3 Components and Characteristics of Asphalt Concrete

Asphalt concrete is a composite material used in construction projects such as road surfaces, airports and parking lots. It consists of two components:

- **Asphalt**—Composed of a Performance Graded (PG) binder or a variation, it constitutes 5 to 10% of the total asphalt concrete mixture by weight.

- **Aggregates**—An inert granular material such as sand, gravel, shell, slag, or broken stone, generally classified into two groups (fine and coarse), constituting 90 to 95% of the total asphalt concrete mixture by weight.

This section of the guide covers the materials used in quality hot mix asphalt (HMA) pavements — what they are, how they behave and how to tell whether or not particular materials are suitable for a paving project.

**Learning Objectives:**

Upon completion of this chapter, you should be able to:

- List the ingredients in asphalt concrete
- Describe the performance properties of binders
- Identify tests for binders and liquid asphalts
- Define sources for and evaluation of aggregates
Ingredients in Asphalt Concrete

DEFINITIONS. The following terms will be used throughout this section:

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt</td>
<td>Composed of a Performance Graded (PG) binder or a variation, it constitutes 5 to 10% of the total asphalt concrete mixture by weight.</td>
</tr>
<tr>
<td>Aggregate</td>
<td>An inert granular material such as sand, gravel, shell, slag, or broken stone, which generally constitutes 90 to 95% of the total asphalt concrete mixture by weight.</td>
</tr>
<tr>
<td>Asphalt concrete</td>
<td>A composite materials consisting of two components: aggregates and asphalts.</td>
</tr>
<tr>
<td>Asphalt cement</td>
<td>Petroleum asphalt for use in pavements is called asphalt cement or paving asphalt. At ambient temperatures, it is a black, sticky, semisolid, highly temperature-dependent visco-elastic material.</td>
</tr>
<tr>
<td>Performance Graded Binder (PG Binder)</td>
<td>The PG Binder system was developed by the AASHTO as way to evaluate asphalt cements for use in pavements based on project specific performance criteria.</td>
</tr>
<tr>
<td>Thermoplastic material</td>
<td>A plastic that softens when heated and hardens when cooled without changing its engineering properties.</td>
</tr>
</tbody>
</table>

Practically all asphalt used in the U.S. is produced by modern oil refineries like the one shown in Figure 3-1, and is called petroleum asphalt. Petroleum asphalt that is used in pavements is usually called paving asphalt or asphalt cement to distinguish it from asphalt made for non-paving uses.

Figure 3-1. Oil Refinery
Asphalt, a by-product of processing liquid petroleum, is isolated through the refining process, which is illustrated in Figure 3-2. Crude petroleum from oil wells is separated into its fractions in a refinery by a process called distillation.

![Diagram of Petroleum Refinement Process]

**Figure 3-2. Petroleum Refinement Process**

During this process, crude petroleum is fed into a tube still, where its temperature is quickly raised for initial distillation. It then enters a fractionating tower where the lighter or more volatile fractions vaporize and are drawn off for further refining. Residue from this fractionating process is the heavy component of crude petroleum, which includes asphalt. Further refinement is necessary to produce asphalt cement, which is also known as Performance Graded (PG) binder.
Characteristics and Properties of Asphalt Cement

Asphalt cement is composed primarily of complex hydrocarbon molecules. Because asphalt cement is sticky, it adheres to aggregate particles (e.g., sand, gravel, crushed stone, blast-furnace slag, lightweight aggregate) 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 is a fundamental reason why asphalt is an important paving material.

Virginia has adopted the Performance Graded Binder system for asphalt cements used VDOT mixes. The Performance Graded system is a method of measuring asphalt binder performance. Performance grading is based on the idea that asphalt binder properties should be related to the conditions under which it is used. Performance graded asphalt binders are selected to meet expected climatic conditions, traffic loading, as well as aging considerations, with a certain level of reliability.

Asphalt binders are most commonly characterized by their physical properties. An asphalt binder’s physical properties directly describe how it will perform as a constituent in asphalt concrete pavement.

