PART ONE

Bituminous Pavements and Surfaces

Bituminous pavements and surfaces are composed of compacted aggregate and bitumen. The aggregate transmits the load from the surface to the base, takes the abrasive wear of traffic, and provides a nonskid surface. The bitumen (bituminous binder) holds the aggregate together, prevents the displacement and loss of aggregate, and provides a waterproof cover for the base.

Bituminous surfaces—

- Are particularly adaptable to stage construction because engineers can add courses to existing pavement for reinforcement if the load or the amount of traffic increases.
- Are flexible, allowing for slight adjustments due to subgrade settlement without detrimental effects.
- Provide a resilient, waterproof medium that protects the base from water and traffic.
- Are less affected by temperature changes than concrete.
- Resist wear, weathering, and deterioration.
- Are highly versatile and meet temporary, expedient, and light traffic requirements where concrete is unjustifiable.
- Lack measurable beam action to carry loads over weak spots in the subbase. (The subbase must have an adequate, uniform bearing strength; and the base must have adequate thickness, bearing capacity, and cohesion.)

Bituminous pavements are comparable to concrete pavements and are designed to carry heavy traffic volume and heavy loads on highways, roads, streets, and airfields.

Chapter 1

Bituminous Materials

Asphalt pavements are composed of asphalt and aggregate. Asphalt-concrete pavement is the highest quality asphalt pavement. It consists of well-graded aggregate and asphalt cement (AC) that are heated and blended together in exact proportions at a hot-mix plant.
SECTION I - BITUMEN

TYPES OF BITUMEN

1-1. Asphalt and tar bitumens are used in road and airfield construction. (See FM 5-472 for field identification of tar and asphalt paving compounds.)

ASPHALT

1-2. Asphalt is a natural or man-made by-product of petroleum distillation. Natural asphalt is found in nature, either as lake (pit) or rock asphalt:

- **Lake asphalt.** It is formed when crude oil seeps to the surface of the earth and lighter fractions (volatile materials) are driven off by the action of sun and wind. Large deposits of lake asphalt exist in Trinidad and Venezuela.
- **Rock asphalt.** It occurs in more than one form. It may be asphalt that is impregnated in porous rocks, or it may be asphalt that is hardened into rock-like forms.

1-3. Manufactured asphalt is more uniform in quality than natural asphalt. AC is the residue (waste product) of crude-oil distillation. It is used alone or in combination with other materials to form asphalt cutbacks and emulsions. All three bituminous compounds (lake, rock, and manufactured) are referred to as asphalt. Use natural asphalt when it is locally available; otherwise, use manufactured asphalt.

TAR

1-4. Tar is extracted from coal. Coal-gas tar is a by-product of coke production, and water-gas tar is distilled from tar vapors. Both are produced, condensed, and collected during the production of illuminating gas and are used in paving tar. Water-gas tar combines with coal-gas tar as a flux. The two types of paving tar are road tar (RT) and road-tar cutback (RTCB).

ASPHALT CEMENT

1-5. AC consistency varies in relation to the amount of volatile substances in the residue. The penetration (hardness) test measures the distance in units of 1/100 centimeter that a standard blunt needle of a penetrometer, under a force of 100 grams, will penetrate an AC sample at 77°F in 5 seconds. (See FM 5-472 for more details on the penetration test.)

1-6. There are nine paving grades of AC. Each grade is designated by a penetration-grade number, an asphalt-petroleum (AP) number, and a relative-consistency (hardness) indicator (hard, medium, or soft). (See Table 1-1.)
Table 1-1. Paving Grades of AC

<table>
<thead>
<tr>
<th>Penetration Grade</th>
<th>AP</th>
<th>Relative Consistency</th>
</tr>
</thead>
<tbody>
<tr>
<td>40-50</td>
<td>7</td>
<td>Hard</td>
</tr>
<tr>
<td>50-60*</td>
<td>6</td>
<td>Hard</td>
</tr>
<tr>
<td>60-70</td>
<td>5</td>
<td>Hard</td>
</tr>
<tr>
<td>70-80*</td>
<td>4</td>
<td>Hard</td>
</tr>
<tr>
<td>85-100</td>
<td>3</td>
<td>Medium</td>
</tr>
<tr>
<td>100-120*</td>
<td>2</td>
<td>Medium</td>
</tr>
<tr>
<td>120-150</td>
<td>1</td>
<td>Medium</td>
</tr>
<tr>
<td>150-200*</td>
<td>0</td>
<td>Soft</td>
</tr>
<tr>
<td>200-300</td>
<td>00</td>
<td>Soft</td>
</tr>
</tbody>
</table>

*Penetration grade is no longer readily available. It is provided to facilitate field identification if necessary.

