

CHAPTER 1

COMPONENTS OF ASPHALT CONCRETE

The modern use of asphalt for road and street construction began in the late 1800s and grew rapidly with the emerging automobile industry. Since that time, asphalt technology has made giant strides so that today the equipment and techniques used to build asphalt pavement structures are highly sophisticated. One rule that has remained constant throughout asphalt's long history in construction is this: A pavement is only as good as the materials and workmanship that go into it. No amount of sophisticated equipment can make up for use of poor materials or poor construction practices.

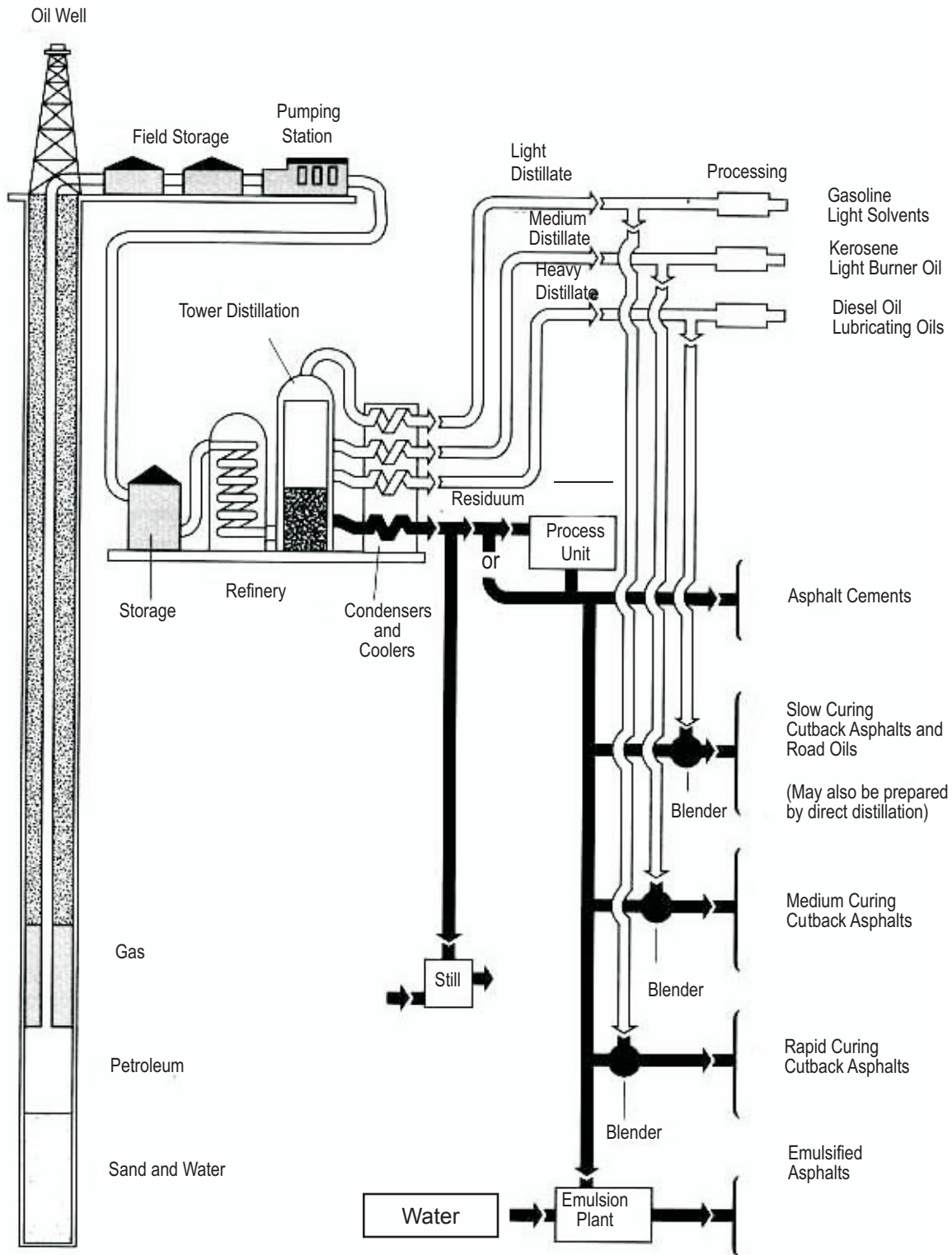
This section of the manual covers the materials used in quality hot-mix asphalt pavements - what they are, how they behave, and how to tell whether or not particular materials are suitable for a paving project. Asphalt concrete is composed of two components, aggregates and asphalt. Aggregates are generally classified into two groups, fine and coarse, and normally constitute from 90 to 95 percent by weight of the total mixture. The asphalt is composed of a **Performance Graded (PG) binder** or some variation of **PG binder**, and ordinarily constitutes 5 to 10 percent by weight of the mixture.