Asphalt binders are characterized by their properties at different temperatures and stages of life simulated by laboratory aging. Binder properties include the following:

- Consistency
- Purity
- Durability
- Adhesion and Cohesion
- Temperature Susceptibility
- Aging and Hardening
- Safety

Each of these is described in more detail in the text that follows.
DEFINITION

**DEFINITIONS.** The following terms will be used throughout this section:

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consistency</td>
<td>The degree of fluidity or plasticity of the binder at any particular temperature.</td>
</tr>
<tr>
<td>Durability</td>
<td>The binder’s resistance to the effects of traffic, water, air and temperature changes.</td>
</tr>
<tr>
<td>Purity</td>
<td>The degree to which the binder is pure (i.e., free from impediments such as moisture).</td>
</tr>
<tr>
<td>Adhesion</td>
<td>The binder’s ability to stick to the aggregate in the paving mixture.</td>
</tr>
<tr>
<td>Cohesion</td>
<td>The binder’s ability to hold the aggregate particles in place in the finished pavement.</td>
</tr>
<tr>
<td>Temperature susceptibility</td>
<td>The effect of temperature on a binder’s viscosity and elasticity.</td>
</tr>
<tr>
<td>Viscosity</td>
<td>A measure of a liquid’s resistance to flow.</td>
</tr>
<tr>
<td>Thin binder film</td>
<td>The film coating aggregate particles.</td>
</tr>
<tr>
<td>Flash point</td>
<td>The temperature at which asphalt will instantaneously flash in the presence of an open flame.</td>
</tr>
</tbody>
</table>

**Consistency**

Consistency is the degree of fluidity or plasticity of binders at any particular temperature. The consistency of binders varies with temperature. Binders are graded based on standard consistency at the design temperature for the project.

When the binder is exposed to air in thin films and is subjected to prolonged heating (e.g., during mixing with aggregates), the binder tends to harden. This means that the consistency or viscosity of the binder has increased for any given temperature. A limited increase is allowable.

**AWARENESS/IMPORTANT**

Careless or missing temperature control can cause more damage to the binder, through hardening, than many years of service on the finished roadway.

Highlights a step in the procedure which is either unusual or very particular to this procedure.

May also indicate awareness (additional information) or a cautionary concern in the procedure.
Components of Asphalt Concrete

Purity

Purity is a determination of the degree to which the binder is pure, or free from impediments such as moisture. Asphalt cement used for paving should consist of almost pure bitumen, which by definition is soluble in carbon disulfide. Refined binders are almost pure bitumen and are usually more than 99.5% soluble in carbon disulfide. Impurities, if present, are inert. Normally, the binder is free of water or moisture as it leaves the refinery.

<table>
<thead>
<tr>
<th>SAFETY WARNING</th>
</tr>
</thead>
<tbody>
<tr>
<td>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).</td>
</tr>
<tr>
<td>Describes a condition where personal safety may be at risk.</td>
</tr>
<tr>
<td>This is used to alert personnel to operating procedures &amp; practices which, if not observed, may result in personal injury.</td>
</tr>
</tbody>
</table>

Durability

Durability is the binder’s resistance to the effects of traffic, water, air and temperature changes. It is a measure of how the asphalt binder’s physical properties change with the normal weathering and aging (sometimes called age hardening) processes. Some qualities that complement a binder’s durability are its resistance to swelling, stripping, oxidation and wear or abrasion.

In general, as a binder ages, its viscosity increases and it becomes more stiff and brittle. The performance grading of current binders includes laboratory tests that simulate the weathering and aging processes and establishes pass/fail limits on the test results.

<table>
<thead>
<tr>
<th>AWARENESS/IMPORTANT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pavement performance is greatly affected by variables including:</td>
</tr>
<tr>
<td>• Mix design</td>
</tr>
<tr>
<td>• Aggregate characteristics</td>
</tr>
<tr>
<td>Highlights a step in the procedure which is either unusual or very particular to this procedure.</td>
</tr>
<tr>
<td>May also indicate awareness (additional information) or a cautionary concern in the procedure.</td>
</tr>
</tbody>
</table>
Adhesion and Cohesion

Adhesion and cohesion are two important and related properties of asphalt binders that can affect asphalt mixture performance. 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.

The adhesive and cohesive properties of asphalts determine how well roads hold up to traffic, weather and other forces working against their integrity.

