Chapter 3

Bituminous Mixtures

This chapter provides information on the materials used in constructing bituminous surfaces, the methods of testing these materials, and the mixes prepared from them. The design considerations—such as bearing capacity and thickness of pavements—are described in FM 5-430-00-1. Mixing and placing operations, as well as the considerations for preparing the mixes, are described in TM 5-337.

SECTION I. BITUMINOUS PAVEMENTS/SURFACES

Bituminous pavements/surfaces are a mixture of mineral aggregates, mineral filler, and a bituminous material or binder. This mixture is used as the top portion of a flexible pavement structure to provide a resilient, waterproof, load-distributing medium that protects the base course from the detrimental effects of water and the abrasive action of traffic.

AGGREGATES

Mineral aggregates may consist of crushed rock, crushed or uncrushed soils (including gravels and sands), slag, mineral filler, or a combination of some of these materials. Other materials that may be used as aggregate in certain geographical areas include vesicular lava and coral. Aggregates normally constitute 90 percent or more by weight of bituminous mixtures, and their properties greatly affect the finished product. The aggregate provides three basic functions when used in bituminous surfaces:

- It transmits the load from the surface down to the base course. In pavement, this is accomplished through the mechanical interlock of the aggregate particles.
- It withstands the traffic's abrasive action. If a wearing surface were laid consisting of binder alone, it soon would be worn away by the abrasive action of tires.
- It provides a nonskid surface. A portion of the aggregate extends slightly above the normal surface of the wearing mat, thereby providing a roughened surface for tires to grip.

BITUMINOUS MATERIALS

A bituminous material is the adhesive agent or binder in a bituminous mixture. This material or binder provides two functions:

- It binds the aggregate together, holds it in place, and prevents displacement.

- It provides a waterproof cover for the base and keeps surface water from seeping into and weakening the base material.

The binder's functions require it to be a waterproof substance having the ability to bind aggregate particles together. All bituminous materials possess these qualities due to being mainly composed of bitumen—a black solid that provides the black color, cementing ability, and waterproofing properties. Bituminous materials are classified into two main groups—asphalts and tars. They are available in several forms suitable for different procedures of mixing or application under wide variations in temperature. Some bituminous materials are solid or semisolid at room temperature. Other grades are a relatively viscous (thick) liquid at room temperature. Mixing bituminous materials with solvents or water produces cutbacks or emulsions that are liquid at atmospheric temperatures. Such liquid asphalts and tars are used for cold mixes or are applied as sprays in building pavements.

ASPHALTS

Asphalt is obtained only from crude petroleum and has two general classes—natural and manufactured. Natural asphalts occur in lakes (as lake asphalt), pits, or rock structures (as rock asphalt). Manufactured asphalt is produced by distilling crude petroleum (see *Figure 3-1*). A military engineer is seldom concerned with natural asphalts because they are not usually available in those areas of interest. Therefore, this chapter discusses the uses and testing of manufactured asphalts.

All asphalt cements are solid or semisolid at room temperature (77°F) and must be converted to a fluid state by heating, emulsifying, or dissolving in a petroleum solvent.

Grading

There are two grade scales used for identifying asphalt cement—penetration grade and viscosity grade. The penetration grade is determined by the distance a standard needle under a standard load will penetrate a sample in a given time under a given temperature condition. A correlating asphalt-petroleum number from 00 to 7 is assigned to these penetration ranges. The viscosity grade is determined using a standard viscometer under standard conditions. *Table 3-1* lists the penetration ranges and correlating asphalt-petroleum numbers presently recognized along with the relative consistencies.

Table 3-1. Penetration grades and asphalt petroleum numbers of asphalt cement

Penetration Grade	Asphalt-Petroleum Number	Relative Consistency
40 to 50	7	Hard
60 to 70	5	
85 to 100	3	Medium
120 to 150	1	Soft
200 to 300	00	

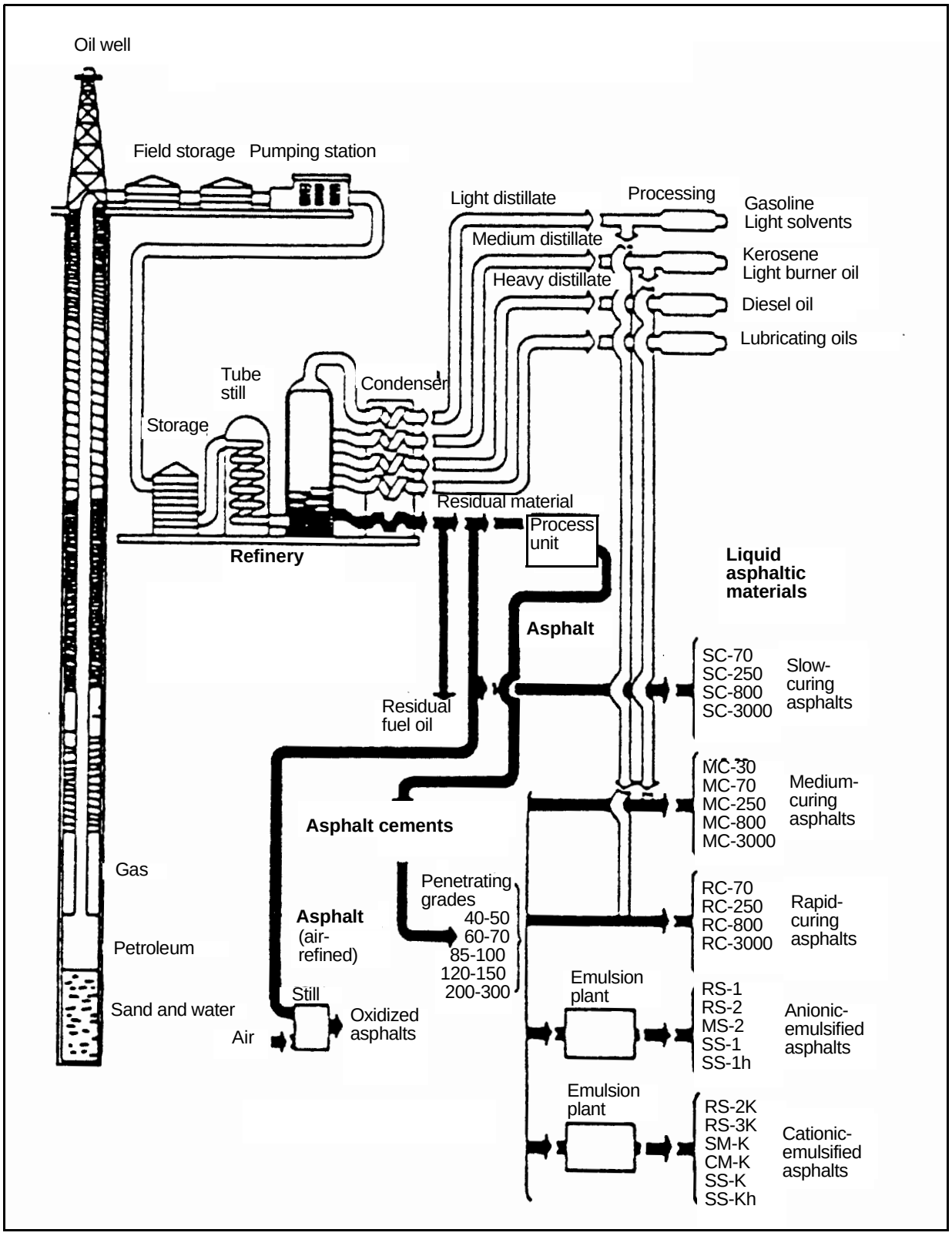


Figure 3-1. Simplified flow chart showing recovery and refinement of petroleum asphaltic materials

Cutback Asphalts

When heating equipment is not available or is impractical to use, asphalt cement can be made fluid by adding solvents (called cutter stock or flux oils). Cutter stock may be any one of the more volatile petroleum-distillate products. The resulting combination is called asphalt cutback. Exposure to air causes the solvents to evaporate and leave the asphalt cement to perform its functions.

The classification of the cutback is based on the evaporation rate of the distillate in the mixture. Gasoline or naphtha (high volatility) produces a rapid-curing (RC) cutback; kerosene (medium volatility) produces a medium-curing (MC) cutback; and fuel oil (low volatility) produces a slow-curing (SC) cutback. Road oils, referred to occasionally, are a heavy petroleum oil in the SC grade of liquid asphalt. *Table 3-2* shows the percentage of components by grade for the three types of asphalt cutbacks.