Ingredients in Asphalt Concrete

Performance Graded (PG) Binder (a.k.a. Asphalt Cement)

Asphalt is a constituent of petroleum with most crude petroleum containing some asphalt. Crude petroleum from oil wells is separated into its fractions in a refinery by a process called distillation. During the process, crude petroleum is fed into a tube still, where its temperature is quickly raised for initial distillation processes. It then enters a fractionating tower where the lighter or more volatile fractions vaporize and are drawn off for further refining. The petroleum asphalt flow chart (Figure 1-1, page 1-2) shows generally the flow of crude petroleum through a refinery. Residue from this fractionating process is the heavy component of crude petroleum, which includes asphalt. However, further refinement is necessary to produce asphalt cement.

Practically all asphalt used in the United States is produced by modern oil refineries and is called petroleum asphalt. Petroleum asphalt for use in pavements is usually called paving asphalt or asphalt cement to distinguish it from asphalt made for non-paving uses. Asphalt cement at normal atmospheric (ambient) temperatures is a black, sticky, semisolid, highly viscous material. It is composed primarily of complex hydrocarbon molecules. Because asphalt cement is sticky, it adheres to aggregate particles and can be used to cement or bind them in asphalt concrete. Asphalt cement is unaffected by most acids, alkalis, and salts. It is a thermoplastic material because it softens as it is heated and hardens as it is cooled. This unique combination of characteristics and properties is a fundamental reason why asphalt is an important paving material.



Petroleum Asphalt Flow Chart
Figure 1-1

Properties of PG Binder

Consistency

Binders (Asphalts) are characterized by their properties at different temperatures and stages of life simulated by laboratory aging. Consistency is the term used to describe the degree of fluidity or plasticity of binders at any particular temperature. The consistency of binder varies with temperature. Binders are graded based on ranges of consistency at a standard temperature. When the Binder is exposed to air in thin films and is subjected to prolonged heating, i.e. during mixing with aggregates, the binder tends to harden. This means that the consistency (viscosity) of the binder has increased for any given temperature. A limited increase is allowable. However, careless temperature and mixing control can cause more damage to the binder, through hardening, than many years of service on the finished roadway.

Purity

Binder (Asphalt) is composed almost entirely of bitumen, which by definition is soluble in carbon disulfide. Refined binders are almost pure bitumen and are usually more than 99.5 percent soluble in carbon disulfide. Impurities, if they are present, are inert. Normally, the binder is free of water or moisture as it leaves the refinery. However, tank transports loading binder may have some moisture present in their tanks. If any water is inadvertently present in the binder, it may cause the binder to foam when it is heated above 212°F (100°C).

Safety

Binder (Asphalt) foaming can be a safety hazard. Specifications usually require that asphalt not foam at temperatures up to 350°F (177°C). Binders, if heated to a high enough temperature, will flash in the presence of a spark or open flame. The temperature at which this occurs is well above the temperatures normally used in paving operations. However, to be sure there is an adequate margin of safety, the flash point of the binder should be known.

Durability

Durability is the measure of how well a binder retains its original characteristics when exposed to normal weathering and aging processes. The performance grading of current binders include laboratory tests that simulate the weathering and aging processes and establishes pass/fail limits on the test results. The pavement performance is still greatly affected by mix design, aggregate characteristics, workmanship and other variables.

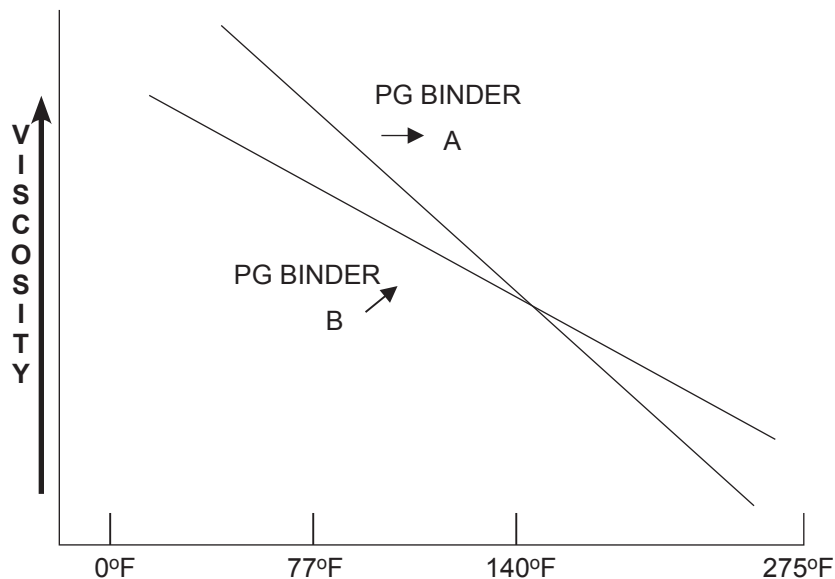
Adhesion and Cohesion

Adhesion is the binder's ability to stick to the aggregate in the paving mixture. Cohesion is the binder's ability to hold the aggregate particles in place in the finished pavement.

