Period #14 Notes: BITUMINOUS MATERIALS (I)

A. Brief Overview

There are two basic classes of bituminous materials: (1) asphalt; and (2) tar. These materials are generally used as water-proofing sealants, and as a binder to hold aggregate together in bituminous pavements. In this set of notes we will discuss the differences between these two bituminous materials, and the sources of these two materials.

B. Characteristics of Bituminous Materials

Common characteristics of bituminous materials are that:

1. <u>They are highly temperature sensitive</u>. At "high" temperatures, bituminous materials feature highly fluid consistencies, whereas at "low" temperatures they tend to become very stiff and brittle. This change of consistency with temperature is generally called *temperature sensitivity* or *temperature susceptibility*.

2. <u>They age or oxidize</u>. Over time, bituminous materials undergo an oxidation process. As the oxidation process continues, the bituminous material tends to become increasingly brittle and thus more prone to cracking/fracturing. The rate of oxidation increases with temperature of the bituminous material. There is usually a color change of bituminous materials as they oxidize. Fresh asphalt is usually black in color and turns grey as it ages. Fresh tar is usually black/brown in color and also turns grey as it ages.

C. Sources of Asphalt

Asphalt comes primarily from two sources: (1) naturally occuring asphalt deposits; and (2) from the refinement of crude petroleum.

1. Natural Asphalt Deposits

Naturally occurring asphalt deposits occur in various locations around the planet. Although these deposits are sometimes called “tar pits” they are in fact natural asphalt deposits. The asphalts in these natural deposits can exist in hard or soft solid form. Just a few examples of natural asphalt deposits are: (1) the Trinidad Lake deposits on the Carribean Island of Trinidad; (2) the “Tar sands” of Western Canada; (3) the Gilsonite deposits of Utah; and (4) the La Brea Tar Pits of Southern California.

While in earlier times, these natural deposits were the most common source for asphalt, the more common source today is from refinement of crude petroleum.

2. Refinement of Petroleum

Unrefined petroleum consists of a spectrum of different products of different volatilities. From highest to least volatility these products are: gasoline, kerosene, light oils, heavy oils, and asphalt residuum. Crude petroleum from different natural deposits generally vary in their yield of these different products.

A simple index that helps to determine the composition of crude petroleum is the API Gravity Index. Here API denotes the American Petroleum Institute.

The API Gravity Index of a given fluid is determined by the following formula:

$$API \text{ Gravity Index} = \frac{141.5}{\mathrm{G_s}} - 131.5 \qquad (15.1)$$

In the equation above, G_s denotes the specific gravity of the fluid at atmospheric pressure (14.7 psi) and T=60^{o}F.

Example: Water at the reference temperature and pressure has G_s=1. Accordingly, the API Gravity Index of water is 10.

The API GI is thus inversely related to the specific gravity of the material. Generally speaking, the lower the API GI of a petroleum, the higher will be its asphalt content, and the lower its content of volatile phases like gasoline and kerosene.

Some examples of the variation in crude petroleum from different oil fields around the world are listed below in Table 15.1.

Table 15.1. Nature of crude petroleum from different sources.

Composition	Crude Type	API GI	Source
High gasoline, low asphalt content	A	34	Arabian Light, Saudia Arabia
		32	Kuwait
	B	28	Hawkins, USA
		26	Tiajuana, Venezuela
	C	19	Galan, Colombia
		18	Cyrus, Iran
	D	16	Lloydminster, Canada
		15	Obeja, Venezuela
	E	12	Panuco, Mexico
High asphalt, low gasoline content		10	Boscan, Venezuela

There are a variety of methods for refinement of petroleum into different products such as gasoline, kerosene, oils, and asphalt. Among the different processes used are: (1) straight distillation; (2) solvent deasphaltification [SDA]; (3) solvent extraction; and (4) continuous air blowing.

The key asphalt products that result from refinement processes are:

1. Asphalt cement;
2. Emulsified asphalts; and
3. Cutback asphalts.

These different asphalt products are discussed later in this set of notes.

