

Asphalt

“Bitumen” redirects here. For naturally occurring bituminous sands used for petroleum production, see **Oil sands**. For other uses, see **Asphalt (disambiguation)**.

Note: The terms **bitumen** and **asphalt** are mostly interchangeable, except where asphalt is used as an abbreviation for **asphalt concrete**. This article uses “asphalt/bitumen” where either term is acceptable.

Asphalt (US [ⓘ]/ˈæsfɔːlt/, UK [ⓘ]/ˈæsfælt/,^{[1][2]} oc-



Natural asphalt/bitumen from the Dead Sea



refined asphalt/bitumen

asionally [ⓘ]/ˈæsfɔːlt^{[3][4]}), also known as **bitumen** (US [ⓘ]/bɪˈtjuːmən, [ⓘ]bar-,^{[5][6]} UK [ⓘ]/ˈbɪtjəmən^[7]) is a sticky, black and highly viscous liquid or semi-solid form of petroleum. It may be found in natural deposits or may be a refined product; it is a substance classed as a pitch. Until the 20th century, the term **asphaltum** was also used.^[8] The word is derived from the Ancient Greek ἄσφαλτος *ásphaltos*.^[9]

The primary use (70%) of asphalt/bitumen is in road construction, where it is used as the glue or binder mixed with aggregate particles to create asphalt concrete. Its other main uses are for bituminous waterproofing prod-



The University of Queensland pitch drop experiment, demonstrating the viscosity of asphalt/bitumen

ucts, including production of roofing felt and for sealing flat roofs.^[10]

The terms *asphalt* and *bitumen* are often used interchangeably to mean both natural and manufactured forms of the substance. In American English, asphalt (or asphalt cement) is the carefully refined residue from the distillation process of selected crude oils. Outside the United States, the product is often called bitumen. Geologists often prefer the term *bitumen*. Common usage often refers to various forms of asphalt/bitumen as “tar”, such as at the La Brea Tar Pits. Another archaic term for asphalt/bitumen is “pitch”.

Naturally occurring asphalt/bitumen is sometimes specified by the term “crude bitumen”. Its viscosity is similar to that of cold molasses^{[11][12]} while the material obtained from the fractional distillation of crude oil boiling at 525 °C (977 °F) is sometimes referred to as “refined bitumen”. The Canadian province of Alberta has

most of the world's reserves of natural bitumen, covering 142,000 square kilometres (55,000 sq mi), an area larger than England.^[13]

1 Composition

See also: *Asphaltene*

The components of asphalt are classified into four classes of compounds:

- saturates, saturated hydrocarbons, the % saturates correlates with softening point of the material
- Naphthene aromatics, consisting of partially hydrogenated polycyclic aromatic compounds.
- Polar aromatics, consisting of high molecular weight phenols and carboxylic acids
- Asphaltenes, consisting of high molecular weight phenols and heterocyclic compounds

The naphthene aromatics and polar aromatics are typically the majority components. Additionally, most natural bitumens contain organosulfur compounds, resulting in an overall sulfur content of up to 4%. Nickel and vanadium are found in the <10 ppm level, as is typical of some petroleum.^[10]

The substance is soluble in carbon disulfide. It is commonly modelled as a colloid, with asphaltenes as the dispersed phase and maltenes as the continuous phase.^[14] and "it is almost impossible to separate and identify all the different molecules of asphalt, because the number of molecules with different chemical structure is extremely large".^[15]

Asphalt/bitumen can sometimes be confused with "coal tar", which is a visually similar black, thermoplastic material produced by the destructive distillation of coal. During the early and mid-20th century when town gas was produced, coal tar was a readily available byproduct and extensively used as the binder for road aggregates. The addition of tar to macadam roads led to the word tarmac, which is now used in common parlance to refer to road-making materials. However, since the 1970s, when natural gas succeeded town gas, asphalt/bitumen has completely overtaken the use of coal tar in these applications. Other examples of this confusion include the La Brea Tar Pits and the Canadian oil sands, both of which actually contain natural bitumen rather than tar. Pitch is another term sometimes used at times to refer to asphalt/bitumen, as in Pitch Lake.



Bituminous outcrop of the Puy de la Poix, Clermont-Ferrand, France

2 Occurrence

The great majority of asphalt used commercially is obtained from petroleum. Nonetheless, large amounts of asphalt occur in concentrated form in nature. Naturally occurring deposits of asphalt/bitumen are formed from the remains of ancient, microscopic algae (diatoms) and other once-living things. These remains were deposited in the mud on the bottom of the ocean or lake where the organisms lived. Under the heat (above 50 °C) and pressure of burial deep in the earth, the remains were transformed into materials such as asphalt/bitumen, kerogen, or petroleum.

Natural deposits of asphalt/bitumen include lakes such as the Pitch Lake in Trinidad and Tobago and Lake Bermudez in Venezuela. Natural seeps of asphalt/bitumen occur in the La Brea Tar Pits and in the Dead Sea.

Asphalt/bitumen also occurs in unconsolidated sandstones known as "oil sands" in Alberta, Canada, and the similar "tar sands" in Utah, US. The Canadian province of Alberta has most of the world's reserves of natural bitumen, in three huge deposits covering 142,000 square kilometres (55,000 sq mi), an area larger than England or New York state. These bituminous sands contain 166 billion barrels (26.4×10⁹ m³) of commercially established oil reserves, giving Canada the third largest oil reserves in the world. and produce over 2.3 million barrels per day (370×10³ m³/d) of heavy crude oil and synthetic crude

oil. Although historically it was used without refining to pave roads, nearly all of the bitumen is now used as raw material for oil refineries in Canada and the United States.^[13]

The world's largest deposit of natural bitumen, known as the Athabasca oil sands is located in the McMurray Formation of Northern Alberta. This formation is from the early Cretaceous, and is composed of numerous lenses of oil-bearing sand with up to 20% oil.^[16] Isotopic studies attribute the oil deposits to be about 110 million years old.^[17] Two smaller but still very large formations occur in the Peace River oil sands and the Cold Lake oil sands, to the west and southeast of the Athabasca oil sands, respectively. Of the Alberta bitumen deposits, only parts of the Athabasca oil sands are shallow enough to be suitable for surface mining. The other 80% has to be produced by oil wells using enhanced oil recovery techniques like steam-assisted gravity drainage.^[18]

Much smaller heavy oil or bitumen deposits also occur in the Uinta Basin in Utah, US. The Tar Sand Triangle deposit, for example, is roughly 6% bitumen.^[16]

Asphalt/bitumen occurs in hydrothermal veins. An example of this is within the Uinta Basin of Utah, in the US, where there is a swarm of laterally and vertically extensive veins composed of a solid hydrocarbon termed Gilsonite. These veins formed by the polymerization and solidification of hydrocarbons that were mobilized from the deeper oil shales of the Green River Formation during burial and diagenesis.^[19]

Asphalt/bitumen is similar to the organic matter in carbonaceous meteorites.^[20] However, detailed studies have shown these materials to be distinct.^[21] The vast Alberta bitumen resources are believed to have started out as living material from marine plants and animals, mainly algae, that died millions of years ago when an ancient ocean covered Alberta. They were covered by mud, buried deeply over the eons, and gently cooked into oil by geothermal heat at a temperature of 50 to 150 °C (120 to 300 °F). Due to pressure from the rising of the Rocky Mountains in southwestern Alberta, 80 to 55 million years ago, the oil was driven northeast hundreds of kilometres into underground sand deposits left behind by ancient river beds and ocean beaches, thus forming the oil sands.^[18]

3 History

3.1 Ancient times

The use of asphalt/bitumen for waterproofing and as an adhesive dates at least to the fifth millennium BC in the early Indus valley sites like Mehrgarh, where it was used to line the baskets in which crops were gathered.^[22]

In the ancient Middle East, the Sumerians used natural

asphalt/bitumen deposits for mortar between bricks and stones, to cement parts of carvings, such as eyes, into place, for ship caulking, and for waterproofing.^[8] The Greek historian Herodotus said hot asphalt/bitumen was used as mortar in the walls of Babylon,^[23] as did Moses in reference to the Tower of Babel.^[24]

The 1 kilometre (0.62 mi) long Euphrates Tunnel beneath the river Euphrates at Babylon in the time of Queen Semiramis (ca. 800 BC) was reportedly constructed of burnt bricks covered with asphalt/bitumen as a waterproofing agent.^[25]

Asphalt/bitumen was used by ancient Egyptians to embalm mummies.^{[8][26]} The Persian word for asphalt is *moom*, which is related to the English word mummy. The Egyptians' primary source of asphalt/bitumen was the Dead Sea, which the Romans knew as *Palus Asphaltites* (Asphalt Lake).