Temperature Susceptibility

Temperature susceptibility refers to the effect of temperature on the binder. All binders are thermoplastic; that is, they become harder (i.e., more viscous) as their temperature decreases and softer (i.e., less viscous) as their temperature increases. This characteristic is known as temperature susceptibility, and is one of a binder’s most valuable assets. Temperature susceptibility is an important control parameter during the mixing, placement, compaction and performance of asphalt concrete. Figure 3-3 illustrates this point, showing the variation in viscosity of a binder at different temperatures. As the temperature increases, the binder becomes less viscous (i.e., more fluid).

![Figure 3-3. Temperature Susceptibility](image)

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 be viscous enough at normal air temperatures to hold the aggregate particles in place in the pavement.
AWARENESS/IMPORTANT

Temperature susceptibility varies among binders from different petroleum sources, even if the binders are of identical grade. 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 the aggregates and the proper temperature at which to compact the mixture on the roadbed.

Highlights a step in the procedure which is either unusual or very particular to this procedure.
May also indicate awareness (additional information) or a cautionary concern in the procedure.

Aging and Hardening

Binders harden in the paving mixture during construction and over time in the pavement itself. This hardening is caused primarily by oxidation (i.e., the binder combining with oxygen), a process that occurs most readily at higher temperatures (e.g., mixing temperature) and in thin binder films (i.e., the film coating aggregate particles). Mixing is the stage at which the most severe oxidation and hardening usually occur. During mixing, the binder is both at a high temperature and in thin films as it coats the aggregate particles. Figure 3-4 shows the increase in viscosity caused by heating a thin film of a binder.

Note: The viscosity range of the original material before the Rolling Thin Film Oven (RTFO) test is significantly lower than after the test.

![Graph showing the hardening of binder after exposure to high temperatures](image)

**Figure 3-4. Hardening of Binder after Exposure to High Temperatures**

The hardening of a binder continues in the pavement after construction. This is caused primarily by oxidation and polymerization. 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.
**AWARENESS/IMPORTANT**

Not all binders harden at the same rate when heated in thin films. 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.

Highlights a step in the procedure which is either unusual or very particular to this procedure. May also indicate awareness (additional information) or a cautionary concern in the procedure.

**Safety**

Binder (asphalt) can be a safety hazard. 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 called the flash point. Specifications usually require that asphalt not flash below 446 °F (230 °C).

**SAFETY WARNING**

The temperature at which binder flash occurs is well above the temperatures normally used in paving operations. However, to be sure there is an adequate margin of safety and that no contamination with flammable distillates (e.g., diesel, kerosene, naphtha), the flash point of the binder should be known and monitored.

Describes a condition where personal safety may be at risk. This is used to alert personnel to operating procedures & practices which, if not observed, may result in personal injury.
Characteristics and Properties of Liquid Asphalt

Cutback asphalt and emulsified asphalts are called liquid asphalts to distinguish them as a group from normal binders. Liquid asphalt is asphalt cement which has been liquefied with petroleum solvents or emulsified, such that they flow readily at ambient to relatively low production temps (below 175F). The specifications for liquid asphalts (cutbacks and emulsions) are described in Section 210 of the current Road and Bridge Specifications.

<table>
<thead>
<tr>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DEFINITIONS. The following terms will be used throughout this section:</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cutting back</td>
<td>The process of dissolving a binder in selected solvents.</td>
</tr>
<tr>
<td>Cutback asphalt</td>
<td>Asphalt cement which has been liquefied by blending it with petroleum solvent. There are three types: <strong>Rapid-Curing</strong> (asphalt and a volatile solvent or light distillate), <strong>Medium-Curing</strong> (asphalt and a solvent of intermediate volatility or medium distillate) and <strong>Slow-Curing</strong> (asphalt and an oily diluent of low volatility).</td>
</tr>
<tr>
<td>Emulsified asphalt</td>
<td>A suspension of asphalt in water containing an emulsifying agent, such as soap.</td>
</tr>
<tr>
<td>Liquid asphalt</td>
<td>Asphalt cement which has been liquefied with petroleum solvents or emulsified.</td>
</tr>
<tr>
<td>Percent residue</td>
<td>The amount of asphalt cement in a liquid asphalt solution.</td>
</tr>
<tr>
<td>Anionic</td>
<td>Binder globules are electro-negatively charged.</td>
</tr>
<tr>
<td>Cationic</td>
<td>Binder globules are electro-positively charged.</td>
</tr>
<tr>
<td>Slurry</td>
<td>A mixture of aggregate, asphalt emulsion, filler, and water, which are mixed together according to a laboratory's design-mix formula.</td>
</tr>
</tbody>
</table>

A binder, which at normal atmospheric temperatures is semisolid and highly viscous, must be temporarily melted or liquefied for handling during construction operations. The binder can be temporarily liquefied for construction operations in three ways:

1. Melting it with heat.
2. Dissolving the binder in selected solvents. This process is called cutting back and the resultant diluted binder is called cutback asphalt.
3. Emulsifying the binder with water. The resulting product is called emulsified asphalt.

