Introduction to Asphalt

Bituminous Materials

Bitumen—also known as asphalt or tar—is a black, oily, viscous form of petroleum, which is a naturally occurring organic byproduct of decomposed plants. Natural bitumen is the thickest form of petroleum there is, and is made up of 83% carbon, 10% hydrogen and lesser amounts of oxygen, nitrogen, sulfur, and other elements.

Bituminous Materials

The use of bitumen as a sealer or glue dates back to antiquity. It appeared in pools or on the surface of bodies of water—having seeped up from deep in the ground—and was collected as a natural resource for use or for export. It was used to waterproof the hulls of boats and as a form of mortar for brickwork.

Bituminous Materials

We can broadly break bituminous materials into three groups: natural asphalts, tars/pitches, and petroleum asphalts. The first group comprises things like “tar pits” and “oil sands”. The last group comprises asphalt derived from the distillation of crude oil to produce things like gasoline. In the middle are bituminous materials obtained by anaerobic heating of organic materials like wood and coal.

Bituminous Materials

Bituminous Materials

- Natural Asphalts
- Tar & Pitch
- Petroleum Asphalts

Natural Asphalt

Asphalt is a component of crude oil, which is the product of immense amounts of time, heat, and pressure acting on the remains of organic material buried deep in the ground. This material seeps to the surface to infiltrate porous sedimentary rocks, saturate deposits of sand, or collect in pools that we colloquially refer to as “tar pits.”

Natural Asphalt

Rock Asphalt

Asphalt Sands

Lake Asphalt

Rock Asphalt

Rock asphalt is formed when natural petroleum harden in the pores of sedimentary rocks such as limestone or sandstone. Over time, the lighter components evaporate away leaving material that ranges in consistency from a thick liquid to a crumbly sand or stone. Only about 5% to 15% of the composition of asphalt rocks is asphalt.

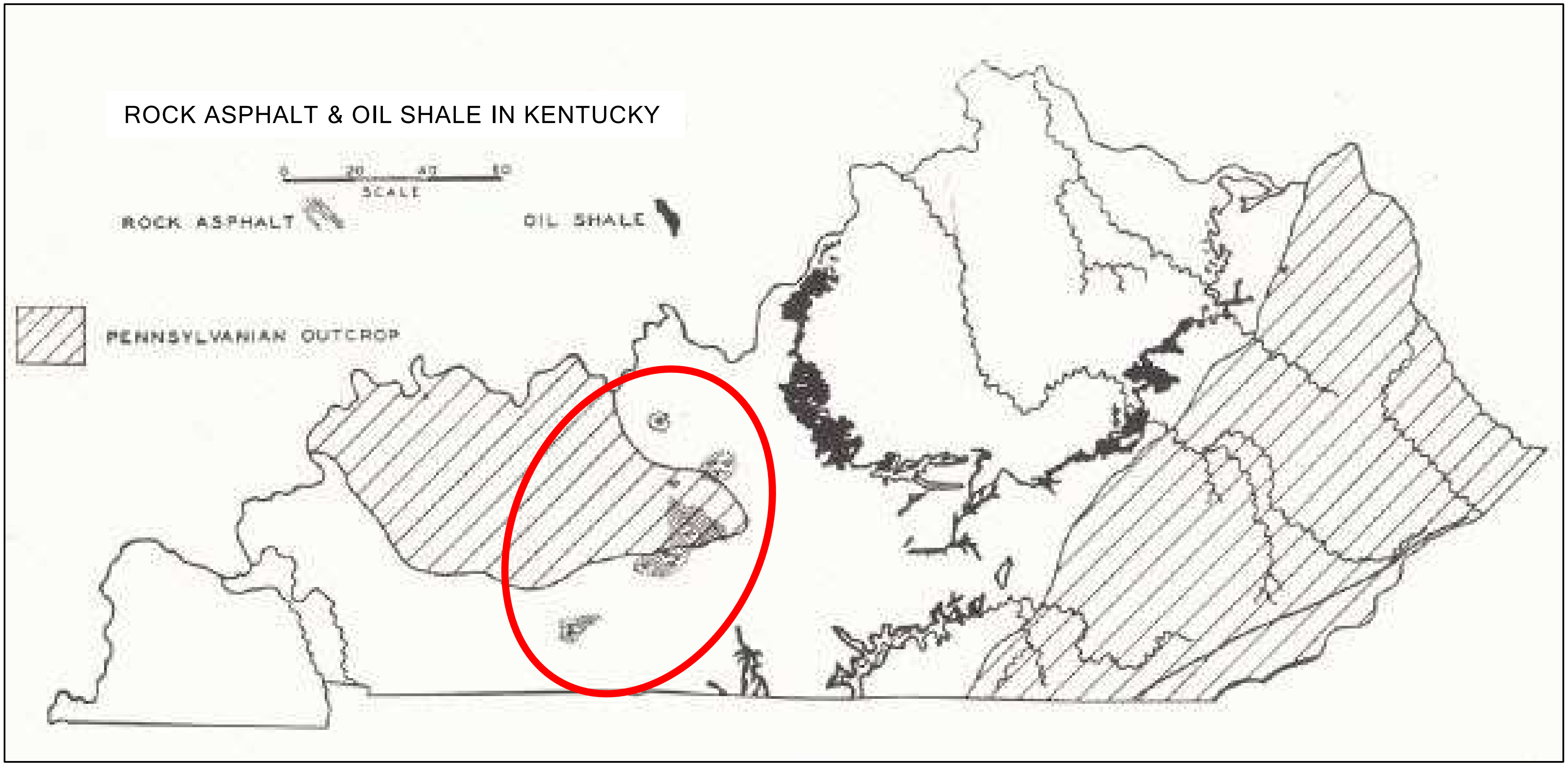
Rock Asphalt

Rock Asphalt

Asphalt rock can be found in several places in the U.S., the closest being Kentucky.

Kentucky Rock Asphalt (known commercially as Kyrock) is one of the earliest asphalt road building materials to be used in America and was the first material used to pave the legendary Indianapolis Motor Speedway.

Rock Asphalt



Asphalt Sands

Asphalt sands (also called oil or tar sands) are either loose sands or partially consolidated sandstone containing a mixture of sand, clay, water, and bitumen. It is increasingly used as a source of crude oil thanks to technological developments such as steam extraction.

Asphalt Sands

Asphalt Sands

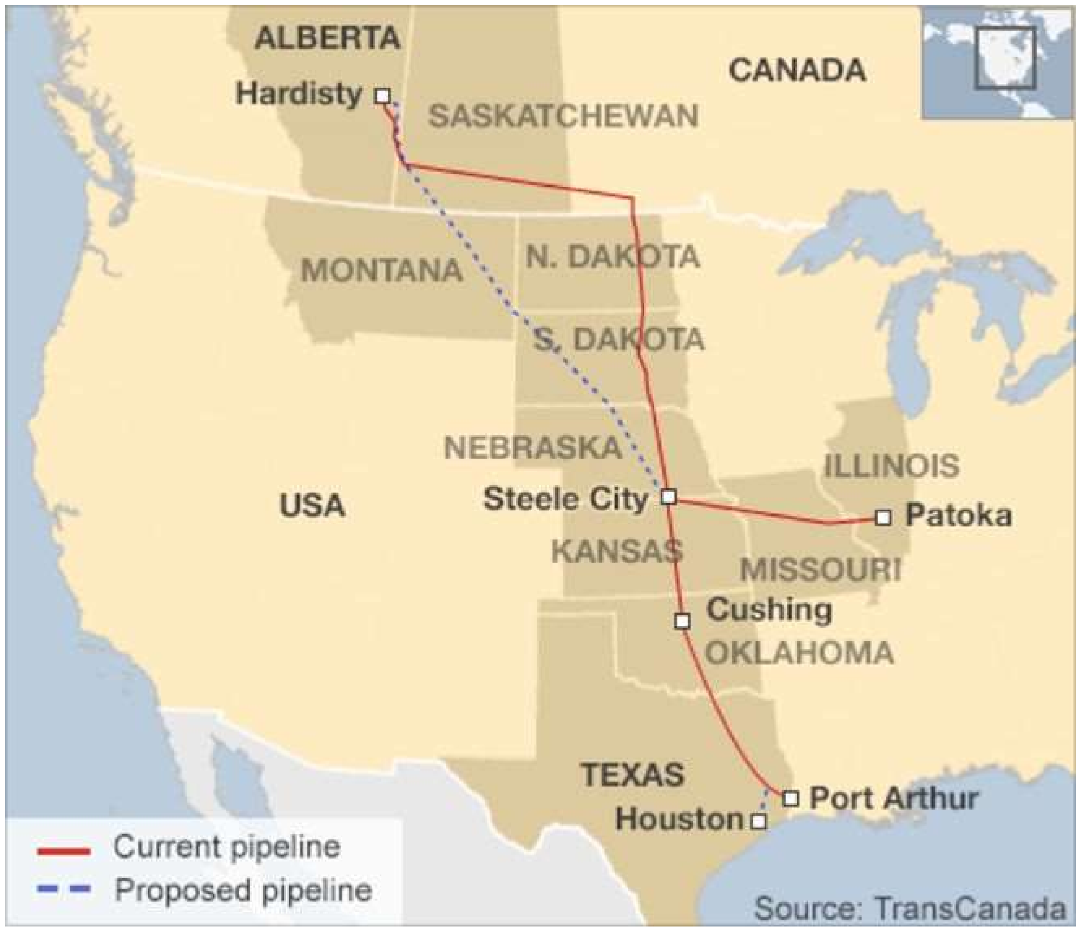
Asphalt Sands

The largest asphalt sand deposit in the world is the Athabasca oil sands in Alberta, Canada. It covers 54,000 square miles and contains the equivalent of 1.7 ***trillion*** barrels of crude oil.