Temperature Susceptibility

All binders are thermoplastic; that is, they become harder (more viscous) as their temperature decreases and softer (less viscous) as their temperature increases. This characteristic is known as temperature susceptibility, and is one of a binder's most valuable assets. Figure 1-2 illustrates this point. The figure shows the variation in viscosity of a binder at different temperatures and as the temperature increases, the binder becomes less viscous (more fluid).

Knowing the temperature susceptibility of the binder being used in a paving mixture is important because it indicates the proper temperature at which to mix the binder with aggregate, and the proper temperature at which to compact the mixture on the roadbed. It should be understood that it is vitally important for a binder to be temperature susceptible. It must be fluid enough at elevated temperatures to permit it to coat the aggregate particles during mixing and to allow these particles to move past each other during compaction. It must then become viscous enough at normal air temperatures to hold the aggregate particles in place in the pavement. Also remember that temperature susceptibility varies among binders from different petroleum sources, even if the binders are of identical grade.



**Viscosity Variation of PG Binders at Different Temperatures
Figure 1-2**

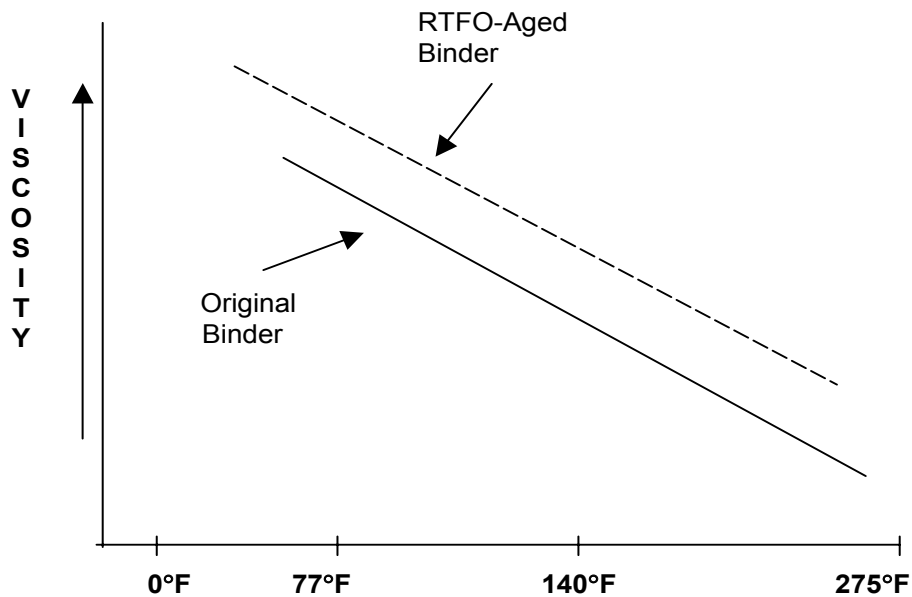
Aging and Hardening

Binders (Asphalts) harden in the paving mixture during construction and in the pavement itself. The hardening is caused primarily by oxidation (binder combining with oxygen), a process that occurs most readily at higher temperatures (such as construction temperature) and in thin binder films (such as the film coating aggregate particles).

During mixing, binder is both at a high temperature and in thin films as it coats the aggregate particles. This makes mixing the stage at which the most severe oxidation and hardening usually occurs. Figure 1-3 shows the increase in viscosity caused by heating a thin film of a binder. The viscosity range of the original material before the Rolling Thin Film Oven (RTFO) test is significantly lower than after the test.

Not all binders harden at the same rate when heated in thin films. Therefore, each binder used should be tested to determine its aging characteristics so that construction techniques can be adjusted to minimize hardening. Such adjustments usually involve mixing the binder with the aggregate at the lowest possible temperature for the shortest practical time.

The hardening of a binder continues in the pavement after construction. Again, oxidation and polymerization are the main causes. These processes can be retarded by keeping the number of connected voids (air spaces) in the final pavement low, and the binder coating on the aggregate particles thick.



