Mix design methods and design requirements are an essential part for all asphalt concrete mixtures. The agency or authority responsible for paving construction (the Department of Transportation) usually establishes the mix design method and design requirements. Once these are established, it becomes the responsibility of the Contractor/Producer and his Technician to develop the mix within the framework of the specification requirements.

This chapter describes the physical properties required of asphalt concrete mixtures and presents mixture types used in Virginia.

**Learning Objectives:**

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

- Identify the physical properties of asphalt concrete mixtures
- Define asphalt mix properties and their effect on pavement performance
- List the types of asphalt mixtures used for highway construction in Virginia
- Identify the individual layers of a pavement structure
Physical Properties Required of Asphalt Concrete Mixtures

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stability</td>
<td>The asphalt pavement’s ability to resist shoving and rutting under loads (e.g., traffic).</td>
</tr>
<tr>
<td>Impermeability</td>
<td>The resistance of an asphalt pavement to the passage of air and water into or through it.</td>
</tr>
<tr>
<td>Workability</td>
<td>The ease with which a paving mixture can be placed and compacted.</td>
</tr>
<tr>
<td>Flexibility</td>
<td>The asphalt pavement’s ability to adjust to gradual settlements and movements in the subgrade without cracking.</td>
</tr>
<tr>
<td>Fatigue resistance</td>
<td>The asphalt pavement’s resistance to repeated bending under wheel loads (e.g., traffic).</td>
</tr>
<tr>
<td>Skid resistance</td>
<td>The ability of an asphalt surface to minimize skidding or slipping of vehicle tires, particularly when wet.</td>
</tr>
<tr>
<td>Stripping</td>
<td>Separation of asphalt binder film from aggregate surfaces.</td>
</tr>
<tr>
<td>Void content</td>
<td>Empty spaces within the aggregate particle that can become filled with water, binder, or both.</td>
</tr>
<tr>
<td>Subbase</td>
<td>The layer of aggregate material laid on the subgrade.</td>
</tr>
<tr>
<td>Subgrade</td>
<td>The native material (i.e., level layer of rock or earth) upon which the foundation of a road is constructed.</td>
</tr>
</tbody>
</table>

Asphalt concrete mixtures are composed of two components:

- **Aggregates**—Fine and coarse, that make up 90-95% of the total mix (by weight)
- **Asphalt**—A performance graded (PG) binder that makes up 5-10% of the total mix (by weight)

Mix design methods and design requirements are essential determinants of asphalt concrete mixtures. The Department of Transportation usually establishes the mix design method and design requirements for paving construction. It is the responsibility of the Contractor/Producer and his Technician to develop the mix within the framework of the specification requirements. The pavement industry relies on the physical properties of asphalt concrete mixtures to ensure performance. The properties of an asphalt concrete mixture are a direct result of its chemical composition.
The following physical properties are required of asphalt concrete mixtures and will be addressed in this section of the chapter:

- Stability
- Durability
- Low Permeability
- Workability
- Flexibility
- Fatigue Resistance
- Skid Resistance

**Stability**

Stability of an asphalt pavement is its ability to resist distortions—shoving and rutting (i.e., surface depression or channels in the wheelpath) under traffic loads. A stable pavement maintains its shape and smoothness under repeated loading.

An *unstable* pavement:

- Develops ruts, as shown in Figure 4-1
- Develops ripples (e.g., washboarding or corrugation)
- Shows other signs of shifting of the mixture.

Stability specifications for a pavement depend on the traffic expected to use the pavement. Consequently, the requirements can be established only after a thorough traffic analysis.

![Figure 4-1. Rutting](image)

**BEST PRACTICE**

Stability specifications should be high enough to handle traffic adequately, but not higher than traffic conditions require. Too high a stability value produces a pavement that is too stiff, and therefore, less durable than desired.

*Describes a best practice to be utilized when possible.*
Insufficient stability in a pavement has many causes and effects. The stability of a mixture depends on:

- **Internal friction**—Friction among the aggregate particles (i.e., interparticle friction), which is related to characteristics of the aggregate, such as its shape and surface texture
- **Cohesion**—Which results from the bonding ability of the binder

A proper degree of both internal friction and cohesion in a mix prevents the aggregate particles from being moved past each other by the forces exerted by traffic. In general, the more angular the shape of the aggregate particles and the more rough their surface texture, the higher the stability of the mix will be. The binding force of cohesion increases:

- With increasing loading (traffic) rate
- As the viscosity of the binder increases
- As the pavement temperature decreases.

