1.00 kPa	**DSR G*/sin δ** (Dynamic Shear Rheometer)																																				
	46			52							58					64						70						76					82				
(Rolling Thin Film Oven) RTFO, Mass Change ≤ 1.00%																																					
≥ 2.20 kPa	**DSR G*/sin δ** (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)				
≤ 5000 kPa	**DSR G*sin δ** (Dynamic Shear Rheometer) Intermediate Temp. = [(Max. + Min.)/2] + 4																																				
	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 ≤ 300 MPa m ≥ 0.300	**BBR S (creep stiffness) & m-value** (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 ≥ 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_f ≥ 1.00%	**DTT** (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	-24

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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

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).
  - The higher the second number is, the softer the asphalt.

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. = ≥ 92°*
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?

- The MSCR test uses the well-established creep and recovery test concept to evaluate the binder's potential for permanent deformation. Using the Dynamic Shear Rheometer (DSR), the same piece of equipment used today in the existing PG specification, a one-second creep load is applied to the asphalt binder sample. After the 1-second load is removed, the sample is allowed to recover for 9 seconds.
- The test is started with the application of a low stress for 10 creep/recovery cycles then the stress in increased and repeated for an additional 10 cycles.
- In the MSCR test, higher levels of stress and strain are applied to the binder, better representing what occurs in an actual pavement. By using the higher levels of stress and strain in the MSCR test, the response of the asphalt binder captures not only the stiffening effects of the polymer, but also the delayed elastic effects (where the binder behaves like a rubber band).

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

State: Missouri	**Materials:** Re: Section 1015 – Bituminous Material
Date Last Reviewed: 9/1/22	**Web Address:** www.modot.org
Materials Engineer: David Ahlvers	**Contact Info:** david.ahlvers@modot.mo.gov

Asphalt Binder		
Section 1015	Highlights	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.
	PMA Notes	See elastic recovery below for M320 graded binders. Ground tire rubber (GTR) with 4.5% transpolyoctenamer rubber (TOR) may be used for modification.
	Exclusions and Limits	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) ≤ 20
Virgin Binder shall be Softened One Grade[a]	21 - 40	11 - 20	20 < RAP + (2*RAS) ≤ 40
Blend Chart[b]	0 - 100	N/A	N/A
Extraction and Grading of Binder from final Mixture[c]	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

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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