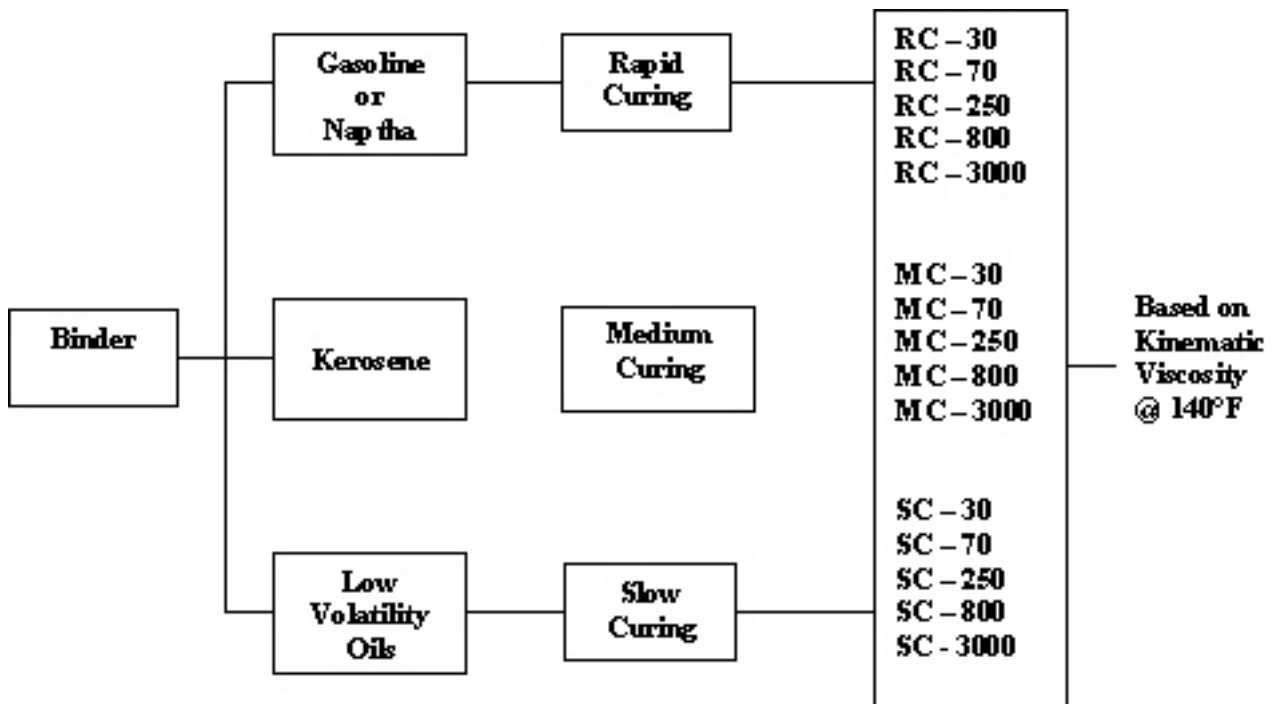
**Hardening of Binder After Exposure to High Temperatures
Figure 1-3**

Liquid Asphalt

The specifications for liquid asphalts (cutbacks and emulsions) are specified in Section 210 of the current Road and Bridge Specifications. Binder, which at normal atmospheric temperatures is semisolid and highly viscous, must be temporarily melted or liquefied for handling during construction operations. Asphalt can be temporarily liquefied for construction operations in three ways:

- (1) By melting with heat.
- (2) By dissolving the binder in selected solvents. This process is called cutting back; the diluted binder is called Cutback Asphalt.
- (3) By emulsifying the binder with water. The resulting product is called Emulsified Asphalt.

Cutback asphalt and emulsified asphalts are called liquid asphalts to distinguish them as a group from normal binders. The petroleum flow chart Figure 1-1 on page 1-2 shows the flow for making liquid materials. It is important to note that, in each case, binder is the base material liquefied by cutting back or emulsifying.



Cutback Asphalt Chart
Figure 1-4

Cutback Asphalt

Petroleum solvents used for dissolving binder are sometimes called distillate, diluent, or cutter stock. If the solvent used in making the cutback asphalt is highly volatile it will quickly escape by evaporation. Solvents of lower volatility evaporate more slowly. On the basis of relative speed of evaporation, cutback asphalts are divided into three types, (Figure 1-4):