Approximately 40 AD, Dioscorides described the Dead Sea material as *Judaicum bitumen*, and noted other places in the region where it could be found.^[27] The Sidon bitumen is thought to refer to asphalt/bitumen found at Hasbeya.^[28] Pliny refers also to asphalt/bitumen being found in Epirus. It was a valuable strategic resource; the object of the first known battle for a hydrocarbon deposit, between the Seleucids and the Nabateans in 312 BC.^[29]

In the ancient Far East, natural asphalt/bitumen was slowly boiled to get rid of the higher fractions, leaving a thermoplastic material of higher molecular weight which when layered on objects became quite hard upon cooling. This was used to cover objects that needed waterproofing,^[8] such as scabbards and other items. Statuettes of household deities were also cast with this type of material in Japan, and probably also in China.

In North America, archaeological recovery has indicated asphalt/bitumen was sometimes used to adhere stone projectile points to wooden shafts.^[30] In Canada, aboriginal people used bitumen seeping out of the banks of the Athabasca and other rivers to waterproof birch bark canoes, and also heated it in smudge pots to ward off mosquitoes in the summer time.^[18]

3.2 Early use in Europe

In 1453, Pierre Belon described in his work *Observations* in 1553 that *pissasphalto*, a mixture of pitch and bitumen, was used in the Republic of Ragusa (now Dubrovnik, Croatia) for tarring of ships from where it was exported to a market place in Venice where it could be bought by anyone.^[31] An 1838 edition of *Mechanics Magazine* cites an early use of asphalt in France. A pamphlet dated 1621, by "a certain Monsieur d'Eyrinys, states that he had discovered the existence (of asphaltum) in large quantities in the vicinity of Neufchatel", and that he proposed to use it in a variety of ways – "principally in the construction of air-proof granaries, and in protecting, by means

of the arches, the water-courses in the city of Paris from the intrusion of dirt and filth”, which at that time made the water unusable. “He expatiates also on the excellence of this material for forming level and durable terraces” in palaces, “the notion of forming such terraces in the streets not one likely to cross the brain of a Parisian of that generation”.^[32] But it was generally neglected in France until the revolution of 1830. Then, in the 1830s, there was a surge of interest, and asphalt became widely used “for pavements, flat roofs, and the lining of cisterns, and in England, some use of it had been made of it for similar purposes”. Its rise in Europe was “a sudden phenomenon”, after natural deposits were found “in France at Osbann (Bas-Rhin), the Parc (Ain) and the Puy-de-la-Poix (Puy-de-Dôme)”, although it could also be made artificially.^[33] One of the earliest uses in France was the laying of about 24,000 square yards of Seyssel asphalt at the Place de la Concorde in 1835.^[34]

3.3 Photography and art

Bitumen was used in early photographic technology. In 1826 or 1827, it was used by French scientist Joseph Nicéphore Niépce to make the oldest surviving photograph from nature. The bitumen was thinly coated onto a pewter plate which was then exposed in a camera. Exposure to light hardened the bitumen and made it insoluble, so that when it was subsequently rinsed with a solvent only the sufficiently light-struck areas remained. Many hours of exposure in the camera were required, making bitumen impractical for ordinary photography, but from the 1850s to the 1920s it was in common use as a photoresist in the production of printing plates for various photomechanical printing processes.^{[35][36]}

Bitumen was the nemesis of many artists during the 19th century. Although widely used for a time, it ultimately proved unstable for use in oil painting, especially when mixed with the most common diluents, such as linseed oil, varnish and turpentine. Unless thoroughly diluted, bitumen never fully solidifies and will in time corrupt the other pigments with which it comes into contact. The use of bitumen as a glaze to set in shadow or mixed with other colors to render a darker tone resulted in the eventual deterioration of many paintings, for instance those of Delacroix. Perhaps the most famous example of the destructiveness of bitumen is Théodore Géricault's *Raft of the Medusa* (1818–1819), where his use of bitumen caused the brilliant colors to degenerate into dark greens and blacks and the paint and canvas to buckle.^[37]

3.4 Early use in the United Kingdom

Among the earlier uses of asphalt/bitumen in the United Kingdom was for etching. William Salmon's *Polygraphice* (1673) provides a recipe for varnish used in etching, consisting of three ounces of virgin wax, two ounces of

mastic, and one ounce of asphaltum.^[38] By the fifth edition in 1685, he had included more asphaltum recipes from other sources.^[39]

The first British patent for the use of asphalt/bitumen was 'Cassell's patent asphalte or bitumen' in 1834.^[33] Then on 25 November 1837, Richard Tappin Claridge patented the use of Seyssel asphalt (patent #7849), for use in asphalte pavement,^{[40][41]} having seen it employed in France and Belgium when visiting with Frederick Walter Simms, who worked with him on the introduction of asphalt to Britain.^{[42][43]} Dr T. Lamb Phipson writes that his father, Samuel Ryland Phipson, a friend of Claridge, was also “instrumental in introducing the asphalte pavement (in 1836)”.^[44] Indeed, mastic pavements had been previously employed at Vauxhall by a competitor of Claridge, but without success.^[34]

In 1838, Claridge obtained patents in Scotland on 27 March, and Ireland on 23 April, and in 1851 extensions were sought for all three patents, by the trustees of a company previously formed by Claridge.^{[33][45][46][47]} This was *Claridge's Patent Asphalte Company*, formed in 1838 for the purpose of introducing to Britain “Asphalte in its natural state from the mine at Pyrimont Seysell in France”,^[48] and “laid one of the first asphalt pavements in Whitehall”.^[49] Trials were made of the pavement in 1838 on the footway in Whitehall, the stable at Knightsbridge Barracks,^{[48][50]} “and subsequently on the space at the bottom of the steps leading from Waterloo Place to St. James Park”.^[50] “The formation in 1838 of Claridge's Patent Asphalte Company (with a distinguished list of aristocratic patrons, and Marc and Isambard Brunel as, respectively, a trustee and consulting engineer), gave an enormous impetus to the development of a British asphalt industry”.^[46] “By the end of 1838, at least two other companies, Robinson's and the Bastenne company, were in production”,^[51] with asphalt being laid as paving at Brighton, Herne Bay, Canterbury, Kensington, the Strand, and a large floor area in Bunhill-row, while meantime Claridge's Whitehall paving “continue(d) in good order”.^[52]

In 1838, there was a flurry of entrepreneurial activity involving asphalt/bitumen, which had uses beyond paving. For example, asphalt could also be used for flooring, damp proofing in buildings, and for waterproofing of various types of pools and baths, with these latter themselves proliferating in the 19th century.^{[8][33][53]} On the London stockmarket, there were various claims as to the exclusivity of asphalt quality from France, Germany and England. And numerous patents were granted in France, with similar numbers of patent applications being denied in England due to their similarity to each other. In England, “Claridge's was the type most used in the 1840s and 50s”.^[51]

In 1914, Claridge's Company entered into a joint venture to produce tar-bound macadam,^[54] with materials manufactured through a subsidiary company called Clar-

mac Roads Ltd.^[55] Two products resulted, namely *Clarmac*, and *Clarphalte*, with the former being manufactured by Clarmac Roads and the latter by Claridge's Patent Asphalte Co., although *Clarmac* was more widely used.^{[56][note 1]} However, the **First World War** impacted financially on the Clarmac Company, which entered into liquidation in 1915.^{[58][59]} The failure of Clarmac Roads Ltd had a flow-on effect to Claridge's Company, which was itself compulsorily wound up,^[60] ceasing operations in 1917,^{[61][62]} having invested a substantial amount of funds into the new venture, both at the outset,^[60] and in a subsequent attempt to save the Clarmac Company.^[58]

3.5 Early use in the US

The first use of asphalt/bitumen in the New World was by indigenous peoples. On the west coast, as early as the 13th century, the **Tongva**, **Luiseño** and **Chumash** peoples collected the naturally occurring asphalt/bitumen that seeped to the surface above underlying petroleum deposits. All three used the substance as an adhesive. It is found on many different artifacts of tools and ceremonial items. For example, it was used on rattles to adhere gourds or turtle shells to rattle handles. It was also used in decorations. Small round shell beads were often set in asphaltum to provide decorations. It was used as a sealant on baskets to make them watertight for carrying water. Asphaltum was used also to seal the planks on ocean-going canoes.