**ASPHALT CUTBACK**

1-7. Asphalt cutback is produced during the refining process or from heated AC that is cut back with a volatile petroleum distillate (cutter stock). In contrast to AC, asphalt cutback is workable at low temperatures. Naphtha, gasoline, kerosene, jet fuel, diesel oil, and fuel oil can be used as cutter stocks. The three types of asphalt cutback are based on the rate of curing:

- **Slow-curing (SC) asphalt cutback.** It contains diesel oil or fuel oil.
- **Medium-curing (MC) asphalt cutback.** It contains a less volatile substance, such as kerosene or jet fuel.
- **Rapid-curing (RC) asphalt cutback.** It contains a highly volatile cutter stock that evaporates rapidly, such as naphtha or gasoline.

1-8. The viscosity (resistance to flow) of asphalt cutback varies according to the amount of cutter stock added and the type of AC used. As the amount of cutter stock increases, the viscosity decreases. Each type of asphalt cutback is produced in four standard grades of kinematic viscosity—70, 250, 800, and 3,000 centistokes. The numerical grade is the lowest kinematic viscosity limit at 140°F, and the upper limit is twice the lower limit. Therefore, RC-250 has a kinematic viscosity range of 250 to 500 centistokes at 140°F.

**ASPHALT EMULSION**

1-9. Asphalt emulsion is a nonflammable liquid substance that is produced by combining asphalt and water with an emulsifying agent such as soap, dust, or certain colloidal clays. The emulsifying agent promotes emulsification and controls certain physical properties of the emulsion. Emulsion is deposited on a surface; and when the water and asphalt break (separate), they leave a thin film of AC.
1-10. The two kinds of emulsions—anionic and cationic—are established according to their electrical charge. The use of anionic (negatively charged) emulsion is restricted because it does not adhere easily to negatively charged siliceous aggregates. However, certain cationic (positively charged) emulsions improve adherence to negatively charged aggregates. In addition, cationic emulsions coat damp aggregates better than anionic emulsions.

1-11. The three basic types of emulsions are rapid setting (RS), medium setting (MS), and slow setting (SS). The setting rate, which is the rate of asphalt and water separation, depends on the amount and kind of emulsifying agent used. Asphalt emulsion is graded on the basis of viscosity and grouped according to its use. (See Table 1-2.)

### Table 1-2. Asphalt Emulsions

<table>
<thead>
<tr>
<th>Emulsion</th>
<th>Type</th>
<th>Viscosity Grade</th>
<th>Mixing Ability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anionic</td>
<td>RS</td>
<td>RS-1, RS-2</td>
<td>Spraying</td>
</tr>
<tr>
<td></td>
<td>MS</td>
<td>MS-2</td>
<td>Mixing and spraying</td>
</tr>
<tr>
<td></td>
<td>SS</td>
<td>SS-1, SS-1H</td>
<td>Mixing and spraying</td>
</tr>
<tr>
<td>Cationic</td>
<td>RS-C</td>
<td>RS-2C, RS-3C</td>
<td>Spraying</td>
</tr>
<tr>
<td></td>
<td>MS-C</td>
<td>MS-C</td>
<td>Mixing (sand) and spraying</td>
</tr>
<tr>
<td></td>
<td>SS-C</td>
<td>SS-C, SS-CH</td>
<td>Mixing and spraying</td>
</tr>
</tbody>
</table>

1-12. Emulsions are nonflammable and liquid at ordinary temperatures. Using water in an emulsion is a disadvantage in freezing weather because the water freezes and breaks the emulsion. Emulsions are also difficult to store or stockpile since they tend to break while still in unopened drums. Due to these disadvantages, emulsions are not used extensively in the theater of operations (TO).