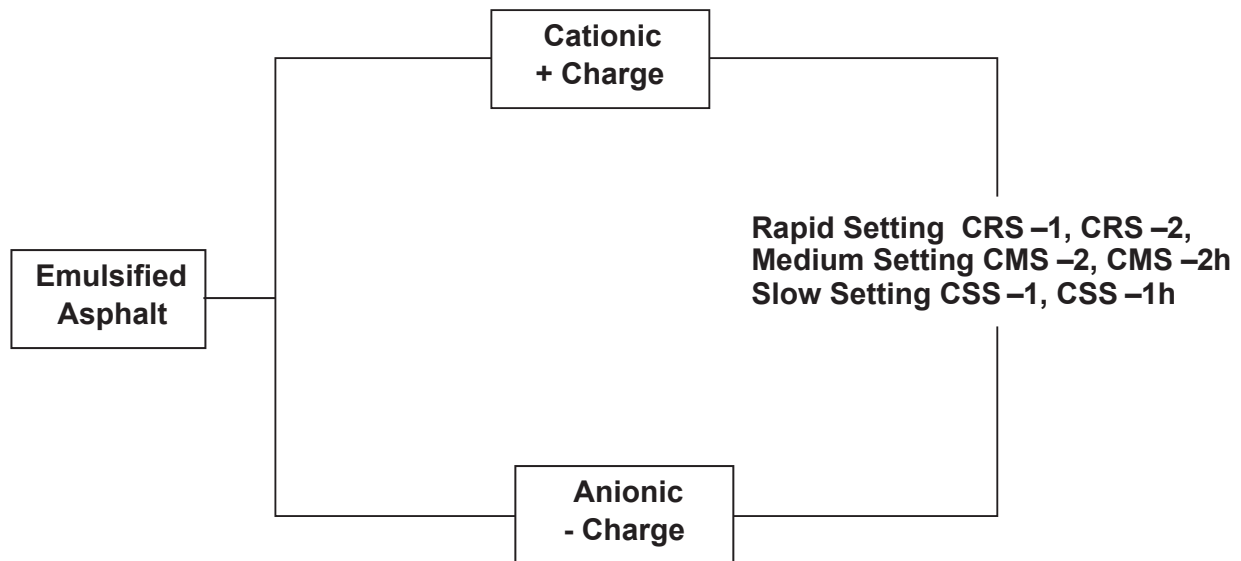
- (1) Rapid-Curing (RC) - asphalt and a volatile solvent or light distillate, generally in the gasoline or naphtha boiling point range
- (2) Medium-Curing (MC) - asphalt and a solvent of intermediate volatility or medium distillate, generally in the kerosene boiling point range
- (3) Slow-Curing (SC) - asphalt and an oily diluent of low volatility. (At present, SC is not used in Virginia.) Slow-curing (SC) asphalts are often called road-oils. This term originated in earlier days when asphaltic residual oil was used to give roads a low-cost, all-weather surface.

The degree of fluidity obtained in each case depends on the grade of asphalt cement, volatility of the solvent, and proportion of solvent to binder. The degree of fluidity results in several grades of cutback asphalt. Some are quite fluid at ordinary atmospheric temperatures and others are somewhat more viscous and may require heating to melt them enough for construction operations.

Cutback asphalts can be used with cold aggregates, with a minimum of heat. RC and MC types of cutback asphalts are used in a variety of highway construction. Among the more important uses are road mixing operations, stockpiling mixes, and spray applications such as prime. The specifications for cutback asphalt are in the Road and Bridge Specifications, Section 210.

Emulsified Asphalts

In the emulsification process, hot binder is mechanically separated into minute globules and dispersed in water treated with a small quantity of emulsifying agent. The water is called the continuous phase and the globules of binder are called the discontinuous phase. The machine used in this process is a colloid mill; the binder globules are extremely small, mostly in the colloidal size range. By proper selection of an emulsifying agent and other manufacturing controls, emulsified asphalts are produced in several types and grades (Figure 1-5).



**Emulsified Asphalt Chart
Figure 1-5**

By choice of emulsifying agent, the emulsified asphalt may be:

- (1) **Anionic** - binder globules are electro-negatively charged.
- (2) **Cationic** - binder globules are electro-positively charged.

Also, by variation in materials and manufacture, emulsified asphalts of both anionic and cationic types are made in several grades. Some of these grades and their uses are:

- (1) **Anionic** - Non -Virginia grades
RS-2 tack and seal coat,
SS-1h slow set slurry and tack,
- (2) **Cationic** - Virginia grades
CRS-2 tack and seal coat,
CRS-1 tack,
CRS-1h tack
CSS-1h two types for slurry (rapid set and slow set) and tack;
CMS-2 prime, tack, seal, and cold mix. (contains 7-12% solvent)

Because particles having a like electrostatic charge repel each other, asphalt globules are kept apart until the emulsion is deposited on the surface of the soil or aggregate particles. At this time, the asphalt globules coalesce through neutralization of the electrostatic charges or water evaporation. Coalescence of asphalt globules occurs in rapid and medium setting grades, resulting in a phase separation between asphalt and water. When this coalescence occurs, it is usually referred to as the break or set.

Emulsified asphalts can be used with cold as well as heated aggregates, and with aggregates that are dry, damp, or wet. The specifications for emulsified asphalts are in the Road and Bridge Specifications, Section 210.

Testing of PG Binders and Liquid Asphalts

A PG binder is specified as a combination of two temperatures (i.e. 70-22). The high temperature (70°C) refers to the 7-day average high temperature for an area whereas the low temperature (-22°C) refers to the single lowest temperature expected in that area.

Purpose

The purpose of PG binder testing is to ensure that the binder conforms to AASHTO M320 specifications for that binder type throughout the life of the binder. The life of a binder can be categorized into three stages as follows:

1. Transport, storage, and handling (Original Binder)
2. Mix production and construction (*RTFO aged Binder)
3. After a long period in a pavement (**PAV aged Binder)

Testing for stage 1 is performed on original binder material.

Testing for stage 2 simulates the binder as it passes through a plant.

Testing for stage 3 simulates the binder after an extended period of time in the pavement.