Roads in the US have been paved with materials that include asphalt/bitumen since at least 1870, when a street in front of the Newark, NJ City Hall was paved. In many cases, these early pavings were made from naturally occurring "bituminous rock", such as at Ritchie Mines in Macfarlan in **Ritchie County, West Virginia** from 1852 to 1873. In 1876, asphalt-based paving was used to pave Pennsylvania Avenue in Washington, DC, in time for the celebration of the national centennial.^[63] Asphalt/bitumen was also used for flooring, paving and waterproofing of baths and swimming pools during the early 20th century, following similar trends in Europe.^[53]

3.6 Early use in Canada

See also: **Bitumount** and **History of the petroleum industry in Canada (oil sands and heavy oil)**

Canada has the world's largest deposit of natural bitumen in the Athabasca oil sands and Canadian First Nations along the Athabasca River had long used it to waterproof their canoes. In 1719, a Cree Indian named **Wapasa** brought a sample for trade to **Henry Kelsey** of the **Hudson's Bay Company**, who was the first recorded European to see it. However, it wasn't until 1787 that fur trader and explorer **Alexander MacKenzie** saw the Athabasca oil sands and said, "At about 24 miles from the fork (of the

Athabasca and Clearwater Rivers) are some bituminous fountains into which a pole of 20 feet long may be inserted without the least resistance."^[18]

The value of the deposit was obvious from the start, but the means of extracting the bitumen were not. The nearest town, **Fort McMurray, Alberta** was a small fur trading post, other markets were far away, and transportation costs were too high to ship the raw bituminous sand for paving. In 1915, Sidney Ells of the Federal Mines Branch experimented with separation techniques and used the bitumen to pave 600 feet of road in **Edmonton, Alberta**. Other roads in Alberta were paved with oil sands, but it was generally not economic. During the 1920s Dr. **Karl A. Clark** of the **Alberta Research Council** patented a hot water oil separation process and entrepreneur Robert C. Fitzsimmons^[64] built the **Bitumount** oil separation plant, which between 1925 and 1958 produced up to 300 barrels (50 m³) per day of bitumen using Dr. Clark's method. Most of the bitumen was used for waterproofing roofs, but other uses included fuels, lubrication oils, printers ink, medicines, rust and acid-proof paints, fire-proof roofing, street paving, patent leather, and fence post preservatives.^[18] Eventually Fitzsimmons ran out of money and the plant was taken over by the Alberta government. Today the Bitumount plant is a **Provincial Historic Site**.^[65]

4 Modern use



The road surface is removed and a new bitumen layer is added

4.1 Rolled asphalt concrete

Main article: **Asphalt concrete**

The largest use of asphalt/bitumen is for making asphalt concrete for road surfaces and accounts for approximately 85% of the asphalt consumed in the United States. Asphalt concrete pavement mixes are typically composed of 5% asphalt/bitumen cement and 95% aggregates (stone, sand, and gravel). Due to its highly viscous nature, asphalt/bitumen cement must be heated so it can be mixed with the aggregates at the asphalt mixing facility. The

temperature required varies depending upon characteristics of the asphalt/bitumen and the aggregates, but **warm-mix asphalt technologies** allow producers to reduce the temperature required. There are about 4,000 asphalt concrete mixing plants in the U.S., and a similar number in Europe.^[66]

When maintenance is performed on asphalt pavements, such as **milling** to remove a worn or damaged surface, the removed material can be returned to a facility for processing into new pavement mixtures. The asphalt/bitumen in the removed material can be reactivated and put back to use in new pavement mixes.^[67] With some 95% of paved roads being constructed of or surfaced with asphalt,^[68] a substantial amount of asphalt pavement material is reclaimed each year. According to industry surveys conducted annually by the **Federal Highway Administration** and the **National Asphalt Pavement Association**, more than 99% of the asphalt removed each year from road surfaces during widening and resurfacing projects is reused as part of new pavements, roadbeds, shoulders and embankments.^[69]

Asphalt concrete paving is widely used in airports around the world. Due to the sturdiness and ability to be repaired quickly, it is widely used for runways dedicated to aircraft landing and taking off.

4.2 Mastic asphalt

Mastic asphalt is a type of asphalt which differs from dense graded asphalt (**asphalt concrete**) in that it has a higher asphalt/bitumen (**binder**) content, usually around 7–10% of the whole aggregate mix, as opposed to rolled asphalt concrete, which has only around 5% added asphalt/bitumen. This thermoplastic substance is widely used in the building industry for waterproofing flat roofs and tanking underground. Mastic asphalt is heated to a temperature of 210 °C (410 °F) and is spread in layers to form an impervious barrier about 20 millimeters (0.79 inches) thick.

4.3 Asphalt emulsion

A number of technologies allow asphalt/bitumen to be mixed at much lower temperatures. These involve mixing with petroleum solvents to form “cutbacks” with reduced melting point, or mixtures with water to turn the asphalt/bitumen into an **emulsion**. Asphalt emulsions contain up to 70% asphalt/bitumen and typically less than 1.5% chemical additives. There are two main types of emulsions with different affinity for aggregates, cationic and anionic. Asphalt emulsions are used in a wide variety of applications. **Chipseal** involves spraying the road surface with asphalt emulsion followed by a layer of crushed rock, gravel or crushed slag. **Slurry seal** involves the creation of a mixture of asphalt emulsion and fine crushed aggregate that is spread on the surface of a road. Cold-

mixed asphalt can also be made from asphalt emulsion to create pavements similar to hot-mixed asphalt, several inches in depth and asphalt emulsions are also blended into recycled hot-mix asphalt to create low-cost pavements.

4.4 Synthetic crude oil

Main article: **Synthetic crude oil**

See also: **Petroleum production in Canada**

Synthetic crude oil, also known as **syncrude**, is the output from a bitumen upgrader facility used in connection with oil sand production in Canada. Bituminous sands are mined using enormous (100 ton capacity) **power shovels** and loaded into even larger (400 ton capacity) **dump trucks** for movement to an upgrading facility. The process used to extract the bitumen from the sand is a hot water process originally developed by **Dr. Karl Clark** of the **University of Alberta** during the 1920s. After extraction from the sand, the bitumen is fed into a **bitumen upgrader** which converts it into a **light crude oil** equivalent. This synthetic substance is fluid enough to be transferred through conventional **oil pipelines** and can be fed into conventional **oil refineries** without any further treatment. By 2015 Canadian bitumen upgraders were producing over 1 million barrels (160×10³ m³) per day of synthetic crude oil, of which 75% was exported to oil refineries in the United States.^[70]

In Alberta, five bitumen upgraders produce synthetic crude oil and a variety of other products: The **Suncor Energy** upgrader near **Fort McMurray, Alberta** produces synthetic crude oil plus diesel fuel; the **Syncrude Canada, Canadian Natural Resources**, and **Nexen** upgraders near **Fort McMurray** produce synthetic crude oil; and the **Shell Scotford Upgrader** near **Edmonton** produces synthetic crude oil plus an intermediate feedstock for the nearby **Shell Oil Refinery**.^[71] A sixth upgrader, under construction in 2015 near **Redwater, Alberta**, will upgrade half of its crude bitumen directly to diesel fuel, with the remainder of the output being sold as feedstock to nearby oil refineries and petrochemical plants.^[72]