The Keystone XL Pipeline, which has been in the news the last couple of years, is intended to transport Athabasca crude oil to refineries on the U.S. Gulf Coast.

Asphalt Sands

Keystone XL Pipeline



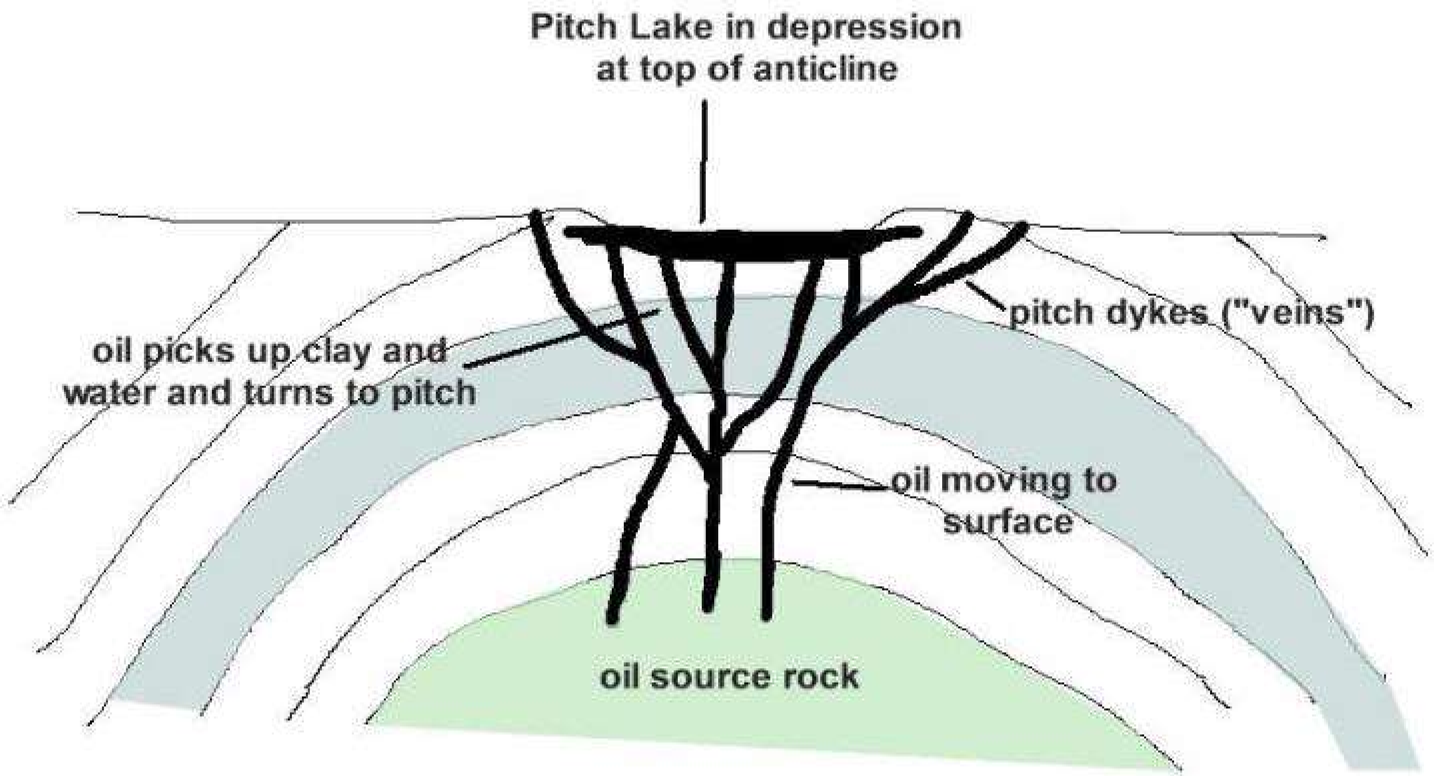
https://www.bbc.com/news/world-us-canada-30103078

Lake Asphalt

Lake asphalt is a surface seepage of petroleum rising from deep oil-bearing rocks. The lighter (i.e., more volatile) components evaporate, leaving behind a viscous or semi-solid deposit.

The asphalt is often so viscous you can walk on the surface, but if you stand on the surface for too long, you will slowly sink into it!

Lake Asphalt



Source: Geological Society of Trinidad and Tobago (www.gstt.org)

Lake Asphalt

Lake Asphalt

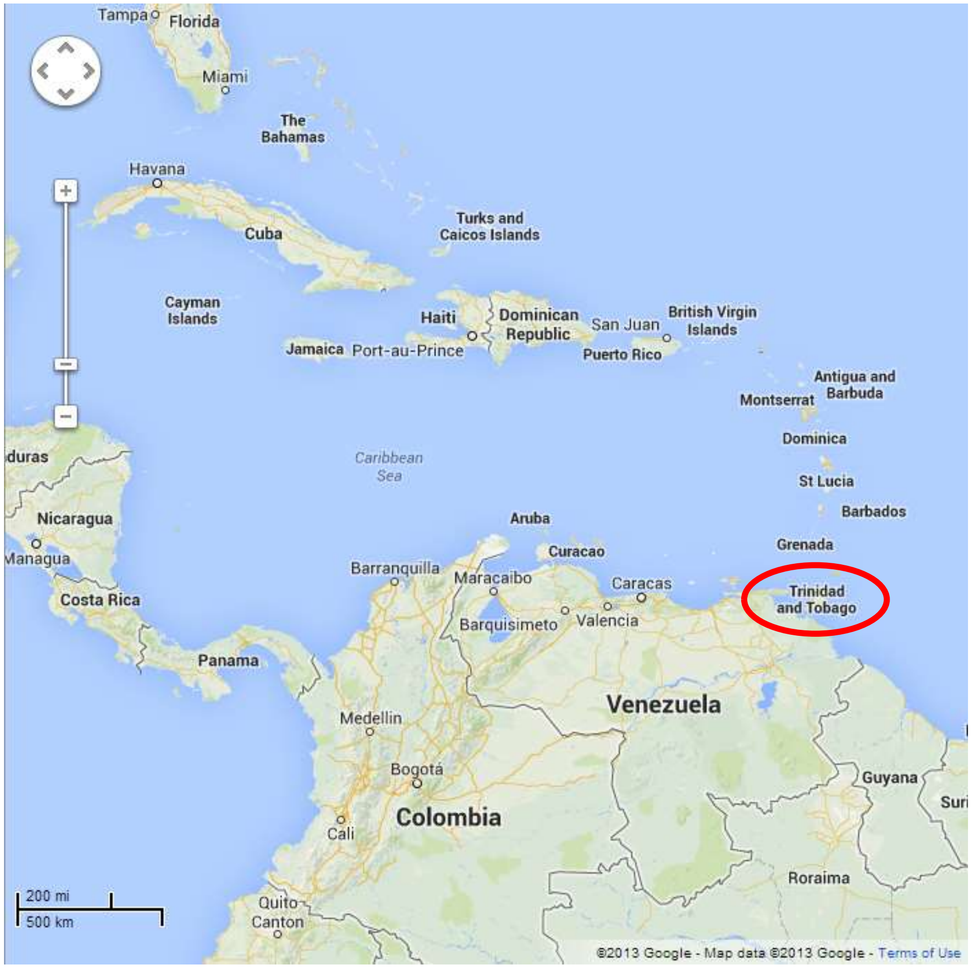
The most famous example of lake asphalt in the United States is the La Brea Tar Pits on Wilshire Blvd. in Los Angeles. It is known for its fossil collection of Ice Age mammoths and other mammals retrieved from the pits. These animals ventured out onto the surface thinking it was solid, but then sank in and got stuck in the gooey material, leading to their demise. Over time their bodies sunk further and their fossils are now being exhumed.