It is important to note that, in each case, the binder is the base material that has been liquefied by cutting back or emulsifying.
Cutback Asphalt

Petroleum solvents used for dissolving binders are sometimes called distillates, diluents or cutter stocks. 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, as illustrated in Figure 3-5:

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. Slow-curing (SC) asphalts are often called road-oils (a term that originated in earlier days). Currently, SC asphalts are not used in Virginia.

![Figure 3-5. Cutback Asphalt Types](image)

The varying degree of fluidity obtained in each case depends on the:

- Grade of asphalt cement
- Volatility of the solvent
- Proportion of solvent to binder.

The degree of fluidity results in several grades of cutback asphalt. Some are quite fluid at ordinary atmospheric temperatures, while 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 cutback asphalts have a variety of uses in highway construction, including road mixing operations, stockpiling mixes, and spray applications. The specifications for cutback asphalt are in the *Road and Bridge Specifications*, Section 210.

**Emulsified Asphalts**

Emulsified asphalt is a suspension of asphalt in water containing an emulsifying agent. In the emulsification process, a machine called a colloid mill mechanically separates hot binder into minute globules (i.e., tiny globes or ball) and disperses them in water treated with a small quantity of an emulsifying agent. The water is called the continuous phase and the globules of binder are called the discontinuous phase. 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, as illustrated in Figure 3-6. By choice of emulsifying agent, the emulsified asphalt may be:

1. **Anionic**—Binder globules with negative electrostatic charge.
2. **Cationic**—Binder globules with positive electrostatic charge.

Emulsions are also classified by how quickly they set-up or break upon application. The typical nomenclature used in the paving and asphalt industry includes:

- Rapid-Setting (RS)
- Medium-Setting (MS)
- Slow-Setting (SS)

![Figure 3-6. Emulsified Asphalt Types](image-url)
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 listed in the table below, per emulsified asphalt type.

<table>
<thead>
<tr>
<th>Grades</th>
<th>Types</th>
</tr>
</thead>
</table>
| **Anionic—Non-Virginia grades** | a. RS-2 tack and seal coat  
                            b. SS-1h slow set slurry and tack |
| **Cationic- Virginia grades**     | a. CRS-2 tack and seal coat  
                                        b. CRS-1 tack  
                                        c. CRS-1h tack  
                                        d. CSS-1h two types for slurry (rapid set and slow set) and tack  
                                        e. 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. When this occurs, 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 both cold and 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

The purpose of PG binder testing is to ensure that the binder conforms to AASHTO M 320: Standard Specification for Performance-Graded Asphalt Binder for that binder type throughout the life of the binder.

A PG binder is specified as a combination of two temperatures (i.e. 70 °C and -22 °C). 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. Consequently, the binder is graded as PG 70-22. Figure 3-7 illustrates this concept.

![Figure 3-7. Performance Grading](image)

The life of a binder can be categorized into three stages, with each stage requiring a different test, as indicated in the table that follows. In the rest of this section, we will explore the tests that are conducted on PG binder, recovered binder and liquid asphalt.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Test Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stage 1</strong>: Transport, storage, and handling</td>
<td>Tests performed during this stage are run on the original binder material.</td>
</tr>
<tr>
<td><strong>Stage 2</strong>: Mix production and construction</td>
<td>Tests performed during this stage are run on Rolled Thin Film Oven-aged (RTFO) binder material. These tests simulate the binder as it passes through a plant.</td>
</tr>
<tr>
<td><strong>Stage 3</strong>: After a long period in a pavement</td>
<td>Tests performed during this stage are run on Pressure Aging Vessel (PAV) binder material. These tests simulate the binder after an extended period of time in the pavement</td>
</tr>
</tbody>
</table>
**PG Binder Testing**

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 better you understand the tests, why they are done and the key factors affecting test results, the better prepared you will be to produce consistent results. PG binder testing includes the tests indicated and described in the table below.