Where aggregates with high internal friction characteristics are not available, more economical mixtures using aggregate with lower friction values can be used where light traffic is expected.

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**AWARENESS/IMPORTANT**

Cohesion will increase with increasing binder content, up to a certain point. Past that point, increasing binder content will create too thick a film on the aggregate particles, resulting in a loss of interparticle friction.

---

**Durability**

The durability of an asphalt pavement is its ability to resist factors such as changes in the binder. Factors that may affect durability include polymerization and oxidation, disintegration of the aggregate and stripping (i.e., separation of asphalt binder film from aggregate surfaces), which is illustrated in Figure 4-2. These factors can be the result of weather, traffic, or a combination of the two.

A lack of sufficient durability in a pavement can have several causes and effects. The durability of a mixture can be enhanced by three methods:

- Using an optimized binder content
- Using a dense gradation of stripping-resistant aggregate
- Designing and compacting the mixture for maximum impermeability

---

*Figure 4-2. Underlying Stripping*
Optimized binder content increases durability because thick binder films do not age and harden as rapidly as thin ones do. Consequently, the binder retains its original characteristics longer. Also, maximum binder content effectively seals off a greater percentage of interconnected air voids in the pavement, making it difficult for water and air to penetrate.

**AWARENESS/IMPORTANT**

A certain percentage of air voids must be left open in the pavement to allow for expansion of the binder in hot weather.

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.

A dense gradation of sound, tough, stripping-resisting aggregate contributes to pavement durability in three ways:

1. It provides closer contact among aggregate particles, which enhances the impermeability of the mixture.
2. It resists disintegration under traffic loading.
3. It resists the action of water and traffic, which tend to strip the binder film off aggregate particles, leading to raveling of the pavement.

Under some conditions, the resistance of a mixture to stripping can be increased by the use of an anti-stripping agent (i.e., a heat stable additive used to prevent the binder from separating from the aggregate) or a mineral filler such as hydrated lime.

**BEST PRACTICE**

Designing and compacting the mixture to give the pavement maximum impermeability minimizes the intrusion of air and water into the pavement.

Describes a best practice to be utilized when possible.

**Impermeability**

Impermeability is the resistance of an asphalt pavement to the passage of air and water into or through it. Impermeability is important for durability of compacted paving mixtures. Impermeability is related to the void content of the compacted mixture, as shown in Figure 4-3. Much of the discussion on voids in the mix design sections relate to impermeability.

Even though void content is an indication of the potential for passage of air and water through a pavement, the character of these voids is more important than the number of voids.

![Figure 4-3. Air Voids in Compacted Asphalt](image)
The degree of impermeability is determined by:

- The size of voids
- Whether the voids are interconnected
- The access of the voids to the surface of the pavement.
- Aggregate structure (shape, size and gradation) within the mix.

### AWARENESS/IMPORTANT

Virtually all asphalt mixtures used in highway construction are permeable to some degree. This is acceptable as long as it is within specified limits.

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.

---

**Workability**

Workability is the ease with which a paving mixture can be placed and compacted, as Figure 4-4 illustrates. Mixtures with good workability are easy to place and compact; those with poor workability are difficult to place and compact.

Workability can be improved by changing mix design parameters, aggregate source, and/or gradation. Binder grade may affect workability (for example, the percentage of binder in the mix). And although not normally a major contributor to workability problems, the asphalt binder can also have some effect on workability.

Figure 4-4. Workability of Paving Material

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### AWARENESS/IMPORTANT

Care should be taken to ensure that the altered mix meets all other design criteria, such as void content and stability. Too high a filler content can also affect workability, causing the mix to become gummy and making it difficult to compact.

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.

The temperature of the mix affects the viscosity of the binder. Too low a temperature will make a mix harsh and unworkable. Too high a temperature may make it tender.