Table 3-2. Asphalt-cutback composition (expressed in percent of total volume)

Type	Components	Grades				
		30	70	250	800	3,000
RC	Asphalt cement		65	75	83	87
	Gasoline or naphtha		35	25	17	13
MC	Asphalt cement	54	64	74	82	86
	Kerosene	46	36	26	18	14
SC	Asphalt cement		50	60	70	80
	Fuel oil		50	40	30	20

As more cutter stock is mixed with a given amount of asphalt cement, a thinner liquid results. In practice, different amounts of cutter stock are added to a given amount of asphalt cement to obtain various viscosities, or grades, of cutbacks. The Corps of Engineers has approved a set of specifications for cutbacks based on kinematic viscosity. The number assigned to each grade corresponds to the lower limit of kinematic viscosity as determined by a standard test. The upper limit of each grade is equal to twice the lower limit or grade number. The units used in the test are centistokes.

Thus, a number 70 cutback refers to a viscosity range of 70 to 140 centistokes. The other grades and their limits are 250 (250 to 500), 800 (800 to 1,600), and 3,000 (3,000 to 6,000). In addition, the MC has a 30 grade (30 to 60). *Figure 3-2* shows the scale of viscosity grades. The higher the viscosity, the thicker the liquid.

Asphaltic penetrative soil binder is a special cutback asphalt composed of low-penetration-grade asphalt and a solvent blend of kerosene and naphtha. It is similar in character to standard low-viscosity, MC cutback asphalt but differs in many specific properties. It is used as a soil binder and dust palliative.

Asphalt Emulsions

It is often advantageous to use an asphalt material that is liquid at room temperature and yet will not burn. Asphalt emulsions possess these

properties. Emulsified asphalt is a liquid material made up of a mixture of asphalt, water, and emulsifier. Asphalt and water will not mix alone so a chemical agent (an emulsifying agent) must be added. Common emulsifying agents are soaps, colloidal clays, and numerous other organic agents. Emulsified asphalt is a heterogeneous system in which water forms the continuous phase of the emulsion and the minute globules of asphalt for the discontinuous phase. There is also an inverted asphalt emulsion in which the continuous phase is asphalt (generally liquid asphalt) and the discontinuous phase is minute globules of water in relatively small quantities. Emulsified asphalts may be of either the anionic (electronegatively charged asphalt globules) or cationic (electropositively charged asphalt globules) types, depending on the emulsifying agent.

Emulsions are classified according to the setting or breaking rate which is the speed at which the emulsion breaks or the asphalt and water separate. This rate usually depends on the emulsifier used and the proportion of water to asphalt. Emulsions are described as rapid-setting (RS), medium-setting (MS), and slow-setting (SS) and also by viscosity numbers (see *Figure 3-2*). Because of this breaking rate, emulsions can also be grouped according to their ability to mix with damp aggregate. The RS emulsion breaks so fast that it cannot be mixed; therefore, it is called a nonmixing type. The MS and SS emulsions break slowly enough to permit good mixing until each particle of the aggregate is uniformly coated. Emulsions may also be satisfactorily used as a tack coat for bituminous pavements.

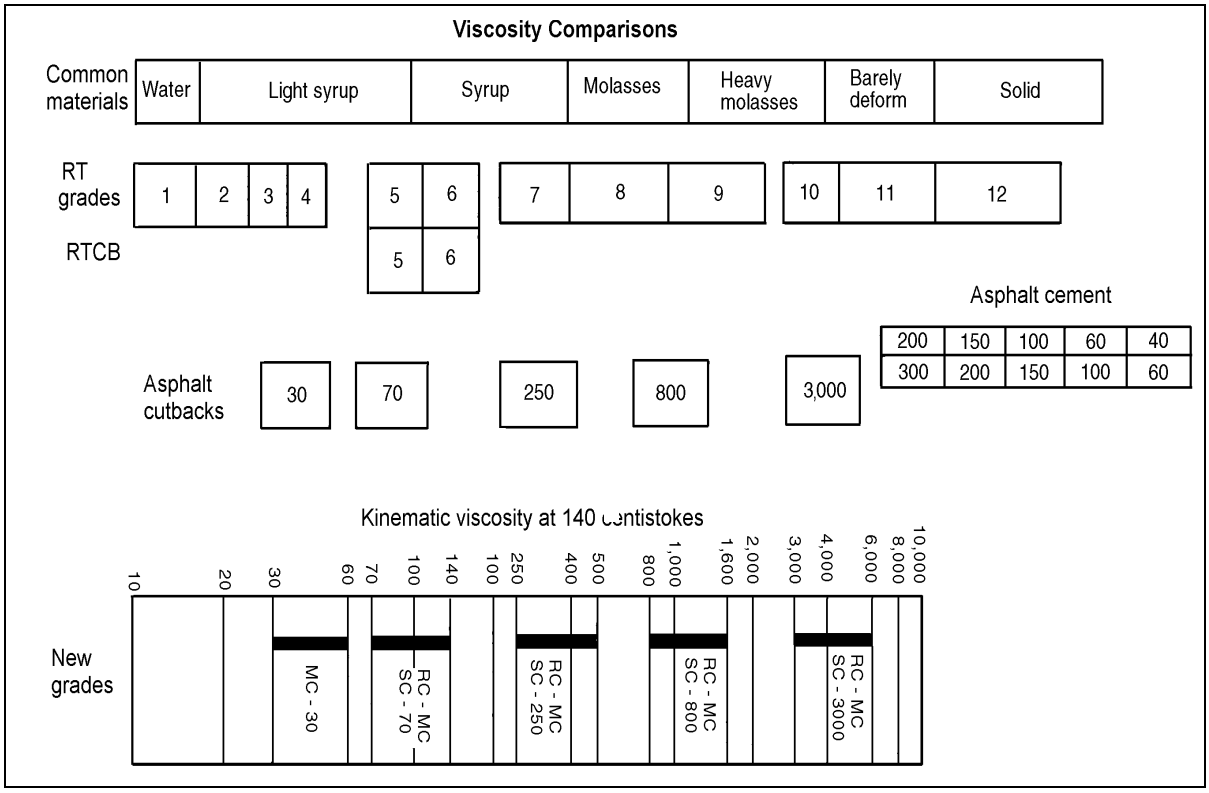


Figure 3-2. Viscosity grades at room temperature

TARS

Tars are products of coal distillation (see *Figure 3-3*). No natural source of tars exists. Coal tar is a general term applied to all varieties of tar obtained from coal. It is produced by one of several methods, depending on the desired end product.

When bituminous coal is destructively distilled, coke and gas are formed. Tar, ammonia, light oils, sulfur, and phenol may be recovered. Coke-oven tar is