La Brea "Tar" Pits

Lake Asphalt

The largest asphalt lake in the world is Pitch Lake on the island of Trinidad and Tobago, off the coast of Venezuela. The lake covers 100 acres to a depth of 250 feet and is thought to be continuously replenished from below. It has been used as a source of paving asphalt for over 150 years and was the source for many of the first asphalt roads in the U.S., which were built in the 1880s. It is still in use today.

Pitch Lake, Trinidad



Pitch Lake, Trinidad

http://www.flickr.com/photos/striderv/4314238332/lightbox/

Pitch Lake, Trinidad

Pitch Lake, Trinidad

Pitch Lake, Trinidad

Pitch Lake, Trinidad

Tar / Pitch

The terms “tar” and “pitch” are used interchangeably, though “tar” is usually more liquid than “pitch.” Both are obtained from a variety of organic materials such as coal, wood, or peat. The source material is heated without oxygen (so it doesn’t ignite) until the tar liquefies and seeps out. What remains is almost pure carbon (coke in the case of coal, charcoal in the case of wood) and is therefore a great fuel source.

Wood Tar

Wood tar (primarily made from pine wood) has many uses as a sealant, a disinfectant, a flavoring agent for candies and alcohol, a spice for meat, and a water repellant. It is also used in cosmetics and is found in most anti-dandruff shampoos.

Historically, wood tar was obtained from ovens cut into a hillside and sealed off in front while the wood was reduced to charcoal.

Wood Tar Kiln, Sweden

https://en.wikipedia.org/wiki/Tar

Coal Tar

Coal tar is produced by heating coal without oxygen to produce coke and oil gas. Coal tar was used to construct the first surfaced roads. This is where we get the term “tarmac” or “tar macadam” (a macadam being a road constructed from densely packed crushed stone). Today it can still be found in some parking lot sealers though it’s being phased out due to environmental and health concerns.

Coal Tar

Coke is essentially pure carbon and is used as fuel for firing the blast furnaces used to make steel. In the heyday of steel making in the U.S. coking ovens dotted the landscape. As with wood tar kilns, these were often cut into a hillside. Others were built from quarried stone. They were sealed in front while the coal was reduced to coke and the coal tar and other "impurities" ran out the front where they could be collected and further refined.

Dunlap, TN Coking Ovens

Chickamauga, TN Coking Ovens

Pennsylvania Coking Ovens

Petroleum Asphalt

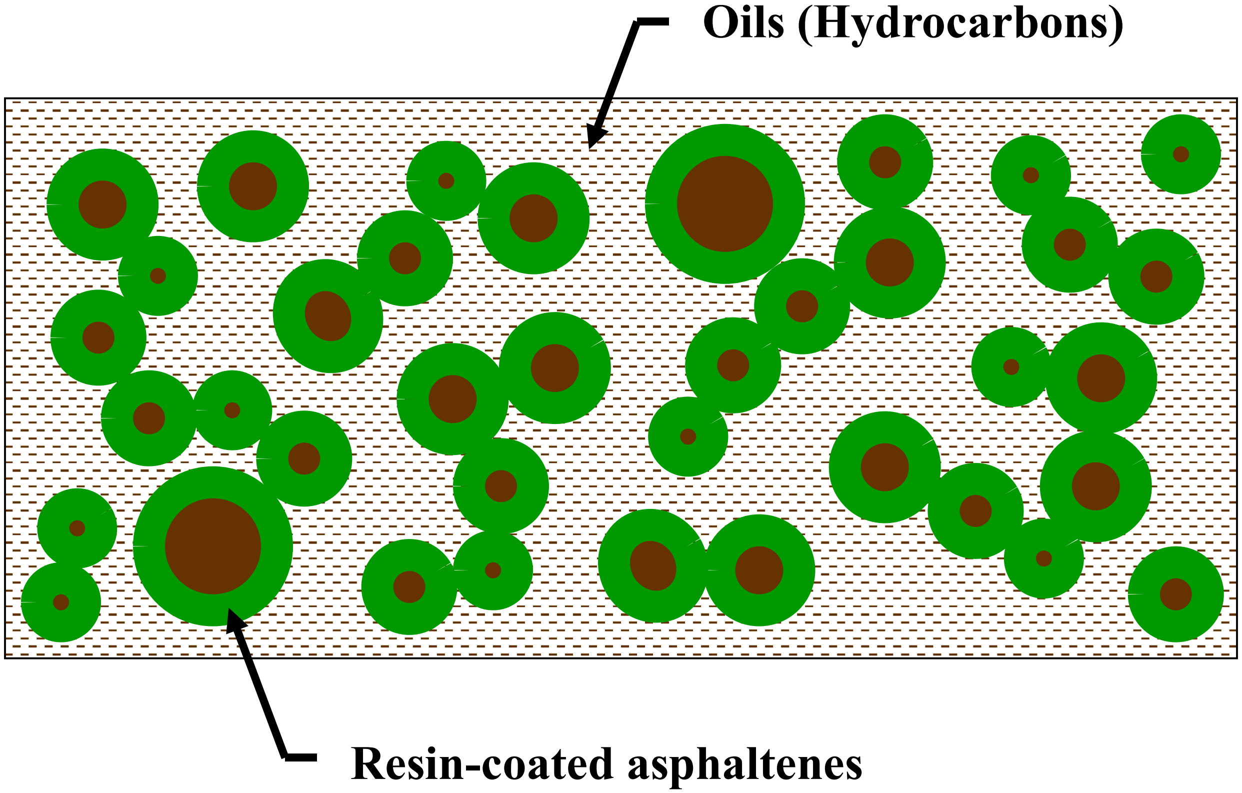
Petroleum asphalt is produced as a byproduct of crude oil distillation. It is the fraction of the crude oil with the highest boiling point (greater than 500°C) so it comprises the residual left over after everything else (gasoline, kerosene, diesel, etc.) has boiled off in the distillation process.

Petroleum Asphalt

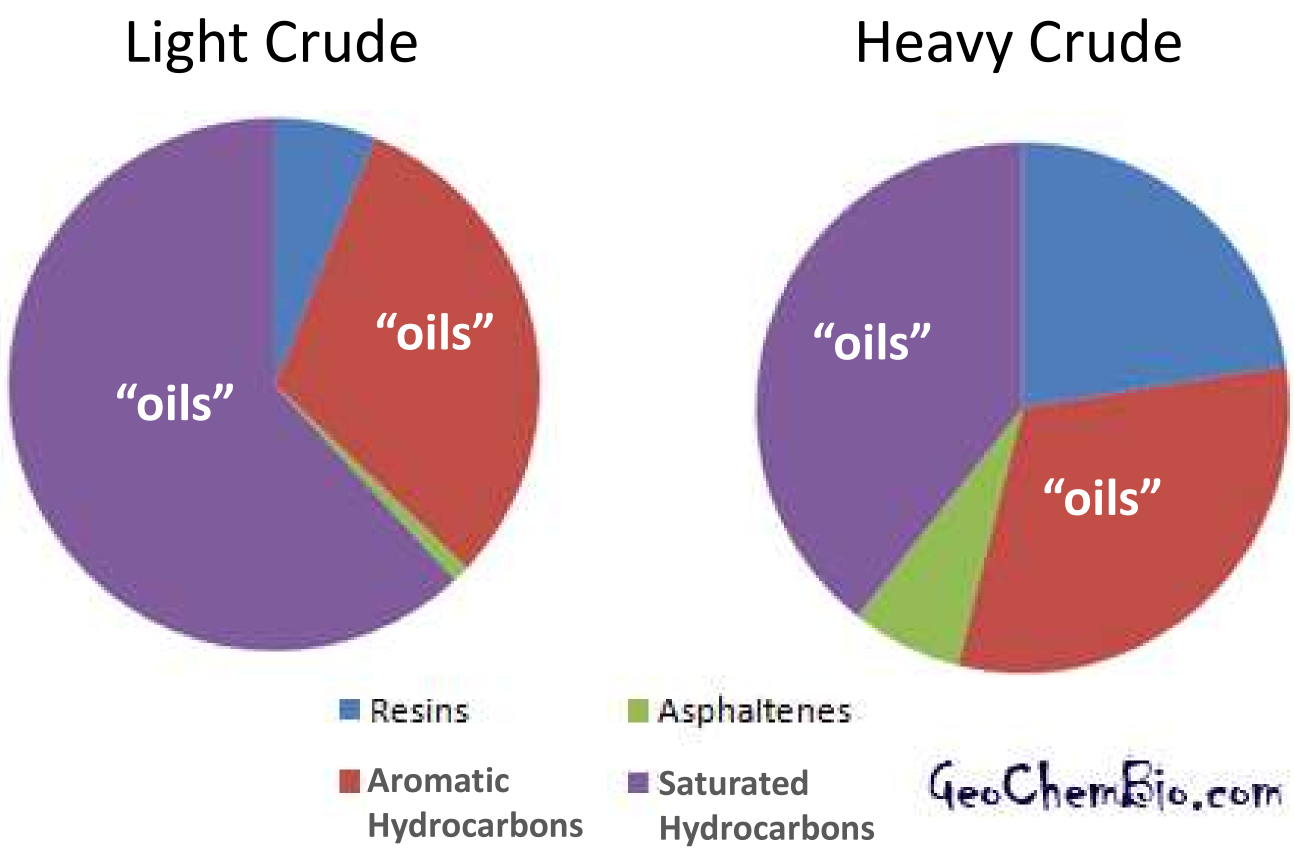
Crude oil consists of small droplets of resin-coated ***asphaltenes*** suspended in a bath of aromatic and saturated hydrocarbons. Crude oil distillation removes much of these hydrocarbons, leaving asphalt cement behind.