**TAR**

1-13. RT is manufactured in 12 grades of viscosity (hardness) at a temperature of 77°F. Grades 1 through 7 are liquid, and grades 8 through 12 are semisolid to solid. Liquid RT contains more liquid coal distillates than solid RT.

1-14. RT is reduced with a coal-tar distillate to form RTCB, which is manufactured only in viscosity grades 5 and 6. Highly volatile coal distillate, such as benzene or a solution of naphthalene and benzol, is used to cut back the heavy grades of RT to produce RTCB. RTCB is similar to asphalt cutback and cures rapidly. The viscosity grades of RT and RTCB are comparable to the viscosity grades of asphalt cutback and AC. (See FM 5-472 for more information.)
SECTION II - AGGREGATE

FUNCTION

1-15. Aggregate is combined with bitumen to form a bituminous wearing surface. This nonskid surface transmits the load from the surface to the base and takes the abrasive wear of the traffic. Aggregate consists of a mineral filler and crushed stone, gravel, sand, slag, coral, or similar material.

TYPES OF AGGREGATE

1-16. For bituminous construction, aggregate is classified according to particle size. The size of aggregate used varies with construction requirements, and gradation particles largely determine the mechanical stability of a bituminous mix. Some types of bituminous surfaces require an aggregate gradation with a wide range of particle sizes, while other types require a uniform gradation of particles that are the same size. Particle size is determined by sorting the materials on standard sieves. (See FM 5-472 for sieve analysis.) The three types of aggregate are—

- **Coarse aggregate (CA).** It consists of crushed rock, broken gravel, slag, or other mineral materials that are retained on a number 8 sieve.
- **Fine aggregate (FA).** It consists of sand or small pieces of crushed rock that pass through a number 8 sieve but are retained on a number 200 sieve.
- **Mineral filler.** It consists of inert, nonplastic particles that pass through a number 200 sieve. Rock dust, hydrated lime, inert fine soil, and portland cement can be used as mineral fillers. Most clays are too plastic for this purpose.

1-17. These three types of aggregate are blended in different proportions to produce various aggregate gradations. Trial-and-error calculations determine the percentage (blend) of each stockpiled aggregate used in the mix. The following aggregate gradations are used in bituminous construction:

- **Uniform gradation.** It consists of same-size aggregate particles that are <1 inch.
- **Macadam gradation.** It consists of uniformly graded aggregate particles that are ≥ 1 inch. The particles are about the same size, but variations do exist. For example, a macadam gradation designated as 1 1/2-inch aggregate may include 1- and 2-inch particles but most of the particles will be about 1 1/2 inches.
- **Open gradation.** It consists of aggregate particles ranging in size from coarse to fine. Open spaces or voids remain in the mix because there is insufficient FA or mineral filler to fill the voids left by CA.
- **Dense gradation.** It consists of a blended, well-graded mix of CA, FA, and mineral filler. In contrast to open gradation, dense gradation has few voids because FA and mineral filler fill the voids around the CA.
CHARACTERISTICS

1-18. The interlocking aggregate action in a bituminous surface is more pronounced when angular, rough-textured particles are used, because angular particles need more asphalt for coating than round particles. Using as much asphalt as possible in a bituminous surface ensures durability without impairing stability. Aggregate must be strong and durable to resist weathering and must hold up under applied loads without cracking or breaking. (See FM 5-472 for tests to determine aggregate strength and durability.)

1-19. Aggregate particles must be clean and dry so that bitumen can penetrate the pores and hold the particles together. Bitumen will not penetrate or adhere if aggregate is coated with clay or dust or if the pores are wet. In addition, aggregate must be hot and dry for hot mixes. The moisture content should be <2 percent for cutback mixes and <5 percent for emulsions. Hydrophilic aggregate is clean and dry, and it does not retain a bituminous coating in the presence of water. Standard laboratory tests for aggregate gravity, absorption, stripping, and moisture properties are described in FM 5-472.