The table on the next page provides descriptors for both harsh and tender mixtures and the typical problems they trigger.
### Mixtures with Poor Workability

<table>
<thead>
<tr>
<th><strong>Typical Problems</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Harsh Mixtures</strong> — Mixtures which contain a high percentage of coarse and or angular aggregates</td>
</tr>
<tr>
<td>Harsh mixtures have a tendency to segregate during handling and also may be difficult to compact. Through the use of trial mixes in the laboratory, additional fine aggregate and perhaps binder, can be added to a harsh mix to make it more workable.</td>
</tr>
<tr>
<td><strong>Tender Mixtures</strong> — Mixtures that can be too easily worked or shoved</td>
</tr>
<tr>
<td>Tender mixtures are too unstable to place and compact properly. They are often caused by:</td>
</tr>
<tr>
<td>• A shortage of mineral filler</td>
</tr>
<tr>
<td>• Too much medium-sized sand</td>
</tr>
<tr>
<td>• Smooth, rounded aggregate particles</td>
</tr>
<tr>
<td>• Too much moisture in the mix</td>
</tr>
</tbody>
</table>

## Awareness/Important

Workability is especially important where quite a bit of hand placement and raking (i.e., luting) around manhole covers, sharp curves, and other obstacles is required. It is important that mixtures used in such areas are highly workable.

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.

## Flexibility

Flexibility is the ability of an asphalt pavement to adjust to gradual settlements and movements in the subgrade (the level layer of rock or earth upon which the foundation of a road is constructed) without cracking. Figure 4-5 illustrates settlement, an example of a flexibility issue.

Since virtually all subgrades either settle (under loading) or rise (from soil expansion), flexibility is a desirable characteristic for all asphalt pavements. An open-graded mix with high binder content is generally more flexible than a dense-graded, low binder content mix.

Sometimes the need for flexibility conflicts with stability requirements. For example, an open-graded mixture, which is generally more flexible, is designed to be water permeable. A dense-graded mix is relatively impermeable, but is less flexible. Both can affect stability and may require that trade-offs be made.

---

Figure 4-5. Settlement

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**Fatigue Resistance**

Fatigue resistance is the pavement’s resistance to repeated bending under wheel loads (i.e., traffic). Figure 4-6 shows an example of pavement that is showing fatigue.

Research shows that air voids (related to binder content) and binder viscosity have a significant effect on fatigue resistance. As the percentage of air voids in the pavement increases, either by design or lack of compaction, pavement fatigue life (i.e., the length of time during which an in-service pavement is adequately fatigue-resistant) is drastically shortened.

Likewise, a pavement containing binder that has aged and hardened significantly has reduced resistance to fatigue.

Pavement life and the prevention of load-associated cracking are also influenced by the thickness and strength characteristics of the pavement and the supporting power of the subgrade. Thick, well-supported pavements do not bend as much under loading as thin or poorly supported pavements do. Therefore, they have longer fatigue lives.

**Figure 4-6. Fatigue Issue after Six Months of Service**

**Skid Resistance**

Skid resistance is the ability of an asphalt surface to minimize skidding or slipping of vehicle tires, particularly when wet. Skid resistance is typically measured in the field at 40 miles per hour with a standard tread tire under controlled wetting of the pavement surface.

Skid resistance is important because inadequate skid resistance will lead to high incidences of road skid accidents. For good skid resistance, tire tread must be able to maintain contact with the aggregate particles instead of riding on a film of water on the pavement surface (hydroplaning).

Three factors have an important impact on skid resistance:

- Pavement texture
- Aggregate texture
- Asphalt content
A rough pavement surface with many little peaks and valleys will have greater skid resistance than a smooth surface. Besides having a rough surface, the aggregates must resist polishing (i.e., smoothing) under traffic. Calcareous aggregates (i.e., aggregates containing calcium carbonate) polish more easily than siliceous aggregates (i.e., composed mainly of silica or silicates).

Unstable mixtures that tend to rut or bleed (i.e., flush asphalt to the surface) present serious skid resistance problems.

### BEST PRACTICE

Best skid resistance is obtained with rough-textured aggregate in a relatively open-graded mixture with a maximum aggregate size of about 3/8 in.-1/2 in. (10-13 mm).

*Describes a best practice to be utilized when possible.*
**Mixture Types Used in Virginia**

<table>
<thead>
<tr>
<th>Definitions. The following terms will be used throughout this section:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Surface mixes (SM)</strong></td>
</tr>
<tr>
<td><strong>Intermediate mixes (IM)</strong></td>
</tr>
<tr>
<td><strong>Base mixes (BM)</strong></td>
</tr>
</tbody>
</table>

The basic requirements in building a road for safe all-weather use by vehicles are to:

1. Prepare a suitable subgrade or foundation (with proper density)
2. Provide necessary drainage
3. Construct a pavement that will:
   - Have sufficient total thickness and internal strength to carry expected traffic loads;
   - Prevent the penetration or internal accumulation of moisture; and
   - Have a top surface that is smooth, skid resistant, and resistant to wear, distortion and deterioration by weather and de-icing chemicals.