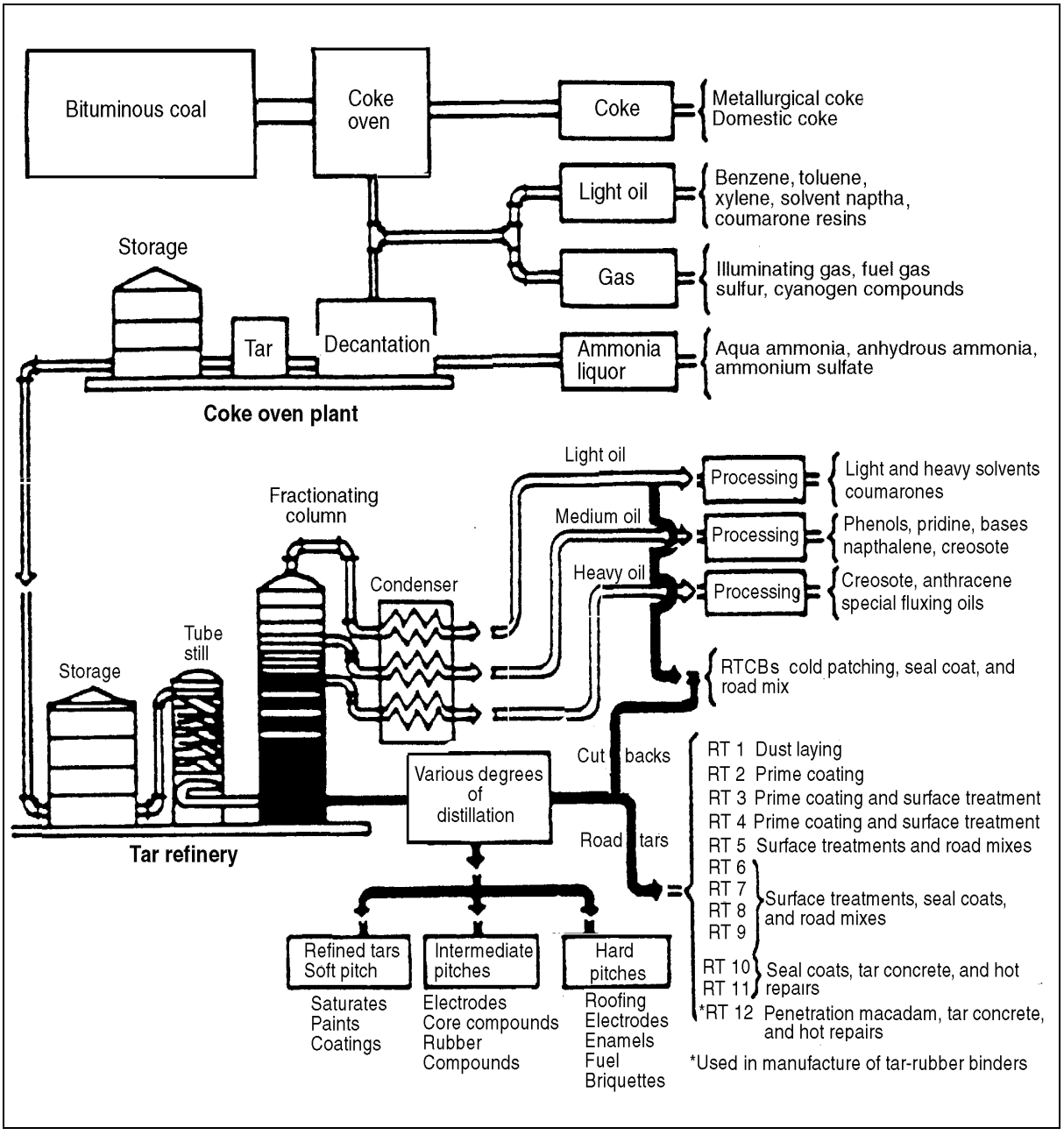


Figure 3-3. Simplified flow chart showing production of road tars from bituminous coals

produced in the greatest amount. Its chemical, physical, and adhesive characteristics make it most suitable for road-tar purposes. Water-gas tar is obtained in the manufacture of carbureted water gas. The nature of the carbureting oil largely determines the character of the water-gas tar produced and may vary widely in specific gravities, viscosities, and other physical and chemical properties.

Road tars are manufactured in 12 grades of viscosity (see *Figure 3-2, page 3-5*). There are also some special grades for use in rubberized-tar binders. Grades 1 through 7 are liquid at room temperature, while grades 8 through 12 are semisolid or solid. The difference is due to the liquid coal distillates in the tar; the more distillate, the more liquid (or less solid) the tar. The road-tar cutbacks (RTCBs) are products of cutting back the heavier or harder grades with coal-tar distillates. RTCBs are manufactured in two viscosity grades (5 and 6) only.

Tar, which is insoluble in petroleum distillates, is sometimes mixed with oil-resistant, unvulcanized rubber to form a rubberized-tar binder material.

CHARACTERISTICS AND USES OF BITUMENS

Tables 3-3 and *3-4, pages 3-8 through 3-11,* list the bituminous materials, sources, curing, temperatures, and grades associated with bituminous operations.

SAFETY PRECAUTIONS

Be extremely cautious when handling bituminous materials. Asphalt cement, which is solid at room temperature, is heated to high temperatures to make it workable as a binder material. Heated asphalt can cause severe burns if allowed to come in contact with the skin. The vapors emitted by heating bituminous materials may be harmful if inhaled. Use care during heating to ensure proper ventilation. Asphalt cutbacks contain highly flammable volatiles. The vapors will ignite at relatively low temperatures. The lowest temperature at which they will ignite is called the flash point. The minimum flash point for RC-250, RC-800, and RC-3,000 is 80°F; for MC-30 and MC-70, about 110°F; for MC-250 to MC-3,000 and SC-70, about 150°F; and for the remaining SC grades, about 25° higher per grade up to 225°F for SC-3,000.

NOTES:

1. The spraying and mixing temperatures in many cases are above the flash point (see *Table 3-3*). Use extreme caution when handling these mixtures. Do not expose their vapors to an open flame.

2. Cutbacks may also be classified as an environmentally hazardous material. Check with unit and installation environmental representatives for further guidance as to proper storage, use, and disposal of these substances. If your unit's environmental representative is not known, consult your commander for assistance.

Table 3-3. Characteristics of bituminous materials

Material	Form	Grade Designation	Temperature of Application Ranges				Flash Point (Min)		Remarks
			Spraying **		Mixing				
			°F	°C	°F	°C	°F	°C	
Penetrative soil binder	Liquid		130-150	55 - 65			80	27	Contains naphtha Caution: Highly flammable
Cutback (RC)	Liquids—asphalt residues fluxed with more volatile petroleum distillate	RC-70 RC-250 RC-800 RC-3,000	*105-175 145-220 180-255 *215-290	*41-79 63-104 *82-124 *102-143	95-135 135-175 170-210 200-240	35-57 57-79 77-99 93-116	80 80 80	27 27 27	RC cutbacks contain highly-volatile naphtha cutter stock. Naphtha evaporates quickly, leaving an asphalt-cement binder, permitting early use of the surface. Caution: Highly flammable
Cutback (MC)	Liquids—asphalt residues fluxed with more volatile petroleum distillate	MC-30 MC-70 MC-250 MC-800 MC-3,000	70-140 105-175 145-220 180-255 215-290	21-60 41-79 63-104 82-124 102-143	55-95 95-135 135-175 170-210 200-240	13-35 35-57 57-79 77-99 93-116	100 100 150 150 150	37 37 65 65 65	MC cutbacks contain less volatile kerosene cutter stock. Kerosene evaporates less rapidly than naphtha. Caution: Flammable.
Cutback (SC)	Liquids—asphalt residues fluxed with more volatile petroleum distillate	SC-70 SC-250 SC-800 SC-3,000	105-175 145-220 180-225 215-290	41-79 63-104 82-124 102-143	95-135 135-175 170-210 200-240	35-57 57-79 71-99 93-116	150 175+ 200+ 225+	65 79+ 93+ 107+	SC cutbacks contain slightly-volatile diesel-fuel cutter stock. Diesel fuel evaporates slowly. Caution: Flammable.
Asphalt cements	Solids	40-50 60-70 85-100 120-150 200-300	285-350 285-350 285-350 260-325	141-177 141-177 141-177 127-163	300-350 275-325 275-325 275-325 200-275	149-177 135-163 135-163 135-163 93-135			Penetrations 40 to 100 used for crack and joint fillers. Penetrations 70 to 300 used for plant mixes, penetration macadam, and surface treatment. Use test to determine flash point.
Powdered asphalt	Hard and solid asphalts ground to powder								Used with SC to produce extra tough road surfaces.

*** RC cutbacks are seldom used for spraying.**

**** Low temperature is based on a viscosity of 200 centistokes kinematic viscosity and the higher temperature is based on a 50-centistoke viscosity.**

Table 3-3. Characteristics of bituminous materials (continued)

Material	Form	Grade Designation	Temperature of Application Ranges				Flash Point (Min)		Remarks
			Spraying **		Mixing				
			°F	°C	°F	°C	°F	°C	
Asphalt emulsions (RS)	Liquids—asphalt particles held in an aqueous suspension by an emulsifying agent	RS-1	50-140	10-60	Nonmixing	10-60			Freezing destroys emulsion. Use for road and plant mixes with coarse aggregates (SS). All emulsions with “K” suffix are cationic.
		RS-2	50-140	10-60	50-140	10-60			
		RS-2K	50-140	10-60	50-140	10-60			
		RS-3K	50-140	10-60	50-140	10-60			
Asphalt emulsions (MS)	Liquids—asphalt particles held in an aqueous suspension by an emulsifying agent	MS-2	50-140	10-60	50-140	10-60			
		SM-K	50-140	10-60	50-140	10-60			
		CM-K	50-140	10-60	50-140	10-60			
Asphalt emulsions (SS)	Liquids—asphalt particles held in an aqueous suspension by an emulsifying agent	SS-1	50-140	10-60	50-140	10-60			
		SS-1h	50-140	10-60	50-140	10-60			
		SS-K	50-140	10-60	50-140	10-60			
		SS-Kh	50-140	10-60	50-140	10-60			
Road tars	Liquids	RT-1	60-125	15-52					Priming oils. RT-4 through RT-12 not generally used.
		RT-2	60-125	15-52					
		RT-3	60-125	27-66					
RTCBs	Liquids	RTCB-5	60-120	16-49					Patching mixtures. Caution: Flammable.
		RTCB-6	60-120	16-49					
Rock asphalt	Solids								Mixed and used locally where found. Cutback may be added if necessary.