* Rolled Thin Film Oven

** Pressure Aging Vessel

PG Binder Testing

Rotational Viscosity Test (ASTM D4402) -

Performed on the original binder, a rotational viscometer is used to evaluate the high temperature workability of binders. This ensures that the binder is sufficiently fluid when pumping and mixing. In addition, the viscosity measured is used to establish the temperature-viscosity plot for a binder type.

Flash Point Test (AASHTO T48 Cleveland Open Cup) -

Performed on the original binder, the flash point of binder is measured to ensure the binder is safe to work with at production temperatures. Flash point is the temperature to which a binder may be safely heated without instantaneous flash in the presence of an open flame.

Dynamic Shear (AASHTO TP 5) -

Performed on original and RTFO and PAV aged binder, the dynamic shear rheometer measures the stiffness or resistance of the binder to deform under loading.

Mass Loss (AASHTO T 240) -

Performed on RTFO aged binder, the mass loss indicates the amount of impurities (i.e. water, gas, hydraulic fluid) present in the binder.

Creep Stiffness (AASHTO TP 1) -

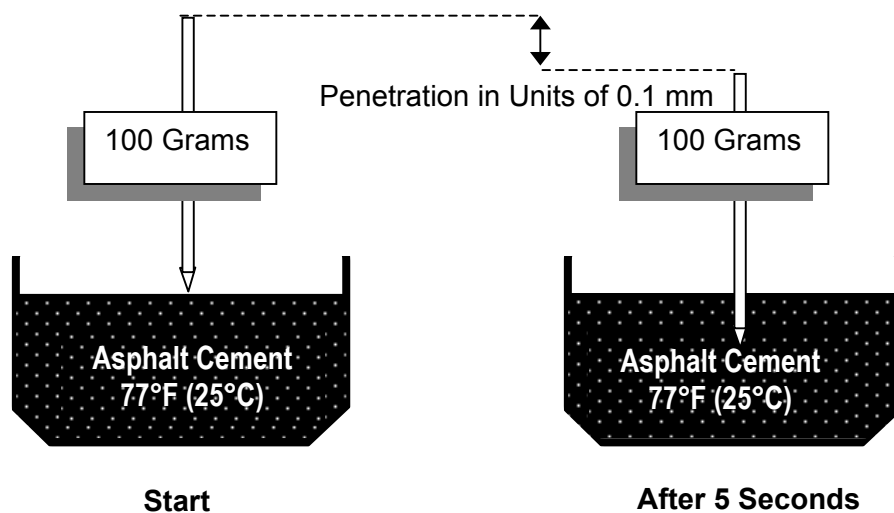
Performed on PAV aged binder, the creep stiffness is a measure of how brittle the binder becomes after an extended period in the pavement.

Recovered Binder Testing

VDOT performs the Abson Recovery Test (AASHTO T170) in which the completed mix has the asphalt cement extracted by a chemical procedure that does not change the asphalt cement properties. The recovered asphalt cement must meet certain properties, such as penetration and ductility, which indicate damage or aging that may have taken place during the storage and mixing of the asphalt. When recycled asphalt pavement (RAP) is a component of the mix, the aged asphalt in the RAP can become a significant contributor to the aged properties of the mix. If a penetration test fails in accordance with Section 211.06, then the binder will be PG graded to determine acceptability of the binder.

Penetration Test (AASHTO T49) -

The penetration test is an empirical measure of asphalt consistency. Figure 1-6 shows the standard penetration test. In testing, a container of asphalt cement is heated to the standard test temperature 77°F (25°C) in a temperature-controlled water bath. A prescribed needle, weighted to 100 grams, is allowed to bear on the surface of the asphalt cement for 5 seconds. The distance, in units of 0.1 mm, which the needle penetrates into the asphalt cement is the penetration factor or measurement. Occasionally, the penetration test is made at a different temperature. When this occurs, needle load, penetration time, or both may be varied.