"Light" crude oil has very little of the resin-coated asphaltenes while "heavy" crude oil can have a significant amount.

Crude Oil Chemistry



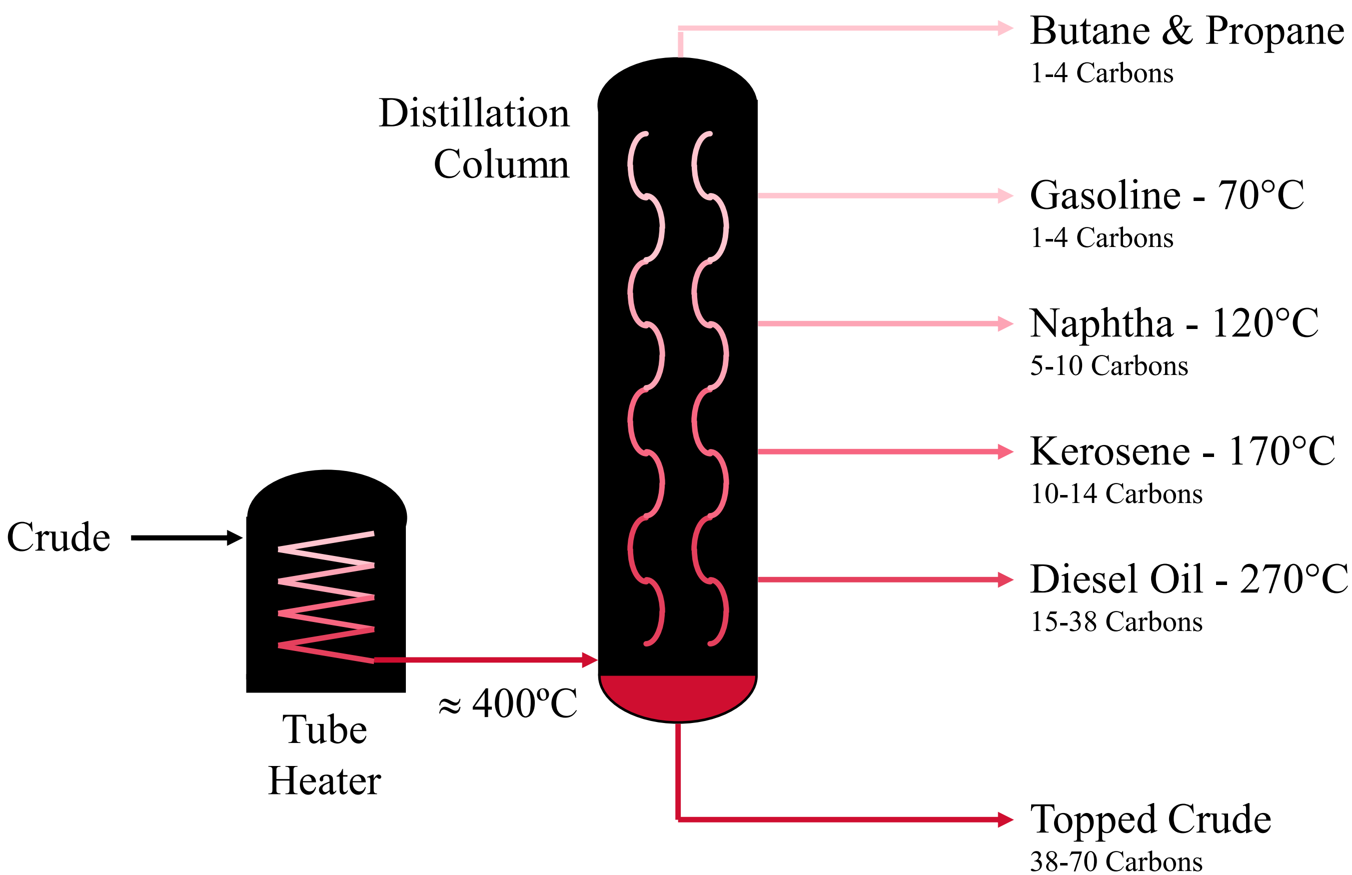
Crude Oil


Light Crude
Heavy Crude
"oils"
"oils"
"oils"
"oils"
Resins
Asphaltenes
Aromatic Hydrocarbons
Saturated Hydrocarbons
GeoChemBio.com

Petroleum Asphalt

To extract gasoline and other fuels from crude oil, it is heated to temperatures in excess of 400°C and injected into the base of a distillation column. As the hot vapor rises in the column it cools and different fractions condense back into liquid. The fractions with the highest boiling points (and highest carbon content) condense out first. Components like butane and propane, which are gases at room temperature, never condense out of the vapor.