It is worth noting here that asphalt is soluble in more volatile phases of petroleum. Consequently, when petroleum-based oil or gasoline is spilled onto asphalt pavements, the pavement will be damaged due to the solution of asphalt in the solvent. One possible reason to use tar as opposed to asphalt as a binder in pavements is that tar is not soluble in petroleum products. Indeed, tar-based pavements might be a better choice than asphalt-based pavements where fuel or oil spills are expected. PCC pavements would also be a viable option as well.

D. Sources and Nature of Tar

While asphalt is essentially a product of petroleum, tar is a product that derives from distillation of coal.

While coal tar was once quite commonly used as a binder in paving materials, it used less often now for a number of reasons:

1. It ages/oxides more rapidly than asphalt does, hence its service lifetime is shorter.

2. It tends to be more be more temperature susceptible than asphalt, which means that it changes in consistency more with temperature than does asphalt.

3. It is a class I carcinogen and hence the vapors can be hazardous to health.

An interesting point about coal tar is that it can be made into special soaps and shampoos used to treat dandruff and psoriasis, and to kill/repel head lice.

E. Alternative Forms of Asphalt Binders

As noted previously, three different forms of asphalt that are used as binders in pavements are: (1) asphalt cement; (2) cutback asphalts; and (3) asphalt emulsions.

1. Asphalt cement:

In this form, asphalt behaves as a solid at normal atmospheric temperatures. To produce a pavement with it, the asphalt is heated to a temperature (275^{o}F/135^{o}C) at which it becomes fluid and can readily be intermixed with aggregate. The product is variously called: *hot mix*, *hot mix asphalt (HMA)*, *asphalt concrete*, and *asphalt cement concrete (acc).* The hot mix is then spread out on roadways and compacted. HMA is used to create high-quality pavements as opposed to patch-quality repairs of pot-holes, or treatments for low-volume country roads.

2. Cutback asphalts:

To be mixed with aggregate, asphalt must be put into liquid form. With asphalt cement, this is done by heating the binder to a sufficiently high temperature so that it becomes very fluid. One alternative is to dissolve asphalt more volatile phases of petroleum that have higher fluidity at low temperatures. Mixtures of asphalt dissolved in petroleum solvents are typically called *cutbacks*. Such cutback asphalts can be applied to roadways. After application, the solvent phase gradually evaporates leaving behind the asphalt binder. The evaporation of the solvent leads to the hardening of the *cutback*, and this is called *curing*. Cutbacks are typically divided into three basic types:

a. Rapid Curing (RC) Cutbacks:

These are achieved by using highly volatile phases of petroleum like gasoline or naptha as the solvent. Because these phases evaporate very quickly, they lead to rapid curing of the cutback.

Such cutbacks are frequently used for tack-coats or surface treatments of roadways.

b. Medium Curing (MC) Cutbacks:

These use petroleum solvents less volatile than gasoline and naptha like kerosene. MC cutbacks are typically used stockpiled patching mixes, or for prime-coats of roadways, or for some ready-mixing operations.

c. Slow Curing (SC) Cutbacks:

These use the least volatile petroleum solvents such as diesel and gas oils. The uses are similar to those of MC cutbacks: patching mixes and prime-coats. An additional application of SC cutbacks is as dust palliatives on low-volume gravel roads.

There are some disadvantages to using cutbacks. Some of these are:

1. Cutbacks release volatile petroleum fumes into the atmosphere.
2. The solvents used in cutbacks, especially RC, have a high value and are essentially wasted.
3. For RC cutbacks, the vapors given off can be potentially flammable.

3. Emulsified Asphalts:

It is well known that water and asphalt will not mix, except under carefully controlled conditions using highly specialized equipment and chemical additives. The blending of asphalt cement and water is somewhat like trying to wash grease from your hands with only water. It is not until a detergent or soapy agent of some type is used that grease can be successfully removed. The soap particles surround the globules of grease, break the surface tension that holds them, and allow them to be washed away. Some of the same physical and chemical principles apply in the formulation, production, and use of asphalt emulsion.