*** RC cutbacks are seldom used for spraying.**
**** Low temperature is based on a viscosity of 200 centistokes kinematic viscosity and the higher temperature is based on a 50-centistokes viscosity.**

Table 3-4. Typical uses of bituminous materials

Purpose or Use	Grade or Designation[1]		
	CB - Asphalt Cutback[2]		
	RC	MC	SC
Dust palliative	DCA-70[3]	MC-30, -70, -250 APSB[4]	SC-70, -250
Prime coat: Tightly bonded surfaces Loosely bonded, fine-grained surfaces Loosely bonded, coarse-grained surfaces		 MC-30 MC-70 MC-250	 SC-70 SC-250
Tack coat	RC-250, -800	MC-250, -800	
Surface treatment and seal coat: Coarse sand cover Clean coarse aggregate cover Graded gravel aggregate cover Gravel mulch	 RC-70, -250 RC-250, -800, -3,000	 MC-250, -800 MC-800 MC-250-, -800 MC-250	 SC-800 SC-250
Mixed in place road mix: Open-graded aggregate: Sand Maximum diameter 1 inch, high percentage passing No. 10	 RC-70, -250	 MC-800 MC-800	
Macadam aggregate	RC-250, -800		
Dense-graded aggregate: High percentage passing No. 200 Maximum diameter 1 inch, medium percentage passing No. 200		 MC-250 MC-250, -800	 SC-250 SC-250, -800
Premix or cold patch: Open-graded aggregate Dense-graded aggregate	 RC-250	 MC-800 MC-250	 SC-800 SC-250
Cold-laid plant mix: Open-graded aggregate: Sand Maximum diameter 1 inch, high percentage passing No. 10 Macadam aggregate Dense-graded aggregate: High percentage passing No. 200 Maximum diameter 1 inch, medium percentage passing No. 200 Aggregate precoating followed with asphalt	 RC-250, -800 RC-800 RC-800, -3,000		 SC-800

[1]Prevailing temperature during construction also affects selection of bitumen and may be the determining factor rather than size and gradation of aggregate.

[2]Caution: Do not overheat aggregate when cutbacks are used to produce hot mixes.

[3]DCA-70 is a water emulsion of a polyvinyl acetate containing chemical modifiers (formerly UCAR-131). Proprietary product of Union Carbide Corporation, New York, NY.

[4]Asphaltic penetrative soil binder (APSB)

Table 3-4. Typical uses of bituminous materials (continued)

Purpose or Use	Grade or Designation[1]		
	CB - Asphalt Cutback[2]		
	RC	MC	SC
Dust palliative	DCA-70[3]	MC-30, -70, -250 APSB[4]	SC-70, -250
Hot-laid plant mix	RC-3,000	MC-3,000	SC-3,000
Penetration macadam: Cold weather Hot weather	RC-800, -3,000		SC-3,000

[1]Prevailing temperature during construction also affects selection of bitumen and may be the determining factor rather than size and gradation of aggregate.

[2]Caution: Do not overheat aggregate when cutbacks are used to produce hot mixes.

[3]DCA-70 is a water emulsion of a polyvinyl acetate containing chemical modifiers (formerly UCAR-131). Proprietary product of Union Carbide Corporation, New York, NY.

[4]Asphaltic penetrative soil binder (APSB).

ADVANTAGES AND DISADVANTAGES

Advantages and disadvantages of the bituminous materials used in construction are as follows:

Asphalt-cement cutbacks are flammable. Asphalt pavements are susceptible to damage by the blast from jet planes, and they can be dissolved by petroleum products that may be spilled on them such as during refueling at an airfield. Tars, on the other hand, are not affected by petroleum derivatives since they are products of coal. Tars, when used as a prime for base courses, seem to possess better penetration qualities than asphalts and are less susceptible to stripping (loss of bond to aggregate) in the presence of water. Tars are affected by temperatures and have a wide range in viscosity with normal surrounding temperature changes. Tar can become so soft during warmer weather that the pavement will rut under traffic. In colder weather, it can become so brittle that the pavement will crack. The temperature susceptibility of tar binders is improved by blending with oil-resistant rubber. Asphalt pavements and tar pavements are generally ready for traffic within a few hours after placement since they can be used as soon as they reach normal temperature.

Asphalt emulsions are not flammable and are liquid at normal temperatures. Since they are mixed with water, they can be used with more damp aggregate than required for the cutbacks. Additional water may be added to the emulsion up to proportions of 1:3 for use in slurry seal coats. Because emulsions contain water, they have certain disadvantages. During freezing weather, the emulsions can freeze and the components separate. Emulsions are difficult to store for extended periods because they tend to break even in unopened drums. When shipped, the water in the emulsion takes up valuable space which could be used to transport hard-to-obtain materials.

SECTION II. SAMPLING MATERIALS

When conducting tests, use the materials that represent those that will be used in construction; otherwise, test results will be misleading. Sampling of materials for testing should receive close attention. When large samples must be subdivided into small units for the actual tests, take care to keep the sample representative of the original mass. Reduce aggregate samples to the proper size for testing by means of quartering. Methods for sampling natural deposits of sands and gravels are discussed in soil surveys and are applicable here.

Take samples of bituminous materials at the place of manufacture or at the delivery point. (This manual assumes that sampling is done at the point of delivery.) Samples may be taken for either of two purposes:

- To obtain an average of the delivered material.
- To find the maximum variation in the material's characteristics.

Take samples for analysis to identify bituminous materials if records are not available. Obtain sufficient quantities of materials at the time of sampling to meet specification requirements and to provide for laboratory pavement-design tests. Normally, aggregates that will produce 150 pounds of the desired gradation and 2 gallons of bituminous material will produce sufficient data.

BITUMINOUS MATERIALS SAMPLING (ASTM D 140-88)

Use clean, dry containers for sampling. Keep the containers tightly closed and properly marked. A sample for a routine laboratory examination should not be less than one quart.

LIQUID MATERIALS

When sampling liquid bituminous materials from nonagitated vertical tanks, take samples from near the top, middle, and bottom. Test the samples from the three levels separately to detect stratification. Materials shipped in tank cars may be sampled from valves and taps. Take samples from drain cocks on the side of the tank or car. If cocks are not present, take the samples by lowering weighted bottles or cans into the material (see *Figure 3-4)*. Fit the bottle or can with a stopper that can be removed by a string or wire after it has been lowered to the proper depth.

SOLID AND SEMISOLID MATERIALS

When sampling solid or semisolid materials in drums, barrels, cartons, and bags, take samples at least 3 inches below the surface and 3 inches from the side of the container or cake. Use a clean hatchet on hard material and a stiff putty knife on soft material.

AGGREGATE SAMPLING (ASTM D 75-87)

Aggregate varies in size from the larger stones or rocks to the gravels and sands. These materials for paving may still be in their natural deposits or may be in stockpiles previously gathered.

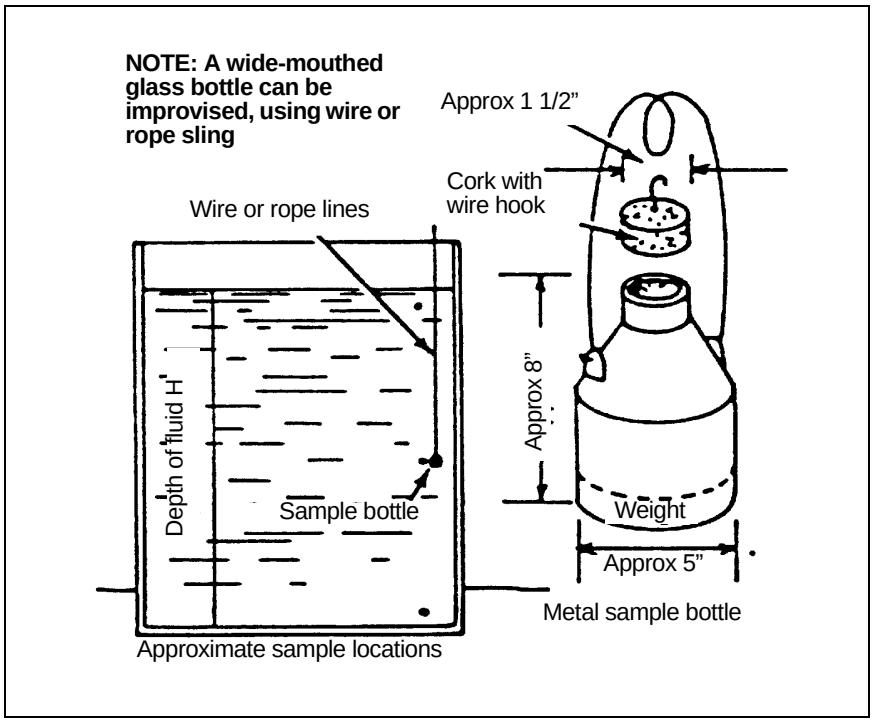


Figure 3-4. Sampling liquid bituminous materials from tank car or storage tank

STONE FROM LEDGES AND QUARRIES

Obtain separate samples of unweathered stone weighing at least 50 pounds each from all strata that appear to vary in color and structure. Prepare a sketch plan with elevation, showing the thickness, length, width, and location of the different layers so that the quantity available can be estimated.