Atmospheric Distillation

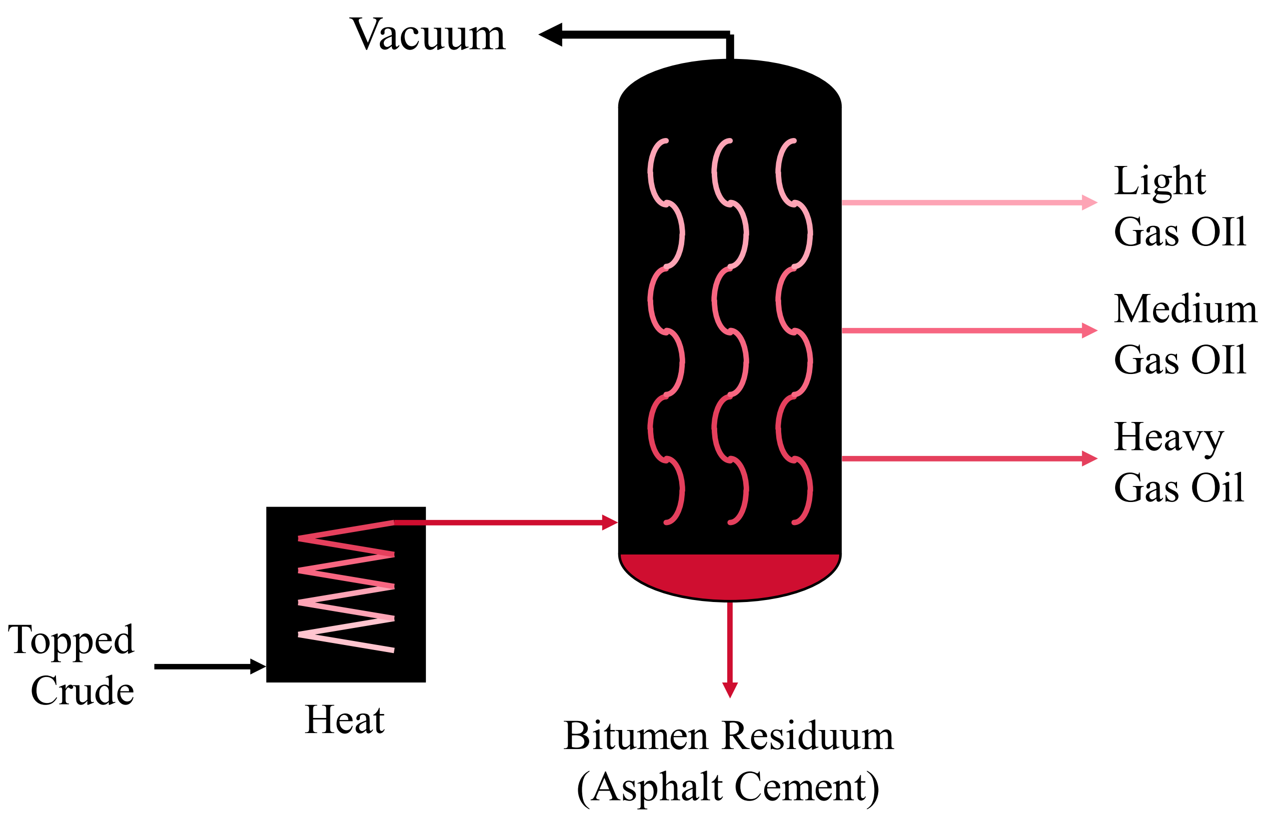


Petroleum Asphalt

Components that boil at temperatures above 400°C remain at the bottom of the distillation column. If you raised the temperature any further, you'd break the hydrocarbon chains. This is called cracking and it's undesirable. Instead, refineries further refine the crude oil by "boiling" it using a vacuum.

The material that still doesn't boil under a vacuum is asphalt cement. It has the most carbon atoms and the highest boiling point.

Vacuum Distillation

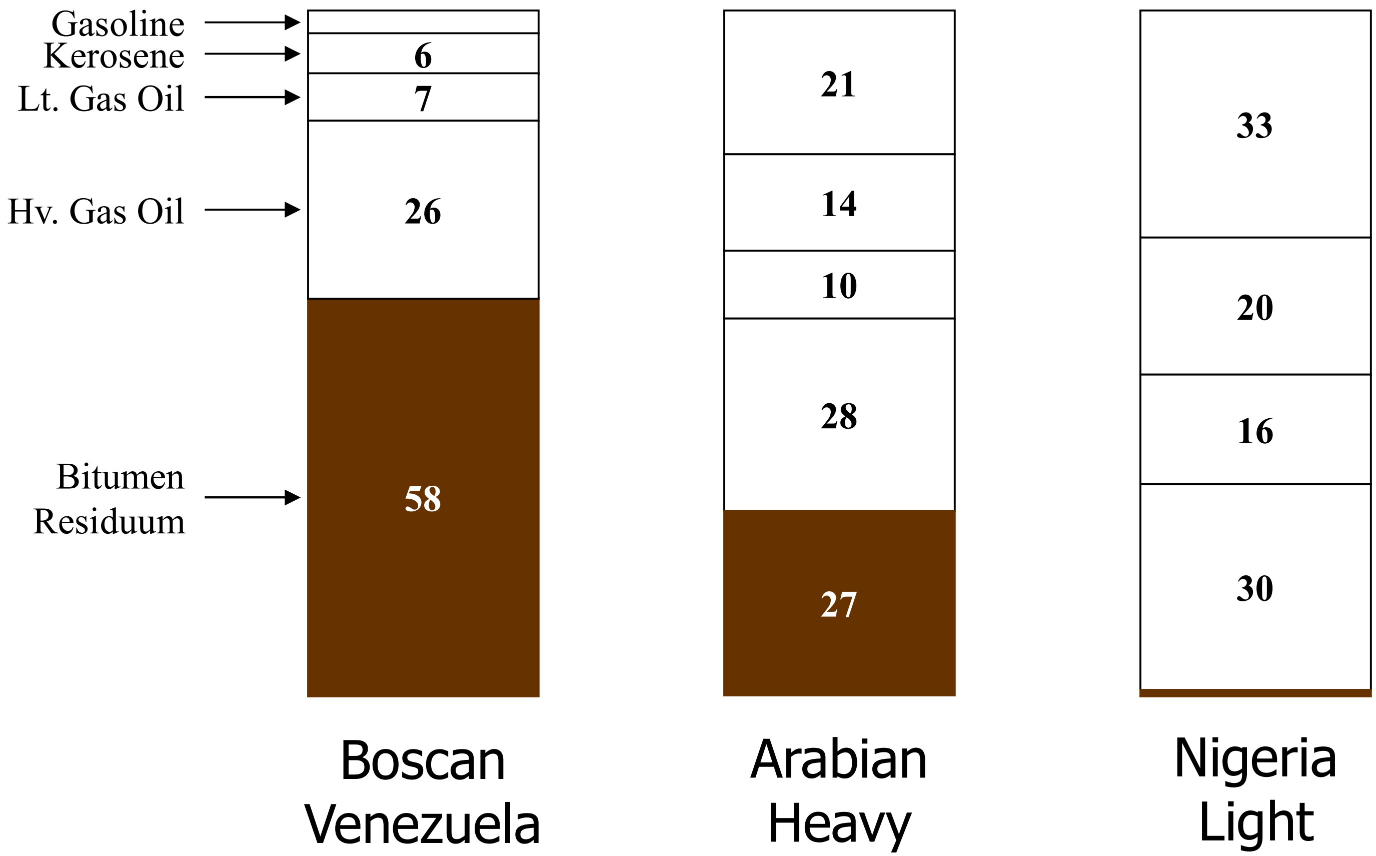


Vaporizes the topped crude without using excessive heat ("cracking")

Petroleum Asphalt

The components in crude oil vary widely around the world. Nigerian “light” crude has almost no asphalt cement left over after distillation. Venezuelan crude, on the other hand, is nearly 60% asphalt cement. It is not a coincidence that the largest asphalt lakes in the world are found in or off the coast of Venezuela. The type of crude oil in that part of the world has a lot of resin-coated asphaltenes relative to the amount of aromatic and saturated hydrocarbons.

Crude Oil



Gasoline
Kerosene
Lt. Gas Oil
Hv. Gas Oil
Bitumen
Residuum
6
7
26
58
21
14
10
28
27
33
20
16
30
Boscan Venezuela
Arabian Heavy
Nigeria Light

Petroleum Asphalt

Petroleum asphalt at room temperature is very stiff. In order to mix it with aggregate to make asphalt concrete, it has to be liquefied so it coats all of the aggregate particles. This is done in one of three ways: heating it, thinning it with solvents, or suspending it in water.

Liquefying Asphalt Cement

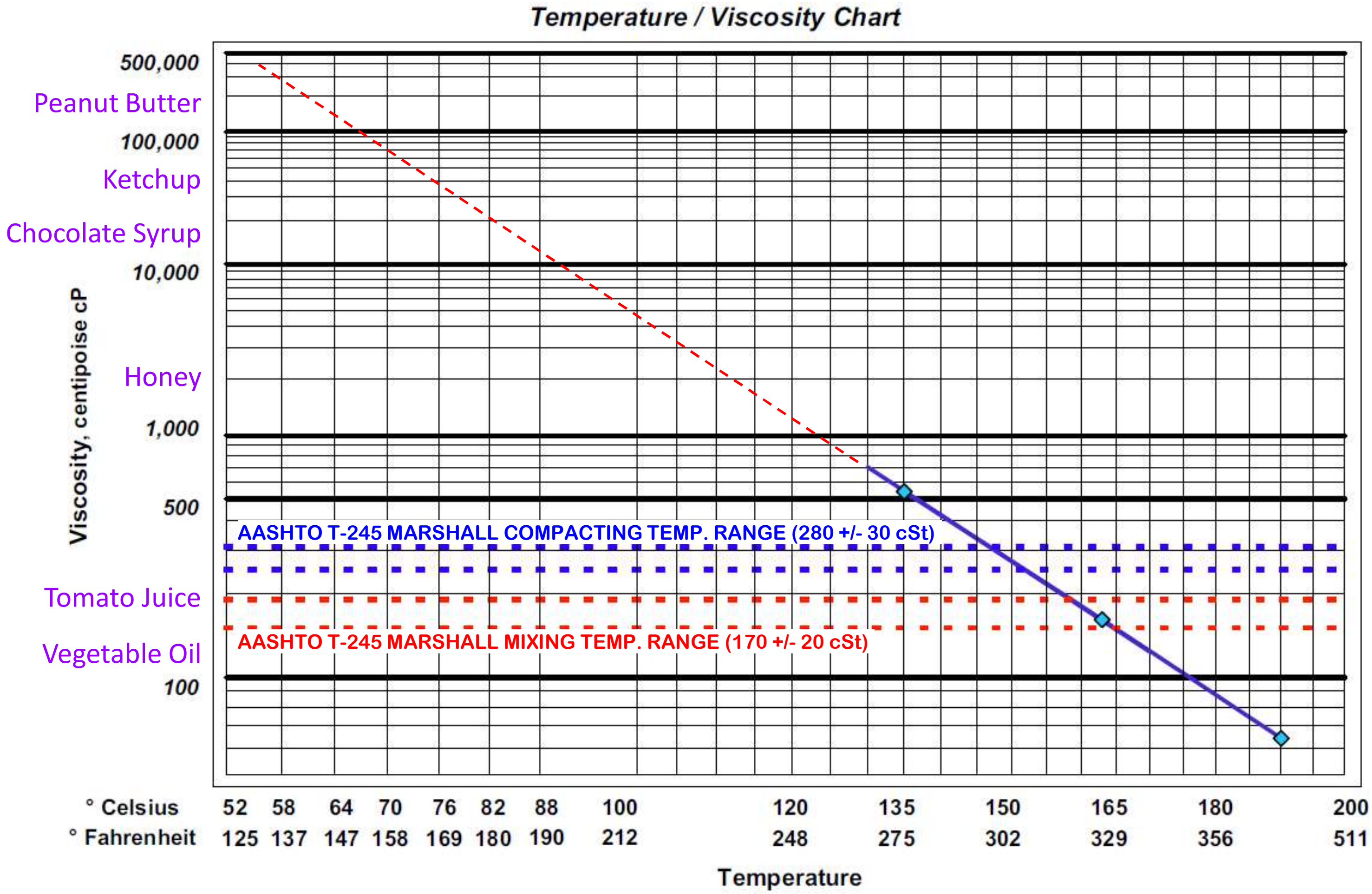
Asphalt Cement
(Bitumen Residuum)