<table>
<thead>
<tr>
<th>Test</th>
<th>Conducted On</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Rotational Viscosity Test (ASTM D4402)</td>
<td>Original Binder</td>
<td>A rotational viscometer is used to evaluate the high temperature workability of a binder. 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.</td>
</tr>
<tr>
<td>2. Dynamic Shear Test (AASHTO T 315)</td>
<td>Original Binder, RTFO-Aged Binder, PAV-Aged Binder</td>
<td>A dynamic shear rheometer is used to measure the stiffness or resistance of the binder to deform under loading.</td>
</tr>
<tr>
<td>3. Flash Point Test (AASHTO T48 Cleveland Open Cup)</td>
<td>Original Binder</td>
<td>The flash point of a 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.</td>
</tr>
<tr>
<td>4. Mass Loss (AASHTO T 240)</td>
<td>RTFO-Aged Binder</td>
<td>The mass loss indicates the amount of impurities (i.e. water, gas, hydraulic fluid) present in the binder.</td>
</tr>
<tr>
<td>5. Creep Stiffness (AASHTO T 313)</td>
<td>PAV-Aged Binder</td>
<td>The creep stiffness is a measure of how brittle the binder becomes after an extended period in the pavement.</td>
</tr>
</tbody>
</table>
Chemical Extraction and Recovery of Binder for Testing

To ensure that the binder used in asphalt mixtures meets State specifications, The Department will sample the plant-produced mixture, chemically extract the binder, and test it for conformance with the state specification (i.e. the PG Binder Grade required for the mix type being produced).

The asphalt binder is first chemically extracted from the mixture using an approved chemical solvent and a high speed centrifuge. The binder is then recovered from this solvent binder solution using the Abson recovery method which slowly distills out the solvent, leaving behind only the binder from the original asphalt mixture sample. The recovered binder is then tested for conformance to PG Grade specified.

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.

Why do it? The purpose of this test is to ensure that the asphalt binder being shipped to the project meets all of the PG Binder specifications required for the mix type being produced. Failure to meet the requirements could 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 PG Binder test fails in accordance with Section 211, then the approval of the mix type being produced may be suspended until the contractor can demonstrate that the mix being produced meets all specification requirements.

Liquid Asphalt Testing

The tests shown in the table below are conducted on liquid asphalt, and recovered asphalt residue, respectively, and are described in the text that follows.

<table>
<thead>
<tr>
<th>Tested on the Liquid Asphalt:</th>
<th>Tested on the Recovered Asphalt Residue:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscosity Test</td>
<td>Penetration Test</td>
</tr>
<tr>
<td>Flash Point Test (Cutback asphalts only)</td>
<td>Ductility Test</td>
</tr>
<tr>
<td>Percent Residue</td>
<td></td>
</tr>
</tbody>
</table>
**Viscosity Test** (AASHTO T201 and T72)—Viscosity is a measure of a liquid’s resistance to flow.

VDOT has adopted the AASTHO specifications for cutbacks and emulsions; these specifications will define the type of viscosity test and the temperature at which the test will be run.

Measurement of viscosity may be made by the Saybolt Furol Viscosity Test (Figure 3-8) or the Kinematic Viscosity Test. These tests and the temperatures at which they are run have been designed based on the field application intended for the material type being used.

**Why do it?** The purpose of the viscosity test is to provide control of asphalt consistency in the range of temperatures normally associated with construction operations (i.e. that a CRS-2 will “spray” easily and uniformly when applied by a distributor Figure 3-9).
**Flash Point Test** (AASHTO T79) — 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. This test is performed on the original liquid binder.

*Why do it?* The flash point is measured to ensure the cutback asphalt is safe to work with at production temperatures. Figure 3-10 illustrates flash point testing.

**Percent Residue** (AASHTO T 59) — Measured either by evaporation or distillation, the non-asphalt cement components are driven off, leaving only the asphalt cement or “residue” behind.

*Why do it?* The percent residue test ensures that the proper amount of asphalt cement is in the liquid asphalt, so that material performs as needed in the field. The recovered asphalt may also then be tested further for penetration and ductility, also to ensure proper performance in the field.