4.5 Non-upgraded crude bitumen

See also: **Western Canadian Select**

Canadian bitumen does not differ substantially from oils such as Venezuelan extra-heavy and Mexican heavy oil in chemical composition, and the real difficulty is moving the extremely viscous bitumen through oil pipelines to the refinery. Many modern oil refineries are extremely sophisticated and can process non-upgraded bitumen directly into products such as gasoline, diesel fuel, and refined asphalt without any preprocessing. This is particu-

larly common in areas such as the US Gulf coast, where refineries were designed to process Venezuelan and Mexican oil, and in areas such as the US Midwest where refineries were rebuilt to process heavy oil as domestic light oil production declined. Given the choice, such heavy oil refineries usually prefer to buy bitumen rather than synthetic oil because the cost is lower, and in some cases because they prefer to produce more diesel fuel and less gasoline.^[71] By 2015 Canadian production and exports of non-upgraded bitumen exceeded that of synthetic crude oil at over 1.3 million barrels ($210 \times 10^3 \text{ m}^3$) per day, of which about 65% was exported to the United States.^[70]

Because of the difficulty of moving crude bitumen through pipelines, non-upgraded bitumen is usually diluted with natural-gas condensate in a form called dilbit or with synthetic crude oil, called synbit. However, to meet international competition, much non-upgraded bitumen is now sold as a blend of multiple grades of bitumen, conventional crude oil, synthetic crude oil, and condensate in a standardized benchmark product such as Western Canadian Select. This sour, heavy crude oil blend is designed to have uniform refining characteristics to compete with internationally marketed heavy oils such as Mexican Mayan or Arabian Dubai Crude.^[71]

4.6 Other uses

Roofing shingles account for most of the remaining asphalt/bitumen consumption. Other uses include cattle sprays, fence-post treatments, and waterproofing for fabrics. Asphalt/bitumen is used to make Japan black, a lacquer known especially for its use on iron and steel, and it is also used in paint and marker inks by some graffiti supply companies to increase the weather resistance and permanence of the paint or ink, and to make the color much darker. Asphalt/bitumen is also used to seal some alkaline batteries during the manufacturing process.

5 Production



Picture of typical asphalt plant for making asphalt.

About 40,000,000 tons were produced in 1984. It is obtained as the “heavy” (i.e., difficult to distill) fraction. Material with a boiling point greater than around $500 \text{ }^\circ\text{C}$ is considered asphalt. Vacuum distillation separates it from the other components in crude oil (such as naphtha, gasoline and diesel). The resulting material is typically further treated to extract small but valuable amounts of lubricants and to adjust the properties of the material to suit applications. In a de-asphalting unit, the crude asphalt is treated with either propane or butane in a supercritical phase to extract the lighter molecules, which are then separated. Further processing is possible by “blowing” the product: namely reacting it with oxygen. This step makes the product harder and more viscous.^[10]

Asphalt/bitumen is typically stored and transported at temperatures around $150 \text{ }^\circ\text{C}$ ($302 \text{ }^\circ\text{F}$). Sometimes diesel oil or kerosene are mixed in before shipping to retain liquidity; upon delivery, these lighter materials are separated out of the mixture. This mixture is often called “bitumen feedstock”, or BFS. Some dump trucks route the hot engine exhaust through pipes in the dump body to keep the material warm. The backs of tippers carrying asphalt/bitumen, as well as some handling equipment, are also commonly sprayed with a releasing agent before filling to aid release. Diesel oil is no longer used as a release agent due to environmental concerns.

5.1 From oil sands

See also: oil sands

Naturally occurring crude asphalt/bitumen impregnated in sedimentary rock is the prime feed stock for petroleum production from “Oil sands”, currently under development in Alberta, Canada. Canada has most of the world’s supply of natural asphalt/bitumen, covering 140,000 square kilometres^[73] (an area larger than England), giving it the second-largest proven oil reserves in the world. The Athabasca oil sands is the largest asphalt/bitumen deposit in Canada and the only one accessible to surface mining, although recent technological breakthroughs have resulted in deeper deposits becoming producible by *in situ* methods. Because of oil price increases after 2003, producing bitumen became highly profitable, but as a result of the decline after 2014 it became uneconomic to build new plants again. By 2014, Canadian crude asphalt/bitumen production averaged about 2.3 million barrels ($370,000 \text{ m}^3$) per day and was projected to rise to 4.4 million barrels ($700,000 \text{ m}^3$) per day by 2020.^[74] The total amount of crude asphalt/bitumen in Alberta which could be extracted is estimated to be about 310 billion barrels ($50 \times 10^9 \text{ m}^3$),^[13] which at a rate of 4,400,000 barrels per day ($700,000 \text{ m}^3/\text{d}$) would last about 200 years.

5.2 Alternatives and bioasphalt

Main articles: [Peak oil](#), [Global warming](#), and [Bioasphalt](#)

Although uncompetitive economically, asphalt/bitumen can be made from nonpetroleum-based renewable resources such as sugar, molasses and rice, corn and potato starches. Asphalt/bitumen can also be made from waste material by fractional distillation of used motor oil, which is sometimes otherwise disposed of by burning or dumping into landfills. Use of motor oil may cause premature cracking in colder climates, resulting in roads that need to be repaved more frequently.^[75]

Nonpetroleum-based asphalt/bitumen binders can be made light-colored. Lighter-colored roads absorb less heat from solar radiation, and have less surface heat than darker surfaces, reducing their contribution to the urban heat island effect.^[76] Parking lots that use asphalt alternatives are called green parking lots.

5.3 Natural bitumen

Selenizza is a naturally occurring solid hydrocarbon bitumen found in the native asphalt deposit of Selenice, in Albania, the only European asphalt mine still in use. The rock asphalt is found in the form of veins, filling cracks in a more or less horizontal direction. The bitumen content varies from 83% to 92% (soluble in carbon disulphide), with a penetration value near to zero and a softening point (ring & ball) around 120 °C. The insoluble matter, consisting mainly of silica ore, ranges from 8% to 17%.

The Albanian bitumen extraction has a long history and was practiced in an organized way by the Romans. After centuries of silence, the first mentions of Albanian bitumen appeared only in 1868, when the Frenchman Coquand published the first geological description of the deposits of Albanian bitumen. In 1875, the exploitation rights were granted to the Ottoman government and in 1912, they were transferred to the Italian company Simsa. Since 1945, the mine was exploited by the Albanian government and from 2001 to date, the management passed to a French company, which organized the mining process for the manufacture of the natural bitumen on an industrial scale.^[77]

Today the mine is predominantly exploited in an open pit quarry but several of the many underground mines (deep and extending over several km) still remain viable. The bitumen Selenizza is produced primarily in granular form, after melting the asphalt pieces selected in the mine.

Selenizza^[78] is mainly used as an additive in the road construction sector. It is mixed with traditional bitumen to improve both the viscoelastic properties and the resistance to ageing. It may be blended with the hot bitumen in tanks, but its granular form allows it to be fed in the mixer or in the recycling ring of normal asphalt plants.

Other typical applications include the production of mastic asphalts for sidewalks, bridges, car-parks and urban roads as well as drilling fluid additives for the oil and gas industry. Selenizza is available in powder or in granular material of various particle sizes and is packaged in big bags or in thermal fusible polyethylene bags.

A Life Cycle Assessment (LCA) study of the natural bitumen Selenizza compared with petroleum bitumen, has shown that the environmental impact of the natural bitumen is about half the impact of the road bitumen produced in oil refineries in terms of carbon dioxide emission.^[79]

5.4 Occupational safety

People can be exposed to asphalt in the workplace by breathing in fumes or skin absorption. The National Institute for Occupational Safety and Health (NIOSH) has set a Recommended exposure limit (REL) of 5 mg/m³ over a 15-minute period.^[80] Asphalt is basically an inert material that must be heated or diluted to a point where it becomes workable for the production of materials for paving, roofing, and other applications. In examining the potential health hazards associated with asphalt, the International Agency for Research on Cancer (IARC) determined that it is the application parameters, predominantly temperature, that affect occupational exposure and the potential bioavailable carcinogenic hazard/risk of the asphalt emissions.^[81] In particular, temperatures greater than 199 °C (390 °F), were shown to produce a greater exposure risk than when asphalt was heated to lower temperatures, such as those typically used in asphalt pavement mix production and placement.^[82]

6 Etymology

The word *asphalt* is derived from the late Middle English, in turn from French *asphalte*, based on Late Latin *asphaltum*, *asphaltum*, which is the latinisation of the Greek ἄσφαλτος (*ásphaltos*, *ásphaltos*), a word meaning “asphalt/bitumen/pitch”,^[83] which perhaps derives from ἄ-, “without” and σφάλλω (*sfallō*), “make fall”.^[84] Note that in French, the term *asphalte* is used for naturally occurring bitumen-soaked limestone deposits, and for specialised manufactured products with fewer voids or greater bitumen content than the “asphaltic concrete” used to pave roads. It is a significant fact that the first use of asphalt by the ancients was in the nature of a cement for securing or joining together various objects, and it thus seems likely that the name itself was expressive of this application. Specifically Herodotus mentioned that bitumen was brought to Babylon to build its gigantic fortification wall.^[85] From the Greek, the word passed into late Latin, and thence into French (*asphalte*) and English (“asphaltum” and “asphalt”).