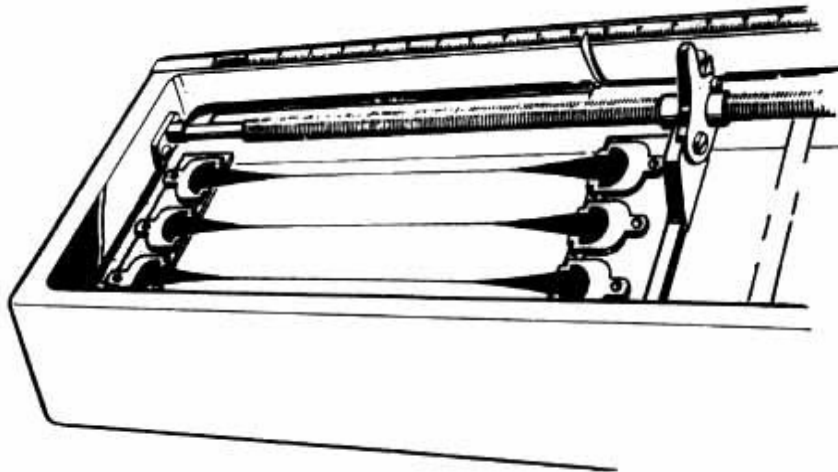


**Penetration Test
Figure 1-6**

Ductility Test (AASHTO T 51) -

In many applications, ductility is considered an important characteristic of binders. The presence or absence of ductility, however, is usually considered more significant than the actual degree of ductility. Binders possessing ductility are normally more adhesive than binders lacking this characteristic. However, some binders with an exceedingly high degree of ductility are also more temperature-susceptible. That is, the change in consistency is apt to be greater for a change in temperature. In some applications, such as paving mixes, ductility and adhesion are more important. In other situations, such as slab undersealing and crack filling, the more essential property is low-temperature susceptibility.

Ductility is measured by an “extension” type of test (Figure 1-7), where a standard briquette of binder is molded under standard conditions and dimensions. It is then brought to standard test temperature, normally 77°F (25°C), and pulled apart at a uniform speed until the briquette ruptures. The distance that the briquette is pulled to produce rupture is measured in centimeters.



Ductility Test
Figure 1-7

Liquid Asphalt Testing

Viscosity Test (AASHTO T201 and T72) -

Asphalt Institute specifications for binders recommend viscosity tests be run at 275°F (135°C). The viscosity test purpose is to provide control of asphalt consistency in the range of temperatures normally associated with construction operations. Measurement of viscosity may be made by the Saybolt Furol Viscosity Test or the Kinematic Viscosity Test.

Flash Point (AASHTO T79) -

Performed on the original liquid binder (cutback), the flash point is measured to ensure the liquid asphalt (cutback) is safe to work with at production temperatures. Flash point is the temperature to which the liquid binder (cutback) may be safely heated without instantaneous flash in the presence of an open flame.

Aggregates

The amount of aggregate in asphalt concrete mixtures is generally 90 to 95 percent by weight and 75 to 85 percent by volume. Aggregates are primarily responsible for the load supporting capacity of a pavement. Aggregate has been defined as any inert mineral material used for mixing in graduated particles or fragments. It includes sand, gravel, crushed stone, slag, screenings, and mineral filler.

Sources of Aggregates

Aggregates for asphalt concrete are generally classified according to their source or means of preparation. They include:

- (1) **Pit aggregates** - Gravel and sand are natural aggregates and are typically pit material.
- (2) **Processed aggregates** - Natural gravel or stone that have been crushed and screened are typical processed aggregates. In the crushing operation, stone dust is also produced.
- (3) **Synthetic or artificial aggregates** - Aggregates resulting from the modification of materials, which may involve both physical and chemical changes are called synthetic or artificial aggregates. Blast furnace slag is the most commonly used artificial aggregate or lightweight aggregate.

Evaluating Aggregates

Selecting an aggregate material for use in an asphalt concrete depends upon the availability, cost, and quality of the material, as well as the type of construction that is intended. The suitability of aggregates for use in asphalt concrete is determined by evaluating the material in terms of:

- (1) **Size and grading** - The maximum size of an aggregate designates the smallest sieve size through which 100 percent of the material will pass. Grading of an aggregate is determined by sieve analysis. Maximum size and grading are invariably controlled by specifications that prescribe the distribution of particle sizes to be used for a particular aggregate material for asphalt mixtures. The distribution of the particle sizes determines the stability and density of the asphalt mixture.
- (2) **Cleanliness** - Some aggregates contain foreign or deleterious substances that make them undesirable for asphalt concrete mixtures. (Example: Clay lumps, shale, organic material, etc.)The sand-equivalent test, described in AASHTO T 176, is a method of determining the relative proportion of detrimental fine dust or clay-like materials in the portion of aggregate passing the No. 4 (4.75 mm) sieve.