**Penetration Test** (AASHTO T49) — The penetration test is an empirical measure of asphalt consistency. The basic assumption is that the less viscous the asphalt, the deeper a needle will be able to penetrate the asphalt, as illustrated in Figure 3-11.

*Why do it?* This penetration depth is correlated with asphalt binder performance. Asphalt binders with high penetration numbers are used for cold climates, while asphalt binders with low penetration numbers are used for warm climates.

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. Figure 3-12 illustrates how the penetration testing process works.

Occasionally, the penetration test is made at a different temperature than shown in Figure 3-12. When this occurs, needle load, penetration time, or both may be varied.
Components of Asphalt Concrete

**Figure 3-12. How Penetration Testing Works**

**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.

**Why do it?** 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, 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, as shown in Figure 3-13. The distance that the briquette is pulled until it ruptures is measured in centimeters.

**Figure 3-13. Ductility Test**
Aggregates

An aggregate is 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, ranging in size from coarse to fine, as depicted in Figure 3-14.

The amount of aggregate in asphalt concrete mixtures is generally 90 to 95% by weight and 75 to 85% by volume.

Aggregates are primarily responsible for the load-supporting capacity of a pavement.

Figure 3-14. Aggregate

Sources of Aggregates

Aggregates for asphalt concrete are generally classified according to their source or means of preparation. The graphic in Figure 3-15 summarizes the various sources of aggregate.

Figure 3-15. Sources of Aggregate
The table that follows summarizes aggregate type by source.

<table>
<thead>
<tr>
<th>Aggregate Type</th>
<th>Source or Means of Preparation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pit Aggregates</td>
<td>Gravel and sand are natural aggregates and are typically pit material.</td>
</tr>
<tr>
<td>Processed Aggregates</td>
<td>Natural gravel or stone that has been crushed and screened are typical processed aggregates. In the crushing operation, stone dust is also produced.</td>
</tr>
<tr>
<td>Synthetic or Artificial Aggregates</td>
<td>Aggregates resulting from the modification of materials, which may involve both physical and chemical changes. Blast furnace slag is the most commonly used artificial aggregate or lightweight aggregate.</td>
</tr>
</tbody>
</table>

**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 for which it 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% 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 (e.g., clay lumps, shale and organic material). 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, placement 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, described in AASHTO T 96, measures wear abrasion resistance of aggregates.

4. **Soundness**—Aggregates for asphalt concrete paving should be durable. They should not deteriorate or disintegrate as a result of weather. Items for consideration under weathering action are freezing, thawing, varying moisture content and changing temperatures. The Soundness Test, described in AASHTO T104, is an indication of the resistance to weathering of fine and coarse aggregates.
5. **Particle Shape** (Flat & Elongated or F/E)—Particle shape changes not only the workability of the mix, but also 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 or CAA, and Fine Aggregate Angularity or FAA)—Like particle shape, the surface texture also influences the workability and strength of asphalt concrete mixtures. In fact, 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. Aggregates with high porosity will require higher asphalt contents due to loss of binder to the stone. They also tend to be weaker and may not be suitable for use in asphalt concrete.

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 the most desirable 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 as 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) 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. Aggregates should be handled, hauled and stored in a manner that will minimize segregation and degradation and avoid contamination. These suggestions should be followed for best results:

1. The aggregate should be stockpiled in the vicinity of the plant on ground that is hard, well drained, and has been denuded of vegetation or otherwise prepared to protect the aggregate from contamination.

2. Stockpiles should be separated to prevent intermingling, as shown in Figure 3-16. This may be accomplished by positive separation of stockpiles and 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.

3. Stockpiles should be constructed in layers, rather than in cones. Individual truckloads should be spotted close together over the entire stockpile surface.

4. 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.

5. 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.

6. 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.

7. Mineral filler is subject to caking or hardening from moisture. Consequently, it is handled differently than other aggregates. Separate storage should be provided to keep it protected from dampness.

![Figure 3-16. Proper Stockpiling, Fine and Coarse](image)

**BEST PRACTICE**

Sufficient material should be on hand prior to starting daily operations to insure continued processing for the working day.

*Describes a best practice.*
Chapter Three Knowledge Check

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 a binder is:
   A. Penetration
   B. Viscosity
   C. Ductility
   D. Impermeability

4. Binder which has been liquefied with heat or 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
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 aggregates
   D. All of the above

9. A suspension of a 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 softer (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?
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