The expression “bitumen” originated in the Sanskrit, where we find the words *jatu*, meaning “pitch,” and *jatukrit*, meaning “pitch creating”, “pitch producing” (referring to coniferous or resinous trees). The Latin equivalent is claimed by some to be originally *gwitu-men* (pertaining to pitch), and by others, *pixtumens* (exuding or bubbling pitch), which was subsequently shortened to *bitumen*, thence passing via French into English. From the same root is derived the Anglo Saxon word *cwidu* (mastic), the German word *Kitt* (cement or mastic) and the old Norse word *kvada*.^[86]

Neither of the terms asphalt or bitumen should be confused with tar or coal tars.

6.1 Modern usage



An asphalt mixing plant for hot aggregate

In British English, the word 'asphalt' is used to refer to a mixture of mineral aggregate and asphalt/bitumen (also called tarmac in common parlance). When bitumen is mixed with clay it is usually called asphaltum.^[87] The earlier word 'asphaltum' is now archaic and not commonly used. In American English, 'asphalt' is equivalent to the British 'bitumen'. However, 'asphalt' is also commonly used as a shortened form of 'asphalt concrete' (therefore equivalent to the British 'asphalt' or 'tarmac'). In Australian English, bitumen is often used as the generic term for road surfaces. In Canadian English, the word bitumen is used to refer to the vast Canadian deposits of extremely heavy crude oil,^[73] while asphalt is used for the oil refinery product used to pave roads and manufacture roof shingles and various waterproofing products. Diluted bitumen (diluted with naphtha to make it flow in pipelines) is known as dilbit in the Canadian petroleum industry, while bitumen "upgraded" to synthetic crude oil is known as syncrude and syncrude blended with bitumen as synbit.^[74] Bitumen is still the preferred geological term for naturally occurring deposits of the solid or semi-solid form of petroleum. Bituminous rock is a form of sandstone impregnated with bitumen. The tar sands of Alberta, Canada are a similar material.

7 See also

- Alveodren^[88]
- Asphalt plant
- Asphaltene
- Bioasphalt
- Bitumen-based fuel
- Bituminous coal
- Bituminous rocks
- Blacktop
- Cooper Research Technology
- Duxit
- Edward de Smedt^[89]
- International Grooving & Grinding Association
- Macadam
- Oil sands
- Pitch (resin)
- Tar
- Tarmac
- Sealcoat
- Stamped asphalt

8 Notes

- [1] *The Building News and Engineering Journal* contains photographs of the following roads where *Clarmac* was used, being “some amongst many laid with 'Clarmac'”: Scott’s Lane, Beckenham; Dorset Street, Marylebone; Lordwood Road, Birmingham; Hearsall Lane, Coventry; Valkyrie Avenue, Westcliff-on-Sea; and Lennard Road, Penge.^[57]

9 References

- [1] **Merriam-Webster:**
- [2] **Oxford Advanced Learner’s Dictionary:**
- [3] **The Canadian Oxford Dictionary:**
- [4] **Macquarie Dictionary:**
- [5] **Dictionary Reference:** bitumen
- [6] **The Free Dictionary:** bitumen
- [7] **Oxford Dictionaries:**

- [8] Abraham, Herbert (1938). *Asphalts and Allied Substances: Their Occurrence, Modes of Production, Uses in the Arts, and Methods of Testing* (4th ed.). New York: D. Van Nostrand Co. Retrieved 16 November 2009. Full text at Internet Archive (archive.org)
- [9] asphalt, Chambers 21st Century Dictionary
- [10] Anja Sörensen and Bodo Wichert “Asphalt and Bitumen” in Ullmann’s Encyclopedia of Industrial Chemistry Wiley-VCH, Weinheim, 2009. doi:10.1002/14356007.a03_169.pub2http://www.qrpoil.com/site/?bitumen
- [11] “Oil Sands – Glossary”. *Oil Sands Royalty Guidelines*. Government of Alberta. 2008. Archived from the original on 1 November 2007. Retrieved 2 February 2008.
- [12] Walker, Ian C. (1998), *Marketing Challenges for Canadian Bitumen* (PDF), Tulsa, OK: International Centre for Heavy Hydrocarbons, Bitumen has been defined by various sources as crude oil with a dynamic viscosity at reservoir conditions of more than 10,000 centipoise. Canadian “bitumen” supply is more loosely accepted as production from the Athabasca, Wabasca, Peace River and Cold Lake oil-sands deposits. The majority of the oil produced from these deposits has an API gravity of between 8° and 12° and a reservoir viscosity of over 10,000 centipoise although small volumes have higher API gravities and lower viscosities.
- [13] “ST98-2015: Alberta’s Energy Reserves 2014 and Supply/Demand Outlook 2015–2024” (PDF). *Statistical Reports (ST)*. Alberta Energy Regulator. 2015. Retrieved 19 January 2016.
- [14] Muhammad Abdul Quddus (1992). “Catalytic Oxidation of Asphalt”. *thesis submitted to Department of Applied Chemistry; University of Karachi*. Pakistan: Higher Education Commission Pakistan: Pakistan Research Repository. p. 6, in ch.2 pdf.
- [15] Muhammad Abdul Quddus (1992), p.99, in ch.5 pdf
- [16] Bungler, J.; Thomas, K.; Dorrence, S. (1979). “Compound types and properties of Utah and Athabasca tar sand bitumens”. *Fuel*. **58** (3): 183–195. doi:10.1016/0016-2361(79)90116-9.
- [17] Selby, D.; Creaser, R. (2005). “Direct radiometric dating of hydrocarbon deposits using rhenium-osmium isotopes”. *Science*. **308**: 1293–1295. doi:10.1126/science.1111081.
- [18] “Facts about Alberta’s oil sands and its industry” (PDF). Oil Sands Discovery Centre. Retrieved 19 January 2015.
- [19] T. Boden and B. Tripp (2012). *Gilsonite Veins of the Uinta Basin, Utah*. Utah, US: Utah Geological Survey, Special Study 141.
- [20] Hayatsu; et al. *Meteoritics*. **18**: 310.
- [21] Kim; Yang. *Journal of Astronomy and Space Sciences*. **15** (1): 163–174.
- [22] McIntosh, Jane. *The Ancient Indus Valley*. p. 57
- [23] Herodotus, Book I, 179
- [24] Genesis 11:3
- [25] Abraham, Herbert (1920). *Asphalts And Allied Substances*. D. Van Nostrand.
- [26] Pringle, Heather Anne (2001). *The Mummy Congress: Science, Obsession, and the Everlasting Dead*. New York, NY: Barnes & Noble Books. pp. 196–197. ISBN 0-7607-7151-0.
- [27] Pedanius Dioscorides. *De Materia Medica*.. Original written ca. 40 AD, translated by Goodyer (1655) or (Greek/Latin) compiled by Sprengel (1829) p. 100 (p. 145 in PDF).
- [28] Connan, Jacques; Nissenbaum, Arie (2004). “The organic geochemistry of the Hasbeya asphalt (Lebanon): comparison with asphalts from the Dead Sea area and Iraq”. *Organic Geochemistry*. **35** (6): 775–789. doi:10.1016/j.orggeochem.2004.01.015. ISSN 0146-6380.
- [29] Arie Nissenbaum (May 1978). “Dead Sea Asphalts—Historical Aspects [free abstract]”. *AAPG Bulletin*. **62** (5): 837–844. doi:10.1306/c1ea4e5f-16c9-11d7-8645000102c1865d.
- [30] The Megalithic Portal and Megalith Map. “C.Michael Hogan (2008) "Morro Creek", ed. by A. Burnham”. Megalithic.co.uk. Retrieved 27 August 2013.
- [31] Africa and the Discovery of America, Volume 1, page 183, Leo Wiener, BoD – Books on Demand, 1920 reprinted in 2012, ISBN 978-3864034329
- [32] “Nothing New under the Sun (on French asphaltum use in 1621)”. *The Mechanic’s magazine, museum, register, journal and gazette*. **29**. London: W.A. Robertson. 7 April – 29 September 1838. p. 176.
- [33] Miles, Lewis (2000). “Section 10.6: Damp Proofing”. in *Australian Building: A Cultural Investigation* (PDF). p. 10.06.1. Retrieved 11 November 2009.. Note: different sections of Miles’ online work were written in different years, as evidenced at the top of each page (not including the heading page of each section). This particular section appears to have been written in 2000
- [34] R.J. Forbes (1958), *Studies in Early Petroleum History*, Leiden, Netherlands: E.J. Brill, p. 24, retrieved 10 June 2010
- [35] Niépce Museum history pages. Retrieved 27 October 2012. Archived 3 August 2007 at the Wayback Machine.
- [36] The First Photograph (Harry Ransom Center, University of Texas at Austin). Retrieved 27 October 2012.
- [37] Spiegelman, Willard (2009-08-21). “Revolutionary Romanticism: 'The Raft of the Medusa' brought energy to French art”. *The Wall Street Journal*. New York City. Retrieved 2016-01-27.
- [38] Salmon, William (1673). *Polygraphice; Or, The Arts of Drawing, Engraving, Etching, Limning, Painting, Washing, Varnishing, Gilding, Colouring, Dying, Beautifying and Perfuming* (Second ed.). London: R. Jones. p. 81.