- (3) **Toughness (Hardness)** - Aggregates are subjected to additional crushing and abrasive wear during manufacture, placing, and compaction of asphalt concrete mixtures. Aggregates are also subjected to abrasion under traffic loads. They must exhibit an ability to resist crushing, degradation, and disintegration. The Los Angeles Abrasion test measures wear abrasion resistance of aggregates. Equipment and procedures for this test are detailed in AASHTO T 96.
- (4) **Soundness** - Aggregates for asphalt concrete paving should be durable. They should not deteriorate or disintegrate under the action of weather. Items for consideration under weathering action are freezing, thawing, variations in moisture content, and temperature changes. The soundness test is an indication of the resistance to weathering of fine and coarse aggregates. For test procedures see AASHTO T 104.
- (5) **Particle Shape (Flat & Elongated or F/E)** - Particle shape changes the workability of the mix as well as the compactive effort necessary to obtain the required density. Particle shape also has an effect on the strength of the asphalt concrete mix. Irregular or angular particles tend to interlock when compacted and resist displacement.
- (6) **Surface Texture (Coarse Aggregate Angularity (CAA) and Fine Aggregate Angularity (FAA))** - Like particle shape, the surface texture also influences the workability and strength of asphalt concrete mixtures. Surface texture has often been considered more important than shape of the aggregate particles. A rough, sandpaper-like surface texture as opposed to a smooth surface tends to increase the strength of the mix.
- (7) **Absorption** - The porosity of an aggregate is generally indicated by the amount of water it absorbs when soaked in water. A certain degree of porosity is desirable, as it permits aggregates to absorb binder, which then forms a mechanical linkage between the binder film and the stone particle.
- (8) **Affinity for Binder** - Stripping (separation) of the binder film from the aggregate through the action of water may make an aggregate material unsuitable for asphalt concrete mixtures. Such material is referred to as hydrophilic (water loving). Many of these materials may be used with the addition of a heat stable additive that reduces the stripping action. Aggregates which exhibit a high degree of resistance to stripping in the presence of water are usually most suitable in asphalt concrete mixes. Such aggregates are referred to as hydrophobic (water hating). Why hydrophobic or hydrophilic aggregates behave as they do is not completely understood. The explanation is not so important as the ability to detect the properties and avoid the use of aggregates conducive to stripping. The strength loss resulting from damage caused by “stripping” under laboratory controlled accelerated water conditioning is determined in accordance with AASHTO T 283.

NOTE: Specification criteria for items (1) through (6) on the previous page can be found in Sections 202 , 203 and 211 of the Road and Bridge Specifications. Item (8) is determined through experience.

Aggregate Storage

Provisions should be made for adequate storage and stockpiling facilities for all component materials. Sufficient material should be on hand prior to starting daily operations to insure continued processing for the working day.

Aggregates should be handled, hauled, and stored in a manner that will minimize segregation and degradation, and avoid contamination. The aggregate should be stockpiled in the vicinity of the plant on ground that is denuded of vegetation, hard, well drained, or otherwise prepared to protect the aggregate from contamination. Stockpiles should be separated to prevent intermingling. This may be accomplished by positive separation of stockpiles, bins, or by using adequate bulkheads. Bulkheads should extend to the full depth of the stockpiles and should be strong enough to withstand the pressures exerted under operating conditions. Stockpiles should be constructed in layers rather than in cones. Individual truckloads should be spotted close together over the entire stockpile surface.

When stockpiling with a crane, each bucket load should be deposited adjacent to another over the entire area so that the thickness of the layers is uniform. When aggregate is discharged from chutes, baffles should be arranged to prevent the coarse aggregate from rolling to the far side while the fine aggregate collects beneath the chute. Perforated chimneys also may be used to prevent segregation of aggregates when stockpiling from a belt conveyor chute.

When cars, barges, or trucks are used as stockpiles, care should be exercised in loading and unloading to prevent segregation. When constructing, maintaining, or withdrawing from stockpiles, care should be taken to prevent aggregate degradation by the hauling equipment.

As mineral filler is subject to caking or hardening from moisture, it is handled differently than other aggregates, and separate storage is provided to keep it protected from dampness.

CHAPTER 1
COMPONENTS OF ASPHALT CONCRETE
Study Questions

1. A method of classification used to determine performance properties of binder is:
 - A. penetration
 - B. variability
 - C. ductility
 - D. performance grading

2. Binder blended with a kerosene-type material is known as:
 - A. emulsified asphalt
 - B. RC asphalt
 - C. MC asphalt
 - D. SC asphalt

3. A method of determining flow properties of binder is:
 - A. penetration
 - B. viscosity
 - C. ductility
 - D. impermeability

4. Binder which has been liquefied with heat, petroleum solvents, or emulsified with water, is known as:
 - A. crude petroleum
 - B. liquid asphalt
 - C. asphalt residue
 - D. air-blown asphalt

5. Binder blended with a naphtha or gasoline-type material is called:
 - A. MC asphalt
 - B. Emulsified asphalt
 - C. SC asphalt
 - D. RC asphalt

6. An example of an artificial aggregate is blast furnace slag.
 - A. True
 - B. False

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Study Questions (continued)

7. Aggregates should be handled and stockpiled in such a manner as to minimize:
 - A. hauling time
 - B. segregation
 - C. waste
 - D. moisture

8. Hot mix asphalt concrete can be considered to be made up of two ingredients:
 - A. cutback asphalt and aggregates
 - B. binder and aggregates
 - C. emulsified asphalt and aggregate
 - D. all of the above

9. A suspension of binder in water containing an emulsifying agent, such as soap, is called:
 - A. cutback asphalt
 - B. air blown asphalt
 - C. crude petroleum
 - D. emulsified asphalt

10. Asphalt binders become harder (more viscous) as their temperature decreases and less soft (less viscous) as their temperature increases
 - A. True
 - B. False

11. How should the site for stockpiles be prepared?

12. How should stockpiles be handled?

13. How much material should to be on hand before starting daily operations?