NATURAL DEPOSITS OF SAND AND GRAVEL

Select samples that represent the different materials available in the deposit. Sketch the area and indicate the approximate quantities of different materials. If the deposit is an open-face bank or pit, take the sample by channeling the face so that it will represent material that visual inspection indicates may be used. Cut the face immediately before sampling, and discard any material that has fallen from the surface along the face. Do not include in the sample any overlying material (overburden) that is not suitable for use as an aggregate, since this material would be stripped away when the aggregate is removed from the pit. It may be necessary to make test borings or dig test pits to determine the approximate extent of the material. If test pits are dug, they must be adequately shored to prevent material from caving in on personnel working in the pit. Obtain from the pit representative samples for each change in strata. If the material being sampled is all sand, about 25 pounds is sufficient for tests. If it consists of sand and gravel, a somewhat larger sample (about 75 pounds) is required for preliminary tests. The coarser the gravel portion, the larger the sample required.

STOCKPILES

If the material has been stockpiled previously, take care in obtaining samples. There is a natural tendency toward separation of similar size fractions into groups in the stockpile. The material near the outer edges and near the base of the pile is likely to be coarser than the average. Cut a face into the stockpile near the base, the center, and the top on at least two opposite sides. Combine samples from at least three different sections of the pile to give a representative sample.

COMMERCIAL AGGREGATES

It is preferable to obtain samples of commercial aggregates at the plant, during loading, from stockpiles or bins. Obtain separate samples at different times while the material is being loaded, to determine variations in the grading of the material. Take bin samples from the entire cross section of the flow of material as it is being discharged. Testing separate samples gives a better idea of variations that occur, but samples should be mixed and reduced by quartering when the average condition is desired. When it is not practicable to visit the plant to obtain samples, the next preferred method is to sample the material in cars or trucks or while it is being unloaded. Take railroad-car samples from three or more trenches dug across the car at points that appear on the surface to be representative of the material. When obtaining the sample, remember that segregation of the different sizes has probably taken place and choose samples that are representative.

SECTION III. FIELD IDENTIFICATION

Laboratory tests conducted on bituminous materials to check compliance with specifications are not considered field tests. They are described in this section for information purposes only. The field tests discussed in this section are limited to the bitumen identification procedures, flash-point tests, and penetration tests. These tests are applicable to both tars and asphalts and are conducted to determine safe uses for a material.

Field identification enables the military engineer to determine the type of surface that can be constructed with the type and grade of material available. With the type of surface known, the construction procedure may be outlined and scheduled. This procedure will then determine the proper equipment and the necessary safety procedures.

The aggregate materials must also be tested for acceptable bituminous construction use.

BITUMEN FIELD-IDENTIFICATION TESTS

Perform field tests to identify the bituminous paving materials as asphalt cement, asphalt cutback, asphalt emulsion, road tar, or RTCB. In addition, identify the viscosity grade of the bitumen. To distinguish among the several asphaltic and tar products, it is necessary to know something of their origin, physical properties, and the manner in which they are normally used. Some of this information is contained in *Tables 3-3* and *3-4*, *pages 3-8 through 3-11*.

The identification procedure outlined in *Figure 3-5* is based on a consideration of the physical properties of these materials.

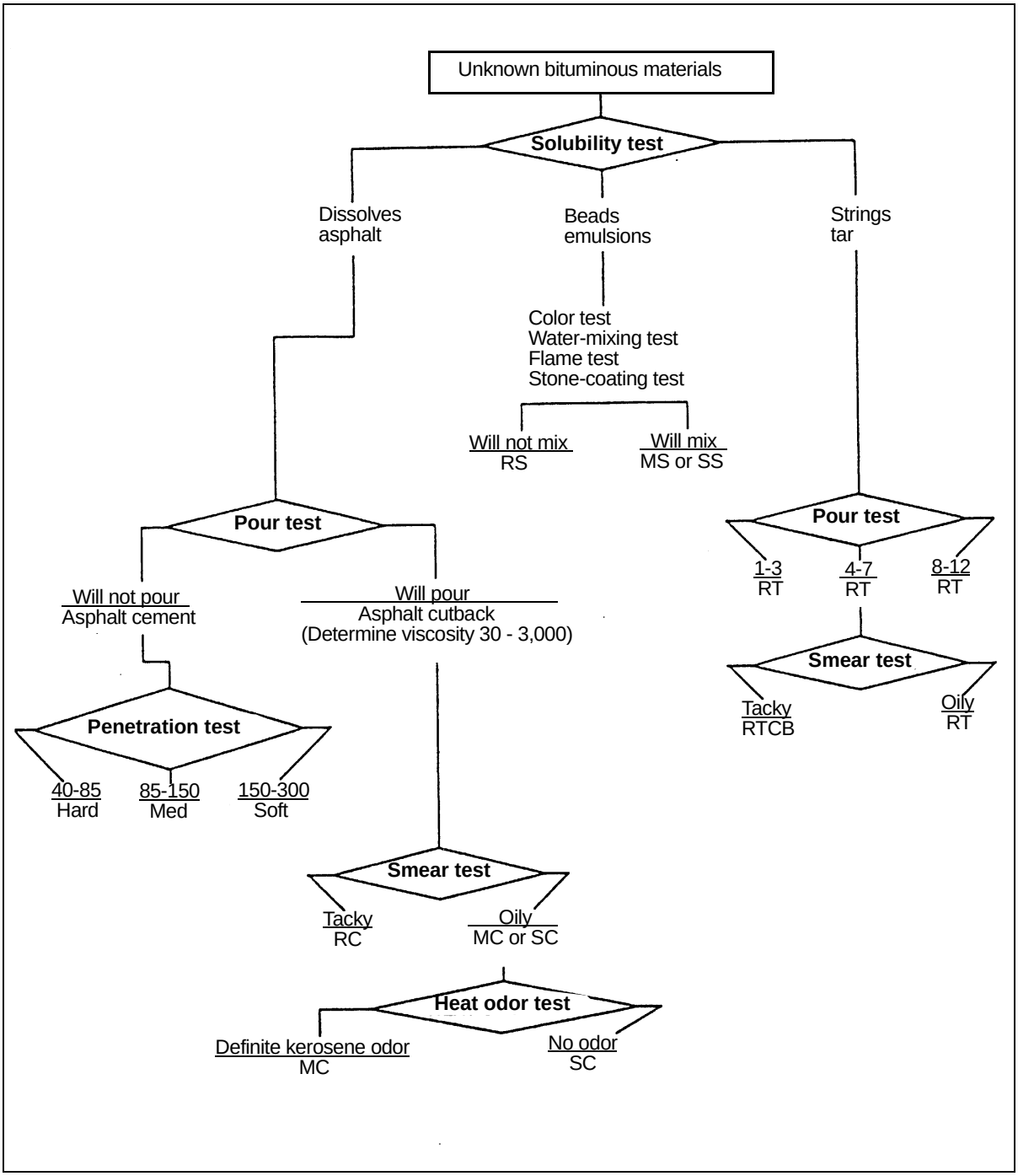


Figure 3-5. Identification of unknown bituminous materials

Ensure that all tests are performed away from open flames and in well-ventilated areas. Also ensure that all materials are properly disposed of according to local environmental policy.

ASPHALTS AND TARS

The first procedure in identifying an unknown bituminous material is to determine, by a solubility test, whether it is an asphalt or a tar. Attempt to dissolve an unknown sample (a few drops, if liquid, or enough to cover the head of a nail, if solid) by stirring it in any petroleum distillate. Kerosene, gasoline, diesel oil, or jet fuel is suitable for this test. Since asphalt is derived from petroleum, it will dissolve in the petroleum distillate. Road tar will not dissolve. If the sample is an asphalt, the sample distillate mix will consist of a dark, uniform liquid. Asphalt cements or cutbacks dissolve completely.

Asphalt in emulsions is also distinguishable as it dissolves and forms black beads or globules in the bottom of the container of distillate. A road-tar sample will be a dark, stringy, undissolved mass in the distillate. A check can be made by spotting a piece of paper or cloth with the mix. Asphalt dissolved in distillate will produce a brown to black stain. The clear distillate above the settled tar will not cause a stain. The solubility test provides a positive method of identification.

ASPHALT CEMENT AND CUTBACKS

Perform the following procedure to determine if the specimen is an asphalt cement or a cutback.

The various grades of asphalt cement are solid at room temperature while cutbacks are liquid, and a pour test will distinguish between them. Place a sample of the material in a small container and attempt to pour it. If the material does not pour, it is an asphalt cement. If it pours, it is a cutback or an emulsion. Note that at 77°F even the softest asphalt cement will not pour or deform if the container is tilted.

The various grades of asphalt cement are distinguished principally by their hardness, as measured by a field penetration test. The information obtained may be sufficient for planning for or starting emergency construction. The exact penetration grade is not determined, but the field test will distinguish between hard, medium, or soft groups of asphalt cement. Perform the test by pushing a sharpened pencil or nail into the container of asphalt (at about 77°F) using about 10 pounds of force. If only a slight penetration is made with considerable difficulty, a hard asphalt cement is present. If the penetration is made with some difficulty, a medium asphalt cement is present. If the penetration is made with ease, the asphalt cement is a soft asphalt cement in the high-penetration scale. Even the highest penetration will not pour or deform at 77°F if its container is tilted.