The object is to make a dispersion of the asphalt cement in water, stable enough for pumping, prolonged storage, and mixing. Furthermore, the emulsion should break down quickly after contact with aggregate in a mixer, or after spraying on the roadbed. Upon curing, the residual asphalt retains all of the adhesion, durability, and water-resistance of the asphalt cement from which it was produced.

In asphalt emulsions, lightly heated asphalt is run through a colloidal mill together with an emulsifying agent to produce 5-10 μm sized globules. The asphalt globules are mixed with water to form a liquid mixture of roughly 75% asphalt and 25% water by mass. The emulsifying agent coats the asphalt globules and imparts a surface charge that makes the globules repel rather than coalesce. The viscosity of the emulsions is usually quite low at ambient temperatures.

Emulsions are typically classified by four different factors:

a. Charge: The emulsifying agent can impart either a positive or negative charge on the asphalt globules. **Anionic** emulsions have negative charges on the asphalt, whereas **cationic** emulsions have positive charges. Anionic emulsions should be used with aggregates that have positive surface charges (such as limestone), and cationic emulsions with aggregates having negative surface charges (such as quartz, siliceous gravels, etc). In the alpha-numeric designation system for emulsions, the letter “C” indicates that an emulsion is cationic. Lack of the letter “C” in the designation indicates that the emulsion is anionic.

   When an emulsion is mixed with an appropriate aggregate, the asphalt in the emulsion coalesces on the aggregate causing the mixture to “set” or “break.” The water can then be squeezed/pumped out of the asphalt-aggregate mixture, or it can gradually evaporate away.

b. Setting rate: Emulsions are further classified on the basis of how quickly the asphalt will coalesce; i.e., revert to asphalt cement. The terms *RS*, *MS*, and *SS* have been adopted to simplify and standardize this classification. They are relative terms only and mean rapid-setting, medium-setting, and slow-setting, respectively. The tendency to coalesce is closely related to the mixing of an emulsion. An *RS* emulsion has little or no ability to mix with an aggregate, an *MS* emulsion is expected to mix with coarse but not fine aggregate, and an *SS* emulsion is designed to mix with fine aggregate.

c. Viscosity: Emulsions are further subdivided by their viscosity. In the alpha-numeric designation system, an digit of either 1 or 2 indicates the relative viscosity of the emulsion, with digit “1” indicating between a”normal viscosity” and “2” indicating a higher than normal viscosity.

The digit “h” can also be used in the designation for emulsions to indicate the underlying hardness or viscosity of the asphalt cement as opposed to that of the emulsion itself.

Example: The designation CRS-1 indicates a cationic, rapid-setting emulsion of normal viscosity suitable for mixing with coarse aggregates in which the base asphalt cement also has normal viscosity.

Example: The designation SS-1h indicates an anionic, slow-setting emulsion of normal viscosity in which the base asphalt cement has a higher than normal viscosity.

d. Float: The "HF" preceding some of the anionic MS grades indicates high-float, as measured by the Float Test (ASTM D 139 or AASHTO 50). High-float emulsions have a quality, imparted by the addition of certain chemicals, that permits a thicker asphalt film on the aggregate particles with minimum probability of drainage.

Example: The designation HFMS-2 for an emulsion indicates that it is a medium-setting high-float anionic emulsion with a higher than normal viscosity.

Table 15.2 shows some of the commonly used grades of emulsions.

Table 15.2 Designations for commonly used asphalt emulsions.

Rapid Setting		Medium Setting		Slow Setting	
Anionic	Cationic	Anionic	Cationic	Anionic	Cationic
RS-1	CRS-1	MS-1	---	SS-1	CSS-1
RS-2	CRS-2	MS-2	CMS-1	SS-1h	CSS-1h
		MS-2h	CMS-2h		
		HFMS-1	---		
		HFMS-2	-----		
		HFMS-2h	----		