Heat it	*Thin it with solvents*	*Suspend it in water*
↓	↓	↓
Hot-Mix Asphalt	**Cutback Asphalt**	**Emulsified Asphalt**

Liquefying Asphalt Cement

The viscosity of asphalt cement is heavily dependent on its temperature. At normal room temperature, it is nearly solid. On a very hot summer day, it has the consistency of peanut butter. If you continue to heat it to temperatures of around 300°F, it develops the consistency of vegetable oil. So one way to liquefy asphalt cement is to simply heat it. When mixed with aggregate, this produces hot-mix asphalt concrete.

Temperature-Viscosity



Cutback Asphalt

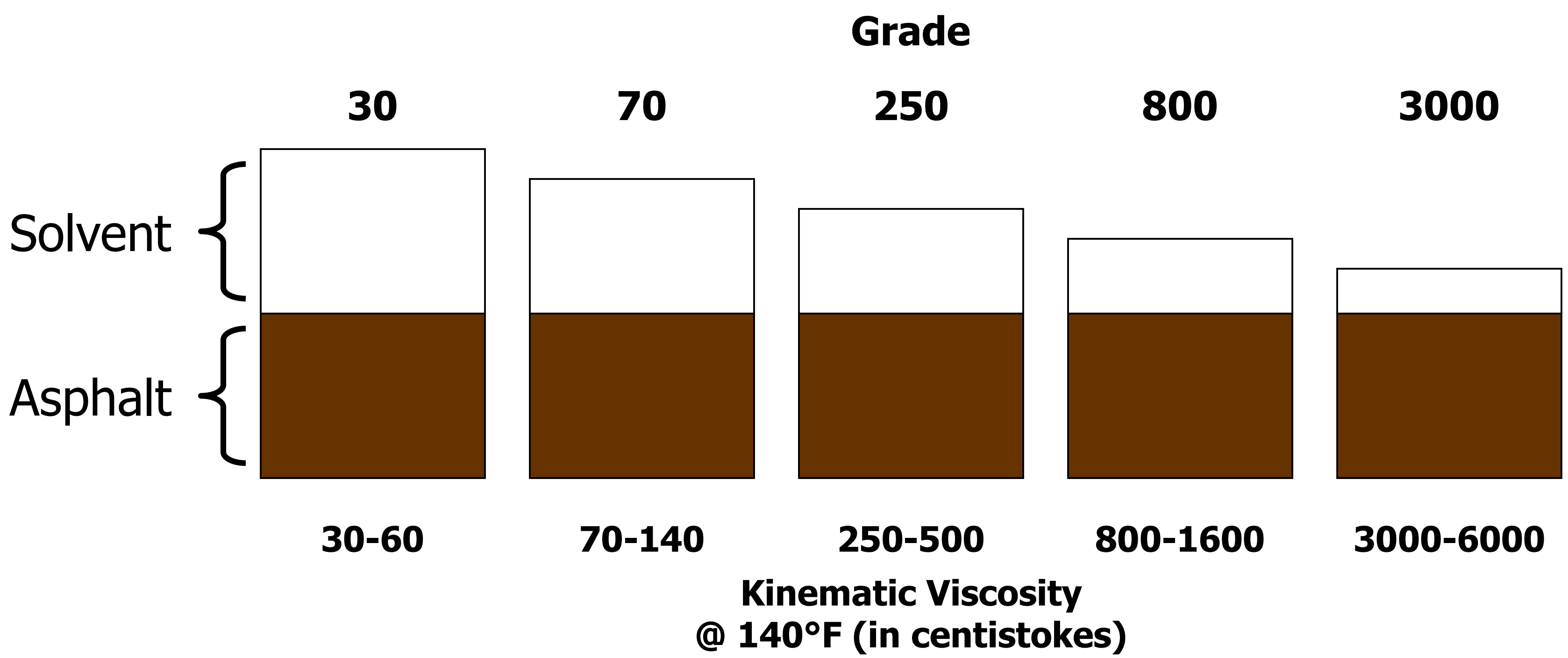
Cutback asphalt is asphalt cement that has been blended with a solvent to reduce its viscosity. After a cutback asphalt is applied the solvent evaporates, leaving behind asphalt cement residue on the surface to which it was applied. A cutback asphalt is said to "cure" as the petroleum solvent evaporates away.

What solvents do we use? The same ones extracted from the crude oil during distillation!

Cutback Asphalt

Cutback asphalt is classified according to the rate at which it cures (fast, medium, slow) and the viscosity of the liquid. The curing rate is a function of the boiling point of the solvent used. More volatile solvents produce a faster cure rate. The viscosity is based on how much of the solvent is used. The grade of a cutback is based on its viscosity.

Cutback Asphalt



Cutback Asphalt

In rapid curing (RC) cutbacks, the solvent evaporates quickly making them good candidates for spray-on applications like tack coats (placed between layers of asphalt concrete to "glue" them together) and seal coats (sprayed on existing pavements to seal cracks and restore some of the "elasticity" that the asphalt loses as it ages due to exposure to oxygen in the air).

Cutback Asphalt

The solvents used in medium curing (MC) cutbacks evaporate more slowly. These are used for thicker spray-on applications like prime coats, which are used to seal the surface of the underlying crushed stone before the first layer of asphalt is placed.

Because they cure more slowly, they can be mixed with aggregate to create a cold-laid asphalt concrete. These are used with open-graded aggregate to create a pavement base course.

Cutback Asphalt

Slow curing (SC) cutbacks cure the slowest so they can stand up to a lot of mixing. These are used for cold-laid pavement bases and things like “patch mix” that you can buy in bags at Home Depot to fill in potholes in your driveway.

Years ago, SC cutbacks were made by leaving behind some of the distillates during distillation. These were called “road oils”. Today, the solvents are added back to the asphalt cement to get better quality control.