ASPHALTIC-CUTBACK TESTS

There are three tests used to determine the grade of an asphaltic cutback:

Pour Test

As stated previously, an asphalt cement will not pour at 77°F, but a cutback will. The pour test can be used to determine whether the unknown material is

an asphalt cutback. If the material pours, it is an asphalt cutback. The approximate viscosity grade number of the cutback is found by comparing the flow to well-known materials such as water, syrup, and others. If this test is made at a temperature below 77°F, the materials will appear more viscous (stiff) than at 77°F and the opposite if tested when warmer than 77°F. The cutbacks of a given viscosity grade will pour in a manner similar to the following:

- 30—water.
- 70—light syrup.
- 250—syrup.
- 800—molasses.
- 3,000—barely deform.

After the pour test, the approximate viscosity grade of the cutback is known, but the type (RC, MC, or SC) is not.

Smear Test

Perform the smear test to determine if a cutback is an RC. This is done by making a uniform smear of the substance on a piece of glazed paper or other nonabsorbent surface. Volatile materials, if present, will evaporate. Since RC materials are cut back with a very volatile substance, most of the volatiles will evaporate within 10 minutes. The surface of the smear then becomes extremely tacky. This is not true of the lighter grades (MC and SC), which remain fluid and smooth for some time. An MC will not result in a tacky surface for a matter of hours. SC materials may require several days.

Perform a prolonged smear test to identify an 800- or 3,000-grade MC or SC cutback. This is necessary because these grades contain such small quantities of cutter stock that they may become tacky in the 10-minute period specified above. Place a thin smear of the material on a nonabsorbent surface and let it cure for at least 2 hours. By the end of that time, if the material being tested is not an MC or SC, the smear will be hard or just slightly sticky. However, if the material being tested is an MC or SC, the smear will be uncured and still quite sticky. If the material is an RC-3,000, it will cure completely in 3 hours, whereas an RC-800 will take about 6 hours to cure. Even after 24 hours, an MC or SC will still be sticky.

Heat-Odor Test

The main difference between MC material and SC material is that the MC material is cut back with kerosene and the SC with diesel or a low-volatility oil class. In this test, apply heat to the sample to drive off the kerosene, if it is present, and make it show up in the form of an odor. Heat the unknown sample in a closed container to capture the escaping vapors, using minimal heat. An MC sample will have a strong petroleum or kerosene odor. An SC sample will have no kerosene or petroleum odor but may have a faint odor of hot motor oil. The ability to differentiate between the RC, the MC, and the SC is an essential part of field identification.

ASPHALT-EMULSION (ANIONIC) TESTS

Another asphaltic material used in paving is asphalt emulsion, which is a mixture of asphalt, water, and an emulsifying agent. The anionic emulsions specifications cover three types of asphalt emulsion—RS grades 1 and 2, MS grade 2, and SS grades 1 and LH.

Solubility Test

The solubility test will make an emulsion's identity known by forming into globules or beads that fall to the bottom of the container of petroleum distillate. During this test, the emulsion will present a distinctive dark brown color while all other bituminous materials are black.

Water-Mixing Test

If mixed with water, an emulsion will accept the extra water and still remain a uniform liquid. The sample and water will mix uniformly if the material is an emulsion. This test is positive since no other bituminous material will mix with water.

Flame Test

Since an emulsion contains water, a small piece of cloth saturated with it will not burn if a flame is applied. The other bitumens will burn or flame.

Stone-Coating Test

After establishing that the material is an emulsion, determine whether the emulsion is a mixing grade (MS or SS) or a nonmixing grade (RS). Mix a small amount (6 to 8 percent by weight) with damp sand using a metal spoon. Exercise care not to add so much emulsion to the sand as to saturate it. An RS emulsion will break so quickly it will not be possible to mix it with sand. It breaks immediately, gumming up the spoon with the relatively hard original asphalt cement. On the other hand, if the sample is a MS or SS emulsion, the material will mix easily and coat all the particles completely (as well as the mixing spoon) with a uniform coating of asphalt.

ROAD-TAR TESTS

There are three tests for road tars—the solubility test, the pour test, and the smear test.

Solubility Test

As determined earlier, if the unknown bituminous material does not dissolve during the solubility test but forms a stringy mass, the material is a tar (see *Figure 3-5, page 3-15*). The next step is to determine its viscosity grade.

Pour Test

By comparing the flow of the material to that of common materials (see *Figure 3-3, page 3-6*), the viscosity of the tar may be closely estimated. The grades run from RT-1 to RT-12 and vary in consistency from very fluid to solid.

Smear Test

If, during the pour test, the identified tar seems to be in the range of an RT-4 to RT-7 material, perform a smear test to determine whether it is a road tar or

an RTCB. Perform the smear test in the manner previously described for cutback asphalt. The material is a road tar if the material remains with the same amount of stickiness. If it shows a great increase in stickiness in 10 minutes, it is an RTCB. If field identification yields a grade of about 5 or 6, it is not of particular importance specifically which grade of cutback it is since both are used under approximately the same conditions.

AGGREGATE IDENTIFICATION AND SELECTION

Identify the aggregate by shape or roughness, hardness, cleanliness, hydrophobicity, gradation, and particle size. Select aggregate with the best combination of these characteristics. Also consider the availability, length of haul, and overburden.

SHAPE AND ROUGHNESS

The aggregate in a pavement must transmit the traffic load to the base, usually by the interlocking of the particles. This interlocking is much more pronounced when the particles are angular in shape and rough in surface texture. If angular pieces of aggregate are in a pavement, the individual particles will not slip or slide over one another, but will lock together. However, more binder may be required since the angular shape has a greater surface area per unit volume than a round particle. Although angular particles are desired, the aggregate should not contain an excessive number of flat or elongated particles, as these particles cause bridging, thereby making compaction difficult.

Aggregates very seldom occur in nature as angular, so it is necessary in most cases to crush the aggregate to obtain the desired angular particles.

HARDNESS AND DURABILITY

The aggregate must be able to withstand the applied loads without cracking or being crushed. Resistance to weathering is also a function of the durability. An aggregate's resistance to wear can be determined by the Los Angeles abrasion test. The Mohs hardness scale may be used to determine the hardness of the aggregate. This scale is fully explained in FM 5-410. It ranges from 1 for talc or mica to 10 for diamond. By trying to scratch the aggregate or the common material, it is possible to establish which is harder; this determines the hardness of the aggregate. If both are scratched, the hardness of both is the same. Rub the scratch mark to see that it is really a scratch and not a powdering of the softer material. Some common materials and their approximate level of hardness are as follows:

- Fingernail—2.0.
- Copper coin—3.5.
- Knife blade—5. 0.
- Window glass—5.5.
- Steel file—6.5.

CLEANLINESS

The bituminous binder must penetrate into the pores of the aggregate and also adhere to the surface of the particles. Aggregates coated with clay or dust or having water-filled pores prevent the penetration or the adherence of bitumen and result in stripping of the binder. If the aggregate is not clean, it should be washed, either as part of the crushing operation or by spreading it on a hard surface and hosing it with water. When washing is impractical, dry screening may remove a great deal of dust and clay. Handpicking may have to be done if no other method can be used. The aggregate should be made as clean as possible with the equipment and manpower available.

HYDROPHOBICITY

Affinity for water can make an aggregate undesirable. If the aggregate is porous and absorbs water easily, the binder can be forced out of the pores, the bond between the aggregate and binder can weaken and break, and stripping can occur. Stripping is the loss of bituminous coating from the aggregate particles due to the action of water, leaving exposed aggregate surfaces. One of the following tests can be used to determine the detrimental effect of water on a bituminous mix:

- The stripping test.
- The swell test.
- The immersion-compression test.

Stripping Test (ASTM D 1664-80)

Prepare a test sample by coating a 100-gram aggregate sample with bituminous material at the right temperature for the grade of bitumen to be used. Spread the mixture in a loose, thin layer and air-cure it for 24 hours. Place a representative sample in a jar (no more than half full) and cover it with water. Close the jar tightly and allow it to stand 24 hours. At the end of 24 hours, vigorously shake the jar with the sample for 15 minutes. Make a visual examination to determine the percentage of exposed aggregate surface and report it as the percent of stripping.

Swell Test

Asphaltic mixtures containing fines of doubtful quality are sometimes measured for swell as a basis for judging the possible effects on a pavement. This test is more frequently used with dense-graded mixtures using emulsified and cutback asphalts. Compact a sample of the mix in a metal cylinder (usually 100 millimeters in diameter), and cool it to room temperature. Obtain a height measurement for the specimen. Place the specimen and mold in a pan of water, and mount a dial gauge above the sample in contact with the surface. Take an initial reading. Allow the specimen to soak for a specified period (usually 24 hours) or until there is no further swelling. Take another dial reading. The difference in readings, divided by the original height and expressed in percent, is the swell of the mixture. Experience has shown that bituminous pavement made with clear, sound stone; slag; or gravel aggregate and mineral filler produced from

limestone will show test values of swell of less than 1.5 percent of the original specimen thickness.