- [39] Salmon, William (1685), *Polygraphice; Or, The Arts of Drawing, Engraving, Etching, Limning, Painting, Washing, Varnishing, Gilding, Colouring, Dying, Beautifying and Perfuming* (5th ed.), London: R. Jones, pp. 76–77, retrieved 18 August 2010 Text at Internet Archive
- [40] “Specification of the Patent granted to Richard Tappin Claridge, of the County of Middlesex, for a Mastic Cement, or Composition applicable to Paving and Road making, covering Buildings and various purposes”. *Journal of the Franklin Institute of the State of Pennsylvania and Mechanics’ Register*. Vol. 22. London: Pergamon Press. July 1838. pp. 414–418. Retrieved 18 November 2009.
- [41] “Comments on asphalt patents of R.T. Claridge, Esq”. *Notes and Queries: A medium of intercommunication for Literary Men, General Readers, etc. Ninth series*. Volume XII, July–December, 1903 (9th S. XII, 4 July 1903). London: John C. Francis. 20 January 1904. pp. 18–19. Writer is replying to note or query from previous publication, cited as *9th S. xi. 30*
- [42] “Obituary of Frederick Walter Simms”. *Monthly Notices of the Royal Astronomical Society*. London: Strangeways & Walden. **XXVI**: 120–121. November 1865 – June 1866. Retrieved 12 November 2009.
- [43] Broome, D.C. (1963). “The development of the modern asphalt road”. *The Surveyor and municipal and county engineer*. London. **122** (3278 & 3279): 1437–1440 & 1472–1475 Snippet view: Simms & Claridge p.1439
- [44] Phipson, Dr T. Lamb (1902). *Confessions of a Violinist: Realities and Romance*. London: Chatto & Windus. p. 11. Retrieved 26 November 2009. Full text at Internet Archive (archive.org)
- [45] “Claridge’s UK Patents in 1837 & 1838”. *The London Gazette*. 25 February 1851. p. 489.
- [46] Hobhouse, Hermione (General Editor) (1994). “British History Online”. ‘*Northern Millwall: Tooke Town*’, *Survey of London: volumes 43 and 44: Poplar, Blackwall and Isle of Dogs*. pp. 423–433 (see text at refs 169 & 170). Retrieved 8 November 2009.
- [47] “Claridge’s Scottish and Irish Patents in 1838”. *The Mechanic’s magazine, museum, register, journal and gazette*. **29**. London: W.A. Robertson. 7 April – 29 September 1838. pp. vii, viii, 64, 128.
- [48] “Joint Stock Companies (description of asphalt use by Claridge’s company)”. *The Civil Engineer and Architects Journal*. Vol. 1. London. October 1837 – December 1838. p. 199. Retrieved 16 November 2009. Full text at Internet Archive (archive.org). Alternative viewing at: <https://books.google.com/books?id=sQ5AAAAAYAAJ&pg>
- [49] Miles, Lewis (2000), pp.10.06.1–2
- [50] Comments on asphalt patents of R.T. Claridge, Esq (1904), p.18
- [51] Miles, Lewis (2000), p.10.06.2
- [52] “1838 bitumen UK uses by Robinson’s and Claridge’s companies, & the Bastenne company”. *The Mechanic’s magazine, museum, register, journal and gazette*. **29**. London: W.A. Robertson. 22 September 1838. p. 448.
- [53] Gerhard, W.M. Paul (1908). *Modern Baths and Bath Houses* (1st ed.). New York: John Wiley and Sons. (Enter “asphalt” into the search field for list of pages discussing the subject)
- [54] “Claridge’s Patent Asphalt Co. ventures into tarred slag macadam”, *Concrete and Constructional Engineering*, London, **IX** (1): 760, January 1914, retrieved 15 June 2010
- [55] “Registration of Clarmac Roads”, *The Law Reports: Chancery Division*, Vol. 1: 544–547, 1921, retrieved 17 June 2010
- [56] “Clarmac and Clarphalte”, *The Building News and Engineering Journal*, Vol. 109: July to December 1915 (No. 3157): 2–4 (n13–15 in electronic page field), 7 July 1915, retrieved 18 June 2010
- [57] Roads laid with Clarmac *The Building News and Engineering Journal*, 1915 **109** (3157), p.3 (n14 in electronic field).
- [58] Clarmac financial difficults due to WW1 Debentures deposited *The Law Reports: Chancery Division*, (1921) **Vol. 1** p.545. Retrieved 17 June 2010.
- [59] “Notice of the Winding up of Clarmac Roads”, *The London Gazette* (29340): 10568, 26 October 1915, retrieved 15 June 2010
- [60] Claridge’s Patent Asphalt Co. compulsorily wound up Funds invested in new company *The Law Times Reports* (1921) **Vol.125**, p.256. Retrieved 15 June 2010.
- [61] “Claridge’s Patent Asphalt Co. winds up 10 November 1917”. *The London Gazette*. 16 November 1917. p. 11863.
- [62] Hobhouse, Hermione (General Editor) (1994). “British History Online”. ‘*Cubitt Town: Riverside area: from Newcastle Drawdock to Cubitt Town Pier*’, *Survey of London: volumes 43 and 44: Poplar, Blackwall and Isle of Dogs*. pp. 528–532 (see text at refs 507 & 510). Retrieved 8 November 2009.
- [63] McNichol, Dan (2005). *Paving the Way: Asphalt in America*. Lanham, MD: National Asphalt Pavement Association. ISBN 0-914313-04-5.
- [64] “Robert C. Fitzsimmons (1881-1971)”. Canadian Petroleum Hall of Fame. 2010. Retrieved 2016-01-20.
- [65] “Bitumount”. Government of Alberta. 2016. Retrieved 2016-01-20.