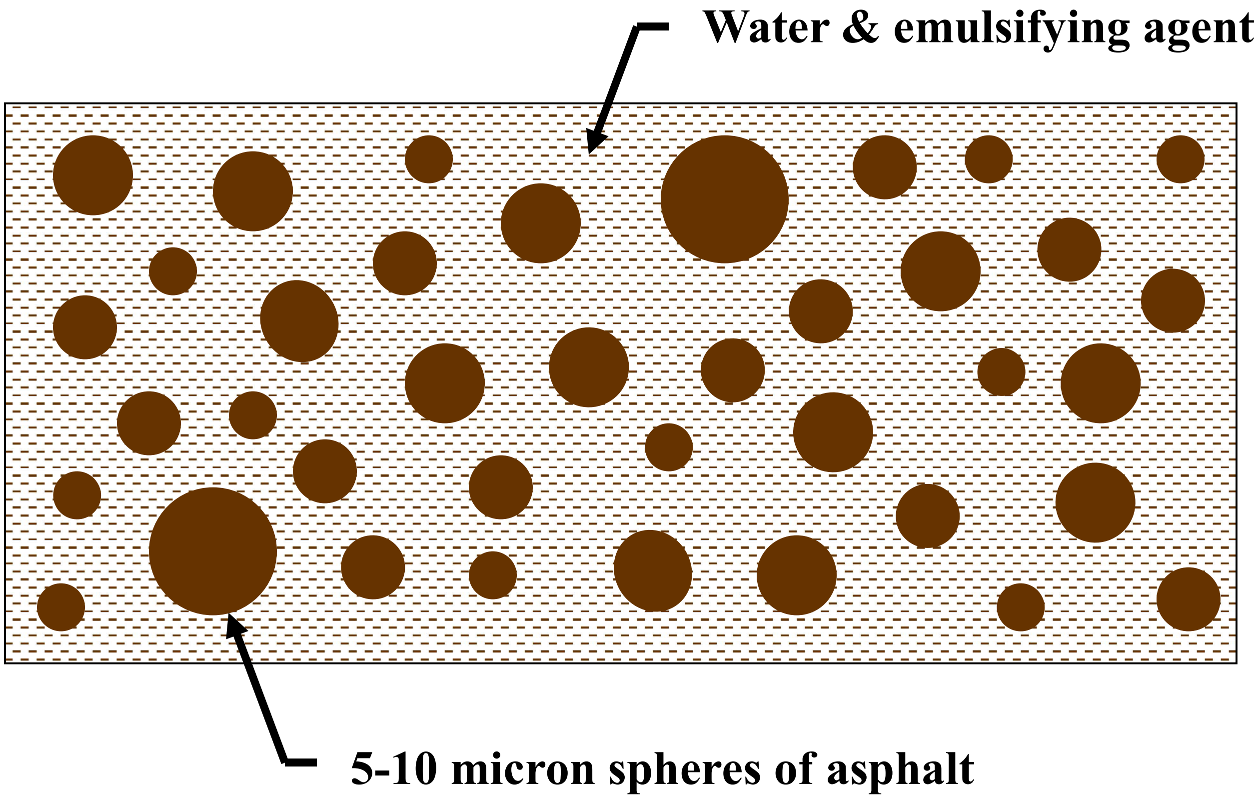
Cutback Asphalt

- Rapid Curing (RC)
  - Asphalt cement thinned with **gasoline** or **naphtha**
  - Used for tack and seal coats (surface applications)
- Medium Curing (MC)
  - Asphalt cement thinned with **kerosene**
  - Used for prime coats, cold-laid pavement bases
- Slow Curing (SC)
  - Asphalt cement thinned with **diesel oil** or **gas oils**
  - Used for cold-laid pavement bases

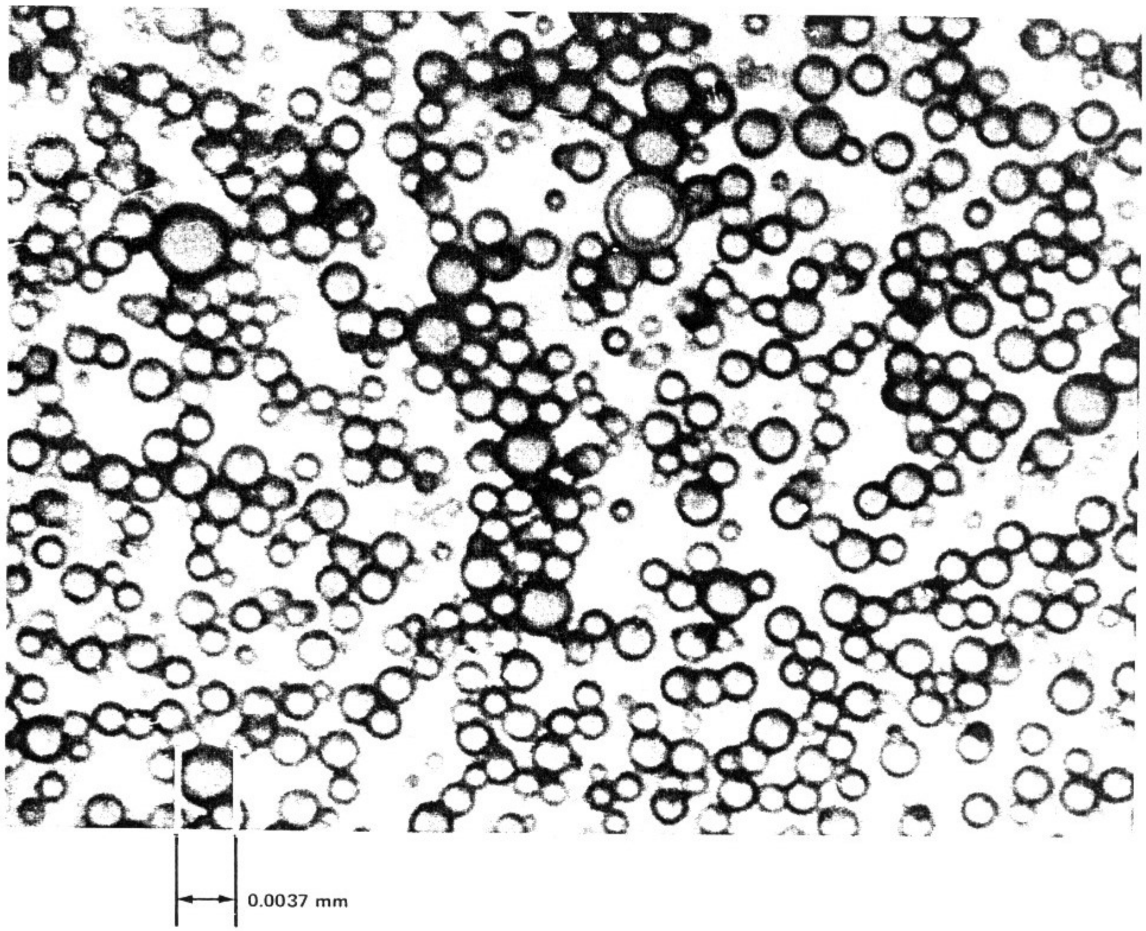
Emulsified Asphalt

Emulsified asphalt is a suspension of very small asphalt cement droplets in water, which is assisted by an emulsifying agent (basically soap or detergent) that forms a “bridge” between the two immiscible phases (asphalt cement and water) that disrupts the surface tension of the water and imparts an electrical charge to the surface of the asphalt cement droplets so that they do not coalesce into larger droplets and fall out of suspension.