Immersion-Compression Test (ASTM D 1075-88)

This test is intended to measure the loss of Marshall stability resulting from the action of water on compacted bituminous mixtures containing penetration-grade asphalt. The result is a numerical index of reduced stability obtained by comparing the Marshall stability with the stability of specimens that have been immersed in water for a prescribed period. Prepare six standard Marshall specimens (4 inches in diameter and 2 1/2 ± 1/16 inches high) for each test. Determine the specific gravity of each specimen. Separate the set of eight into two sets of four so that the average specific gravity of one set is essentially the same as the other. Test one set using the Marshall method. Immerse the other set in water (at 140°F ± 1°) for 24 hours and then test it. Compute the result as a ratio of soaked stability to unsoaked stability, and express it as a percentage as follows:

$$index\ or\ reduced\ stability\ = \frac{S_2}{S_1} \times 100$$

where—

S_1 = *average stability of unsoaked specimens*

S_2 = *average stability of soaked specimens*

Mixes with an index of less than 75 percent are rejected or an approved method of processing aggregate and treating asphalt is required to increase the index to a minimum of 75 percent.

GRADATION

The following designations help identify aggregates:

- Uniform gradation occurs when all particles are about the same size, normally less than 1 inch.
- Macadam gradation consists of uniformly sized particles except that they are in excess of 1 inch.
- Open gradation involves a considerable range of particle size, from large to small, usually containing little or no mineral filler. The void spaces in the compacted aggregate are relatively large.
- Dense gradation occurs when there is a good representation of all particle sizes and coarse, fine, and mineral fillers.

PARTICLE SIZE

In bituminous construction, it is common practice to designate aggregates according to particle size. There are three types of designations under this system, based on two sieve sizes—No. 4 and No. 200.

- Coarse aggregate is all material too large to pass the No. 4 sieve (see ASTM D 692-88).

- Fine aggregate passes the No. 4 sieve but is retained on the No. 200 sieve. In bituminous paving, the fine aggregate is usually a sand, but small pieces of crushed rock may be used (see ASTM D 1073-88).
- Mineral filler or mineral dust refers to all nonplastic materials which pass the No. 200 sieve. Most clays are too plastic and are not used. Generally, crushed rock dust, agricultural mineral filler, lime, or portland cement may be used as the mineral filler (see ASTM D 546-88).

SECTION IV. BITUMEN TESTING

The field-identification tests on bitumens identify the material during expedient conditions or until more detailed tests can be performed. The identification determines whether the material is an asphalt or a tar and whether it is a cutback or an emulsion.

Bituminous materials are manufactured to meet specifications established by the federal government, the AASHTO, and the ASTM. These specifications define the extreme limits permitted in the manufacture of the material and assure the user that the material will possess definite characteristics and fulfill the project requirements. Conforming to specifications tests includes determining the material's specific gravity, solubility, analysis by distillation, and softening point. The equipment for performing these tests is not included in the asphalt test set and is not normally available to the materials technician. However, these tests are described for information and, when the equipment is available, to identify the material beyond field identification, to furnish information for mix design, or to establish safe-handling procedures.

SPECIFIC-GRAVITY TEST (ASTMS C 127-88 AND C 128-93)

Specific gravity of a bituminous material is defined as the ratio of the weight of a given volume of the material at 77°F to the weight of an equal volume of distilled water at the same temperature. The results of a bitumen's specific-gravity test are used in the selection of the temperature-volume-weight correction factor to convert volumes to volume at 77°F. Space is provided on DD Form 1216 to make this determination (see *Figure 3-6*). Weigh an empty pycnometer (specific-gravity bottle), fill it with water, then reweigh. Empty the water from the bottle and add the bitumen. Weigh the pycnometer and bitumen. Add water to the same level as the start of the test and weigh the entire combination. Follow the procedure outlined on the form to compute the weight of water displaced by the bitumen and the bitumen's apparent specific gravity. The specific gravity of asphalt cements will usually be in the range of 1.00 to 1.06, with the higher values being characteristic of the harder materials. The specific gravity of an asphalt has little bearing on quality or other properties of the asphalt. However, the specific gravity is needed for other tests and computations. It is needed to adjust the specific gravity of the water bath in the ductility test. In acceptance and control testing on a job, it is used as a check on the uniformity of succeeding shipments of asphalt.

SPECIFIC GRAVITY OF BITUMINOUS MIX COMPONENTS

DATE: 2 APR 1997

PROJECT: HIGHWAY #203

JOB: No. 47236

COARSE AGGREGATE	UNITS (Grams)			
MATERIAL PASSING 1" SIEVE AND RETAINED ON #16 SIEVE				
SAMPLE NUMBER	CA			
1. WEIGHT OF OVEN - DRY AGGREGATE	378.3			
2. WEIGHT OF SATURATED AGGREGATE IN WATER	241.0			
3. DIFFERENCE (Line 1 minus 2)	137.3			
APPARENT SPECIFIC GRAVITY, G = (Line 1) / (Line 3)	378.3 / 137.3 = 2.755			
FINE AGGREGATE	UNITS (Grams)			
MATERIAL PASSING NUMBER ____ SIEVE				
SAMPLE NUMBER	FRBS			
4. WEIGHT OF OVEN - DRY MATERIAL	478.8			
5. WEIGHT OF FLASK FILLED WITH WATER AT 20°C	678.6			
6. SUM (Line 4 + 5)	1157.4			
7. WEIGHT OF FLASK + AGGREGATE + WATER AT 20°C	977.4			
8. DIFFERENCE (Line 6 minus 7)	180.0			
APPARENT SPECIFIC GRAVITY, G = (Line 4) / (Line 8)	478.8 / 180.0 = 2.660			
FILLER	UNITS (Grams)			
SAMPLE NUMBER	LSD			
9. WEIGHT OF OVEN - DRY MATERIAL	466.5			
10. WEIGHT OF FLASK FILLED WITH WATER AT 20°C	676.1			
11. SUM (Line 9 + 10)	1142.6			
12. WEIGHT OF FLASK + AGGREGATE + WATER AT 20°C	973.8			
13. DIFFERENCE (Line 11 minus 12)	168.8			
APPARENT SPECIFIC GRAVITY, G = (Line 9) / (Line 13)	466.5 / 168.8 = 2.762			
BINDER	UNITS (Grams)			
SAMPLE NUMBER	6873			
14. WEIGHT OF PYCNOMETER FILLED WITH WATER	61.9595			
15. WEIGHT OF EMPTY PYCNOMETER	37.9215			
16. WEIGHT OF WATER (Line 14 minus 15)	24.0380			
17. WEIGHT OF PYNOMETER + BINDER	47.8617			
18. WEIGHT OF BINDER (Line 17 minus 15)	9.9402			
19. WEIGHT OF PYCNOMETER + BINDER + WATER TO FILL PYCNOMETER	62.1568			
20. WEIGHT OF WATER TO FILL PYCNOMETER (Line 19 minus 17)	14.2951			
21. WEIGHT OF WATER DISPLACED BY BINDER (Line 16 minus 20)	9.7429			
APPARENT SPECIFIC GRAVITY, G = (Line 18) / (Line 21)	9.9402 / 9.7429 = 1.020			

SAMPLE

TECHNICIAN (Signature): SP4 Jones

COMPUTED BY (Signature): SSG Schmid

CHECKED BY (Signature): SGT. Allen

DD FORM 1216, DEC 65 — PREVIOUS EDITION OF THIS FORM IS OBSOLETE. — USAPPC V1.00

Figure 3-6. Sample DD Form 1216

FLASH-POINT AND FIRE-POINT TESTS

These tests are applicable to asphaltic materials and are of some use in identifying these materials. Their greatest usefulness, however, is in determining safe heating temperatures. Material heated above its flash point presents a real danger, particularly if it is exposed to an open flame.

FLASH POINT AND FIRE POINT BY CLEVELAND OPEN CUP

Perform this test on all petroleum products except fuel oils and those having open-cup flash points above 175°F.

Equipment

Use the following equipment for this test:

- The flash-point apparatus (see *Figure 3-7*).
- A knife.
- A frying pan or copper beaker.
- A hot plate.
- A stopwatch.