9.1 Bitumen usage Totally

The vast majority of refined bitumen is used in construction: primarily as a constituent of products used in paving and roofing applications. According to the requirements of the end use bitumen is produced to specification. This

is achieved either by refining process or blending. It is estimated that the current world use of bitumen is approximately 102 million tonnes per year. Approximately 85% of all the bitumen produced is used as the binder in asphalt for roads. It is also used in other paved areas such as airport runways, car parks and footways. Typically, the production of asphalt involves mixing sand, gravel and crushed rock with bitumen, which acts as the binding agent. Other materials, such as polymers, may be added to the bitumen to alter its properties according to the application for which the asphalt is ultimately intended. A further 10% of global bitumen production is used in roofing applications, where its waterproofing qualities are invaluable. The remaining 5% of bitumen is used mainly for sealing and insulating purposes in a variety of building materials, such as pipe coatings, carpet tile backing and paint. Bitumen is applied in construction and maintenance of:

- Highways · Airport runways · Footways / Pedestrian Ways · Car parks · Racetracks · Tennis courts · Roofing · Damp proofing · Dams · Reservoir and pool linings · Soundproofing · Pipe coatings · Cable Coatings · Paints · Building Water Proofing · Tile underlying waterproofing · Newspaper Ink Production · And many other applications

- [66] *The Asphalt Paving Industry: A Global Perspective, 2nd Edition* (PDF). Lanham, Maryland, and Brussels: National Asphalt Pavement Association and European Asphalt Pavement Association. February 2011. ISBN 0-914313-06-1. Retrieved 27 September 2012.
- [67] “How Should We Express RAP and RAS Contents?”. *Asphalt Technology E-News*. **26** (2). 2014. Retrieved 2015-08-13.
- [68] “Highway Statistics Series: Public Road Length Miles by Type of Surface and Ownership”. Federal Highway Administration. 2013-10-01. Retrieved 2015-08-13.
- [69] “Asphalt Pavement Recycling”. *Annual Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt Usage: 2009–2013*. National Asphalt Pavement Association. Retrieved 13 August 2015.
- [70] “Crude Oil and Petroleum Products”. National Energy Board of Canada. Retrieved January 21, 2016.
- [71] “2015 CAPP Crude Oil Forecast, Markets & Transportation”. Canadian Association of Petroleum Producers. Retrieved January 21, 2016.
- [72] “The Project”. North West Redwater Partnership. Retrieved January 21, 2016.
- [73] “What is Oil Sands”. Alberta Energy. 2007. Archived from the original on 5 February 2016. Retrieved 10 January 2008.
- [74] “2007 Canadian Crude Oil Forecast and Market Outlook”. Canadian Association of Petroleum Producers. June 2007. Retrieved 30 May 2008.
- [75] Hesp, Simon A.M.; Herbert F. Shurvell (2010). “X-ray fluorescence detection of waste engine oil residue in asphalt and its effect on cracking in service”. *International Journal of Pavement Engineering*. **11** (6): 541–553. doi:10.1080/10298436.2010.488729. ISSN 1029-8436. Retrieved 2014-03-24.
- [76] Heat Island Effect. From the website of the U.S. Environmental Protection Agency.
- [77] Giavarini, Carlo (March 2013). *Six Thousand Years of Asphalt*. SITEB. pp. 71–78. ISBN 978-88-908408-3-8.
- [78] , Selenice Bitumi for more information about Selenizza
- [79] Giavarini, C.; Pellegrini, A. “Life cycle assessment of Selenice asphalt compared with petroleum bitumen”. *The 1st Albanian Congress on Roads*: 234–237.
- [80] “CDC - NIOSH Pocket Guide to Chemical Hazards - Asphalt fumes”. *www.cdc.gov*. Retrieved 2015-11-27.
- [81] IARC (2013). *Bitumens and Bitumen Emissions, and Some N- and S-Heterocyclic Polycyclic Aromatic Hydrocarbons*. **103**. Lyon, France: International Agency for Research on Cancer. ISBN 978-92-832-1326-0. Retrieved 2015-12-07.
- [82] Cavallari, J. M.; Zwack, L. M.; Lange, C. R.; Herrick, R. F.; Mcclean, M. D. (2012). “Temperature-Dependent Emission Concentrations of Polycyclic Aromatic Hydrocarbons in Paving and Built-Up Roofing Asphalts”. *Annals of Occupational Hygiene*. **56** (2): 148–160. doi:10.1093/annhyg/mer107. ISSN 0003-4878.
- [83] ἄσφαλτος, Henry George Liddell, Robert Scott, *A Greek-English Lexicon*, on Perseus
- [84] σφάλω, Henry George Liddell, Robert Scott, *A Greek-English Lexicon*, on Perseus
- [85] Herodotus, *The Histories*, 1.179.4, on Perseus
- [86] Abraham, Herbert (1938), p.1
- [87] Béguin, André. “A technical dictionary of printmaking - Bitumen”. *www.polymetaal.nl*. Retrieved 27 January 2016.
- [88] Eco roofing
- [89] – History of roads.
- [1][1]

10 Sources

- Barth, Edwin J., *Asphalt: Science and Technology* Gordon and Breach (1962). ISBN 0-677-00040-5.
- Forbes, R.J. (1993) [Reprint of 1964 ed.], *Studies in Ancient Technology*, Volume 1, The Netherlands: E.J. Brill, ISBN 90-04-00621-4
- Lay, Maxwell G (1992), *The Ways of the World: A History of the World's Roads and of the Vehicles that Used Them*, Rutgers University Press, ISBN 0-8135-2691-4

11 External links

- Redwood, Boverton (1911). "Asphalt". *Encyclopædia Britannica*. 2 (11th ed.). p. 768.
- International Chemical Safety Card 0612
- Pavement Interactive – Asphalt
- Asphalt Magazine
- CSU Sacramento, The World Famous Asphalt Museum!
- National Institute for Occupational Safety and Health – Asphalt Fumes
- "Bitumen". *New International Encyclopedia*. 1905.

[1]