Emulsified Asphalt



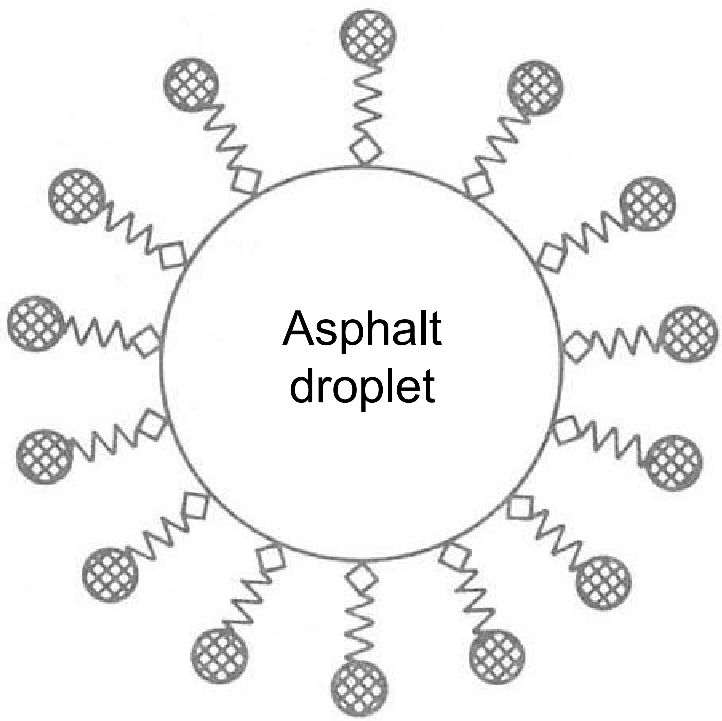
Emulsified Asphalt

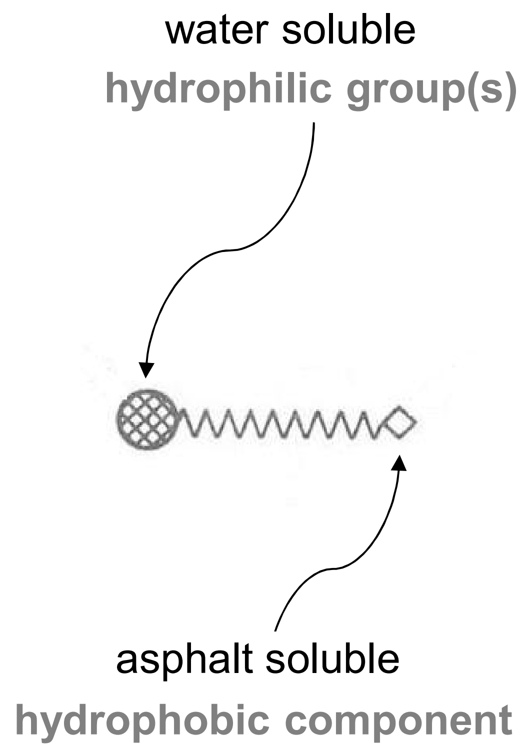


Emulsified Asphalt

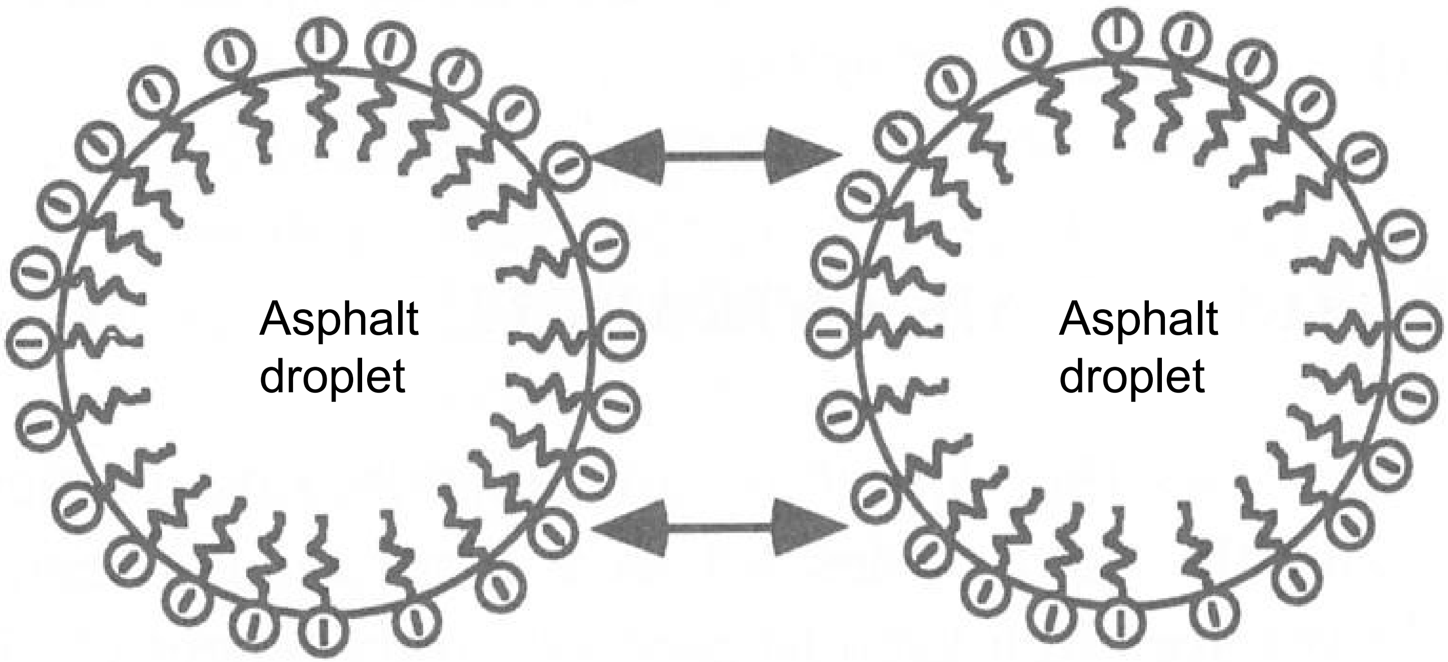
The soap molecules are like little tadpoles, having a hydrocarbon tail that is soluble in liquid asphalt and an electrically charged (ionic) head soluble in water. The asphalt particles are thus enveloped by an ionic charge, which causes the droplets to repel each other (like charges repel) and stay suspended in the water.

Emulsified Asphalt





Emulsified Asphalt



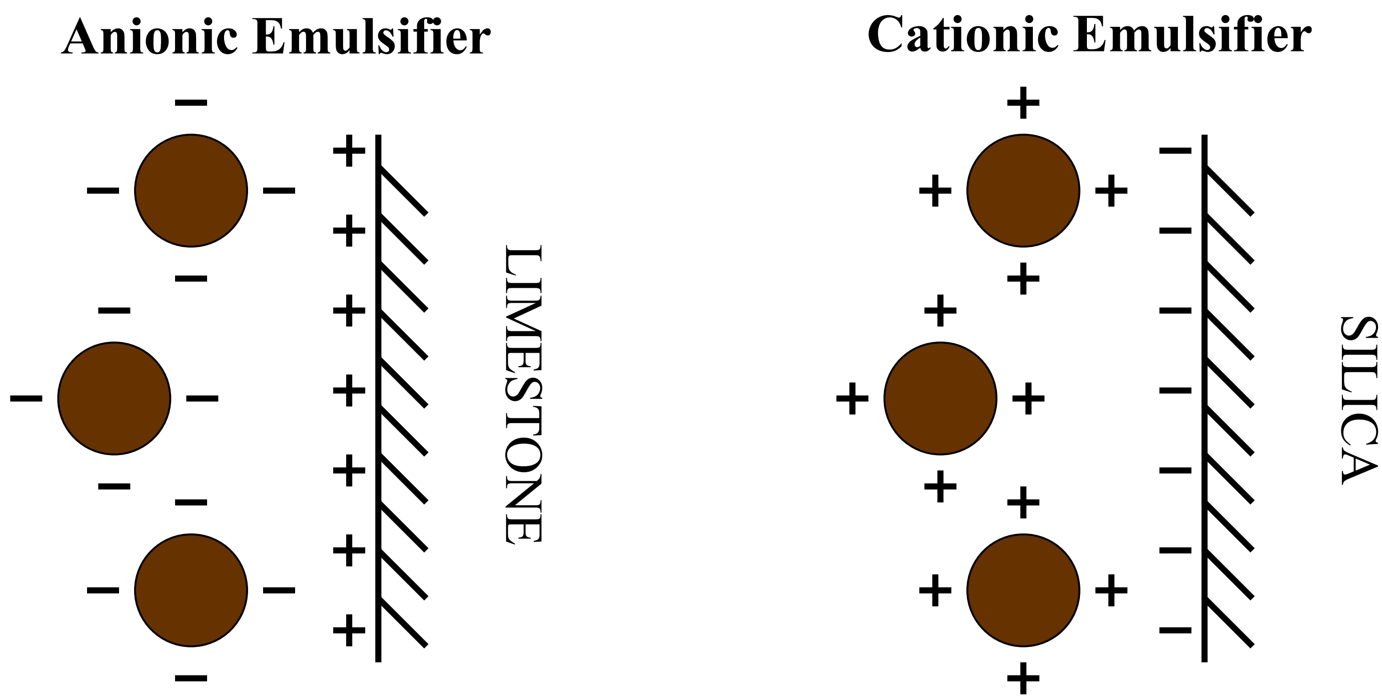
Repulsion between negative surface charges prevents coalescence

Emulsified Asphalt

Some emulsifying agents have negative charges and some have positive charges keeping the droplets apart.

Since aggregate particles also have a surface charge (derived from their mineralogy) you have to select an emulsified asphalt with the correct charge or the aggregate will repel it!

Emulsified Asphalt



Emulsified Asphalt

Emulsified asphalts appear as a thick brown liquid when first applied. When the asphalt droplets start to adhere to the aggregate the color changes to black and the emulsion is said to "break" (i.e., separate). As the water evaporates, the emulsion behaves more like pure asphalt cement. Once all the water has evaporated, the emulsion is said to have "set".

Emulsified Asphalt

There are three main emulsion grades: rapid set, medium set and slow set. The terms relate to the amount of time it takes for the emulsion to set and the amount of mixing that can be performed before the emulsion breaks. Slow setting emulsions can stand up to more mixing than fast setting emulsions.

Emulsified Asphalt

- Rapid Setting (RS or CRS)
  Used for surface coats, penetration macadam
- Medium Setting (MS or CMS)
  Used for open-graded asphalt-treated base
- Slow Setting (SS or CSS)
  Used for dense-graded asphalt-treated base