The goal of a flexible pavement structure is to achieve these requirements.

A flexible pavement structure consists of all the asphalt concrete courses or layers above the prepared subgrade (native material, such as rock or earth), as shown in Figure 4-7.

Together, these courses support the wheel loads on the pavement surface and transfer and spread these loads to the subgrade without exceeding the support capability of the subgrade material or over-stressing the pavement components.

**Figure 4-7. Flexible Pavement Structure (Muench, 2003)**
There are many types of asphalt concrete mixtures used in highway construction to meet the previously stated requirements. In Virginia however, there are three basic types, each of which has a specific purpose and location within an asphalt concrete pavement structure:

- Surface mixes (“SM”)
- Intermediate mixes (“IM”)
- Base mixes (“BM”).

Note: Section 211 discusses each type in more detail.

**Surface Mixes (“SM”)**

The upper most layer of the pavement structure is called the surface or wearing course. It is the layer in contact with traffic loads and normally contains the highest quality materials. It is meant to take the brunt of traffic wear and can be removed and replaced as it becomes worn. It provides characteristics such as friction, smoothness, noise control, resistance to rutting and shoving, and drainage.

This course or layer is usually composed of an “SM” mix. Figure 4-8 illustrates the application of an SM type mix.

![Figure 4-8. Applying an SM Type Mix](image)

**Intermediate Mixes (“IM”)**

In special cases where added strength is needed in the pavement structure, “IM” type mixes are sometimes used in the surface course. It provides the bulk of the HMA structure. Its chief purpose is to distribute load.

This binder or intermediate course is composed of an “IM” type mix. Figure 4-9 illustrates an IM type mix.

![Figure 4-9. IM Type Mix](image)
**Base Mixes (“BM”)**

The base course is placed immediately below the surface course (or binder course if a binder course is found to be necessary).

The base course is the structural strength element of the asphalt concrete pavement system. It provides additional load distribution and contributes to drainage and frost resistance. It is composed of a “BM” type mix.

Figure 4-10 is a photo showing a BM type mix.

*Figure 4-10. Base Type Mix*
Chapter Four Knowledge Check

1. The frictional resistance of the surface of the pavement to insure safe driving and stopping of the vehicle is called:
   A. Durability
   B. Stability
   C. Flexibility
   D. Skid resistance

2. The ability of the asphalt pavement to withstand repeated flexing or slight bending caused by the passage of wheel loads is called:
   A. Ductility
   B. Fatigue resistance
   C. Flexibility
   D. Variability

3. The resistance of pavement to the effects of traffic, water, air and temperature changes is known as:
   A. Durability
   B. Flexibility
   C. Variability
   D. Ductility

4. The ability of a pavement to adjust itself to settlement of the base without cracking is known as:
   A. Impermeability
   B. Stability
   C. Workability
   D. Flexibility

5. The ease with which the material can be placed to the desired uniformity and compacted to the required density is known as:
   A. Viscosity
   B. Stability
   C. Workability
   D. Flexibility
6. Type SM-12.5A asphalt concrete is a:
   A. Base course mix
   B. Surface course mix
   C. Binder course mix
   D. Cold mix

7. Four physical properties that are required of asphalt concrete mixtures are:
   A. Binder content, flexibility, stability, and rolling
   B. Stockpile analysis, hardness, stability, and durability
   C. Specific gravity, stability, durability, and flexibility
   D. Stability, flexibility, durability, and resistance to skidding

8. Type IM-19.0A asphalt concrete is a:
   A. Base course mix
   B. Surface course mix
   C. Intermediate course mix
   D. Cold mix

9. The resistance an asphalt concrete pavement has to the passage of air and water into or through the pavement is known as:
   A. Penetration
   B. Flexibility
   C. Impermeability
   D. Skid resistance

10. Type BM-25.0 asphalt concrete is a:
    A. Base course mix
    B. Surface course mix
    C. Binder course mix
    D. Cold mix
11. The upper or top layer of an asphalt concrete pavement structure is the:
   A. Base course
   B. Surface course
   C. Binder course

12. The subgrade ultimately carries all traffic loads.
   A. True
   B. False

13. The main structural strength element of a pavement is the:
   A. Subgrade
   B. Base course
   C. Surface course

14. The layer of an asphalt concrete pavement that distributes traffic loads to the subgrade is the:
   A. Surface course
   B. Intermediate course
   C. Base course
   D. Drainage layer

15. Stability may be improved by using aggregates with rough surface texture.
   A. True
   B. False
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