12 Text and image sources, contributors, and licenses

12.1 Text

- Asphalt** *Source:* <https://en.wikipedia.org/wiki/Asphalt?oldid=749178935> *Contributors:* Bryan Derksen, Zundark, Mcwee, Cdani, Karen Johnson, SimonP, DavidLevinson, Heron, Hephaestos, Tedernst, Edward, Lir, Michael Hardy, Dominus, Tregoweth, Looxix~enwiki, Mac, Jimfbleak, Andres, Cimon Avaro, Mxn, Dwo, Charles Matthews, Vanished user 5zariu3jjsj0j4irj, Dcoetzee, Dysprosia, Snickerdo, Indefatigable, Ortonmc, Hajor, Jeffq, Donarreiskoffer, Robbot, AlainV, Nurg, Merovingian, Toiyabe, Wikibot, Quadalpha, Pengo, Rossqk, DocWatson42, Alan W, Micru, Gilgamesh~enwiki, Fooobar, Bobblewik, Pgan002, Yath, Quadell, Beland, Cederal, Eranb, Arosa, Sonett72, Tcr25, Esperant, Kmccoy, Brianjd, Blanchette, Rich Farmbrough, Vsmith, GPoss, Bender235, Flapdragon, El C, Kwamikagami, The bellman, Alga, Guettarda, Sole Soul, Spalding, StoatBringer, Vortexrealm, Jojit fb, Kjkolb, Caeruleancentaur, Jjron, Anthony Appleyard, Mr Adequate, AzaToth, Jaardon, NTK, Snowolf, Wtmitchell, Velella, Pauli133, Sleigh, Gene Nygaard, HenryLi, Feezo, Stemonitis, Robin F., Woohookitty, Faithtear, PeterR2, SCEhardt, SDC, Cshirky, Mandarax, Bossonova, Search4Lancer, Rjwilmsi, Ian Page, Pleiotrop3, Bob A, Michlt, Hlangeveld, DonSiano, Bfigura, Vuong Ngan Ha, Azalero, Ground Zero, Physchim62, Bgwhite, YurikBot, Wavelength, DMa-halko, Fabricationary, Ikar.us, Stephenb, Shell Kinney, Gaius Cornelius, Neilbeach, Salsb, NawlinWiki, ReddyRose, Flyset, Aaron Schulz, Gadget850, Zouden, Wknight94, Alasdair, Hudsojt, Jade Knight, Attilios, SmackBot, Dweller, Verne Equinox, Anastrophe, Zaqarbal, Gilliam, Hmains, Betacommand, JAn Dudik, GregMaxey, Bidgee, MidgleyDJ, Bazonka, CyberSach, CSWarren, Huji, Ww2censor, DinosaursLoveExistence, AlexJP, RaCha'ar, Smokefoot, Sokolesq, Kendrick7, TenPoundHammer, Ohconfucius, ThurnerRupert, JzG, John, JackLumber, Robofish, Breno, Mbeychok, JHunterJ, Beetstra, Optakeover, Ace Frahm, Peter Horn, Hu12, Iridescent, Paul venter, Joseph Solis in Australia, RekishiEJ, N0TABENE, Tawkerbot2, Chetvorno, Eastlaw, JForget, Wolfdog, CmdrObot, The Librarian, Mann.benoit, Zarex, Smably, RockyMtnGuy, Chrissy385, Mmoyer, Cydebot, MC10, DumbBOT, RottweilerCS, Sharonlees, Omicronpersei8, Hubba, Kirk Hilliard, Cuthbertwong, Casliber, Thijs!bot, Epbr123, Tomboy Man, Zé da Silva, Gierszep, Mayray, Hires an editor, SummerPhD, Dougher, JAnDbot, Defective, MER-C, Appaloosasunset, 100110100, The elephant, Magioladitis, AuburnPilot, Nyttend, Beagel, Philg88, Calltech, Drm310, MartinBot, Ecopave, Bobcoyote, Saintjimmy777, Paracel63, Keith D, CommonsDelinker, Fact idiot, Webmasters, Helping, Rod57, HornColumbia, Natobxl, Afluegel, Paulbracegirdle, Time River, Potatoswatter, KylieTastic, Antepenultimate, Cometstyles, Treisijis, Pickleklk, Metro67, Wjrwjring, Krispykorn, Hellno2, Deor, Metal.lunchbox, Thomas.W, Macedonian, Triskele Jim, Tzetzes, Philip Trueman, TXiKiBoT, Hobe, GDonato, Crap casserole, Cremepuff222, BotKung, Sorenmarklund, Andy Dingley, WatermelonPotion, Mgfant222, Taedxy, Biscuittin, SieBot, Ghimboueis, Mnbitar, Yintan, LeadSongDog, AndrewNJ, Bentogoa, Wombatcat, Stephen Shaw, Runner5k, DRTllbrg, Into The Fray, ObfuscatePenguin, Mr. Granger, JediZombie, ClueBot, The Thing That Should Not Be, Mild Bill Hiccup, Jmn100, Niceguyedc, LizardJr8, Mr Accountable, Tisdalepardi, Alexbot, Blabbermouth69, Testers456, Whistleblower69, TheRedPenOfDoom, Cypress.cool1, Thehelpfulone, El bot de la dieta, XLinkBot, AgnosticPreachersKid, Ost316, LeaW, Dwight Burdette, Benjaminruggill, Cewvero, MrOllie, Logan41, LinkFA-Bot, West.andrew.g, Liuliu45, Kimlee2, Sortie897, Samsung2, Tassedethe, Smoke and Mirrors2, 102orion, Tide rolls, Lightbot, Andrevruas, Quantumobserver, Legobot, आशीष भटनागर, Luckas-bot, Yobot, Yngvadotir, AnomieBOT, lexec1, Jim1138, Mrqwerty987, Mahmudmasri, MaterialsScientist, Bob Burkhardt, LilHelpa, Ellielopez, Gymnophoria, Blusterybrew, XZeroBot, Chipsealer, Anna Frodesiak, BritishWatcher, GrouchoBot, Fanclubprez, Omnipaedista, SciberDoc, AlexPlante, Silverije, Sahehco, Smbrown123, Shadowjams, Fixentries, Erik9, Oneliketadow, Muktar223, Seankoenig, Pinethicket, I dream of horses, Masteve, Abductive, RedBot, Jauhienij, FoxBot, Trappist the monk, Wotnow, Pny, Scikris, WCCasey, RjwilmsiBot, DexDor, Missasphalt, Burwoodm, Vostok 129, CalicoCatLover, DASHBot, Look2See1, RA0808, Snorgway, Dcirovic, AsceticRose, Ore0654, Pivren, John Cline, PBS-AWB, Checkingfax, SporkBot, Likeafreighttrain, Smartpotato, L Kensington, AVarchaeologist, Xiaoyu of Yuxi, Chuck Entz, Thiagoreis leon, Llightex, Spicemix, ClueBot NG, Brownbill98, Cntras, Mmbreuer, Armedrocker, Reify-tech, Soursob, Helpful Pixie Bot, Mcomplete, Carterdu, BG19bot, Beaumont877, Imgaril, ProjectManhattan, Richardndea, PhnomPencil, CitationCleanerBot, Snow Blizzard, Averonicaw, Jmccormick927, Strgrzr101, Lieutenant of Melkor, Dourios, Skunk44, Mddkpp, BattyBot, HueSatLum, Cyberbot II, ChrisGualtieri, Oranjblud, BrightStarSky, Dexbot, Wywin, Wikipwner1337, AmaryllisGardener, AmericanLemming, Bschrnid3, Bitumat-company, Kogge, Cptmmrcmillan, Giverodge Construction, Stamptrader, Junaidjag, Shaq123shaq, Cornhorn, Dat Smart Person, Monkbot, Qavami, Vieque, Trackteur, Sferriin, USAthegreat, Wjkxy, Shmovenub, Wikisay, Emily Temple-Wood (NIOSH), Hinaqin, Mousaalipoor, KasparBot, Mehranarabi, Feedar, Warmlytech, CallahanK, Maczkopeti, CLCStudent, InternetArchiveBot, Dannyclopp, GreenC bot, Armarcogemaque, Gulumeemee, Yaseen ansari and Anonymous: 325

12.2 Images

- File:Asfaltna_baza_Ivanovec.1.jpg** *Source:* https://upload.wikimedia.org/wikipedia/commons/a/a7/Asfaltna_baza_Ivanovec.1.jpg *License:* CC BY-SA 4.0 *Contributors:* Own work *Original artist:* Silverije
- File:Asphalt_plant_pic.jpg** *Source:* https://upload.wikimedia.org/wikipedia/commons/c/cc/Asphalt_plant_pic.jpg *License:* CC BY-SA 1.0 *Contributors:* <http://www.asphaltplant.cn> direct link *Original artist:* Unknown photographer
- File:Bitumen.jpg** *Source:* <https://upload.wikimedia.org/wikipedia/commons/2/28/Bitumen.jpg> *License:* Public domain *Contributors:* Own work *Original artist:* Daniel Tzvi
- File:Commons-logo.svg** *Source:* <https://upload.wikimedia.org/wikipedia/en/4/4a/Commons-logo.svg> *License:* CC-BY-SA-3.0 *Contributors:* ? *Original artist:* ?
- File:Puy_de_Poix_gisement_bitumeux.JPG** *Source:* https://upload.wikimedia.org/wikipedia/commons/5/5d/Puy_de_Poix%2C_gisement_bitumeux.JPG *License:* Public domain *Contributors:* Own work *Original artist:* Vales
- File:Refined_bitumen.JPG** *Source:* https://upload.wikimedia.org/wikipedia/commons/4/45/Refined_bitumen.JPG *License:* Public domain *Contributors:* Own work *Original artist:* Burger
- File:Road_repaving.jpg** *Source:* https://upload.wikimedia.org/wikipedia/commons/4/48/Road_repaving.jpg *License:* CC0 *Contributors:* Own work *Original artist:* ProjectManhattan
- File:Speakerlink-new.svg** *Source:* <https://upload.wikimedia.org/wikipedia/commons/3/3b/Speakerlink-new.svg> *License:* CC0 *Contributors:* Own work *Original artist:* Kelvinsong
- File:University_of_Queensland_Pitch_drop_experiment-white_bg.jpg** *Source:* https://upload.wikimedia.org/wikipedia/commons/9/99/University_of_Queensland_Pitch_drop_experiment-white_bg.jpg *License:* CC-BY-SA-3.0 *Contributors:* This file was derived from University of Queensland Pitch drop experiment.jpg: <a href="//commons.wikimedia.org/wiki/File:University_of_

Queensland_Pitch_drop_experiment.jpg' class='image'>
Original artist: University_of_Queensland_Pitch_drop_experiment.jpg: John Mainstone

- **File:Wiki_letter_w_cropped.svg** *Source:* https://upload.wikimedia.org/wikipedia/commons/1/1c/Wiki_letter_w_cropped.svg *License:* CC-BY-SA-3.0 *Contributors:* This file was derived from Wiki letter w.svg:
Original artist: Derivative work by Thumperward
- **File:Wiktionary-logo-v2.svg** *Source:* <https://upload.wikimedia.org/wikipedia/commons/0/06/Wiktionary-logo-v2.svg> *License:* CC BY-SA 4.0 *Contributors:* Own work *Original artist:* Dan Polansky based on work currently attributed to Wikimedia Foundation but originally created by Smurrayinchester

12.3 Content license

- Creative Commons Attribution-Share Alike 3.0