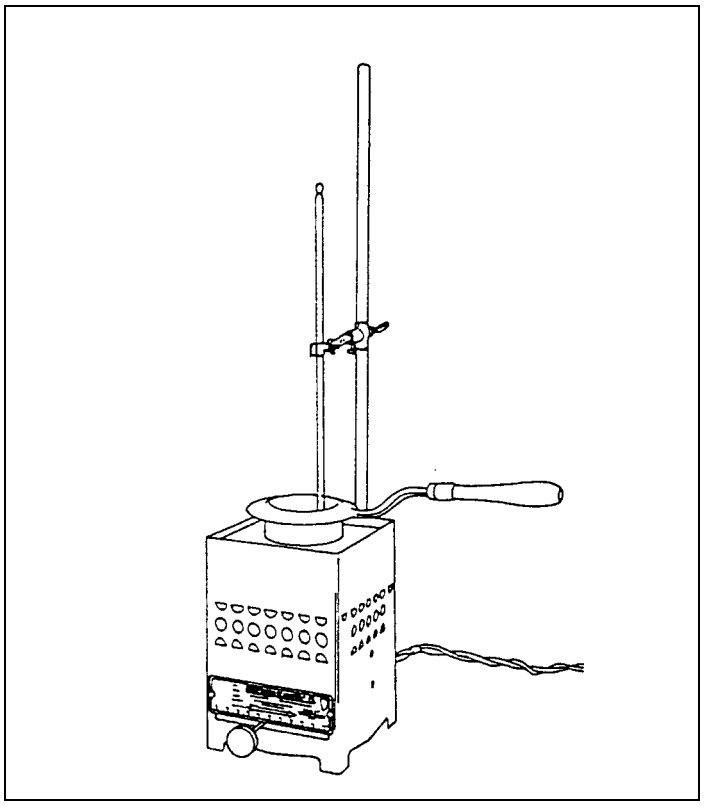


Figure 3-7. Flash-point apparatus; Cleveland open cup

Steps

Perform this test away from any bright light or shield the apparatus, if necessary. Clean the cup thoroughly before starting. Heat the bituminous material until it is fluid enough to pour into the cup. Do not move or disturb the cup and its contents within the last 30° before the expected flash point is reached. Prevent air movement or drafts across the specimen's surface.

Perform the following steps:

Step 1. Set up the open-cup apparatus.

Step 2. Adjust the thermometer in a vertical position, 1/4 inch above the bottom of the cup and about midway between the center and back of the cup.

Step 3. Fill the cup with the heated material until the top of the meniscus is exactly at the fill line. Let the material cool.

Step 4. Apply heat to the cup so the specimen's temperature is raised at a rate of 25° to 30° per minute until a temperature of about 100° below the probable flash point is reached.

Step 5. Reduce the heat and adjust it so that for the last 50° before the expected flash point the temperature rise will be not less than 9° and not more than 11° per minute. Use the stopwatch to regulate this rate. Failure to set the rate of rise between these limits will result in inaccurate readings.

Step 6. Adjust a test flame to 1/8 to 3/16 inch in diameter, the size of the comparison bead if one is mounted on the apparatus.

Step 7. Start at least 50° below the expected flash point and pass the test flame in a straight line across the center of the cup at right angles to the thermometer and level to the upper edge of the cup. The time for each pass should be no more than 1 second. Repeat the test-flame pass for each successive 5°. The flash point is reached when a flash (distinct flicker) appears at any point on the surface of the material. Read the thermometer at this time and record the temperature as the flash point.

Step 8. Continue heating at the same rate and applying the test flame at the same interval until the oil ignites and continues to burn for at least 5 seconds. Record the temperature at this point as the fire point.

Results

Duplicate tests on the same material by the same operator should not differ by more than 15°. Results by different laboratories should be considered suspect if the flash points differ by more than 30° and the fire points differ by more than 25°.

FLASH POINT BY TAG OPEN CUP (ASTM D 4552-87)

Perform this test on RC- and MC-asphalt cutbacks having a flash point below 200°F.

Equipment

Use the following equipment for this test:

- A flash-point tester.
- A tag open cup (see *Figure 3-8).*
- A hot plate.
- A thermometer (20° to 230°F in 1° divisions).
- A torch or test flame.

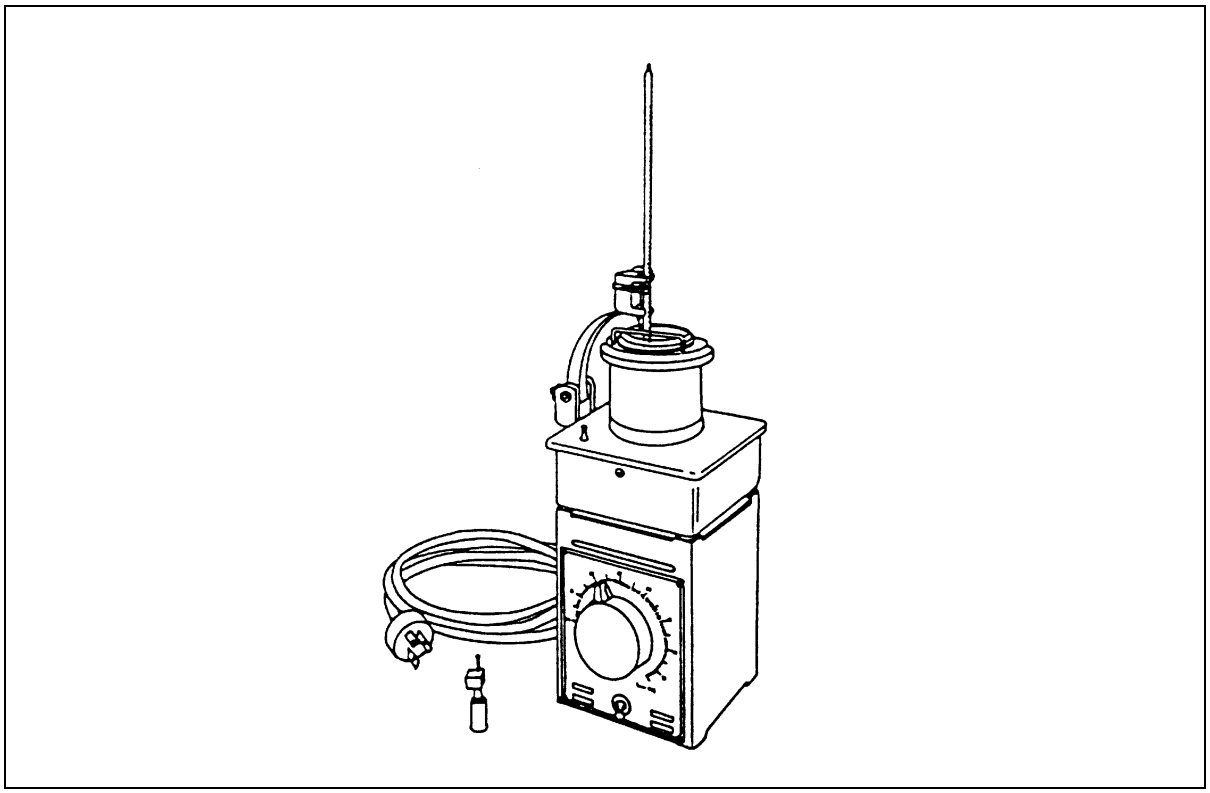


Figure 3-8. Flash-point apparatus; tag open cup

Steps

Set up the tester in a draft-free and dimly-lit location. Fill the copper water bath to 1/8 inch below the top of the glass cup (when the top is in place). The bath may have an overflow to control the water level. Clean and dry the glass cup and assemble the water bath. Perform the following steps:

Step 1. Place the thermometer vertically midway between the center and the outer edge of the cup and diametrically across from the guide wire. Set the bottom of the bulb about 1/4 inch above the bottom of the glass cup.

Step 2. Fill the glass cup with the sample to 5/16 inch below the edge.

Step 3. Place the guide wire in position, touching the rim of the glass cup.

Step 4. Adjust the heat for the sample temperature to rise at 2° ± 1/2° per minute. Stir thicker material occasionally.

Step 5. Adjust the test flame to not greater than 5/32 inch in diameter, the size of the comparison bead if one is mounted on the apparatus. (Some instruments have a 5/32-inch hole in comparison instead of the bead.)

Step 6. Remove any bubbles that may have formed on the surface before starting the flame test.

Step 7. Pass the flame at successive 2° intervals; pass the flame across the sample in a continuous motion, making each pass last 1 second.

Step 8. Record as the flash point the temperature at the time the test-flame application causes a distinct flash in the interior of the cup.

Step 9. Repeat the test using a fresh sample and starting at least 20° below the previously determined flash point.

Results

The results of two properly conducted tests by the same operator on the same asphalt should not differ by more than 18°F. The results of two properly conducted tests from two different samples of the same asphalt should not differ by more than 27°F.

PENETRATION TEST (ASTM D 5-86)

The penetration test determines the grade of an asphalt cement. Penetration is defined as the distance that a standard needle vertically penetrates a sample of the material under standard conditions of time (5 seconds), temperature (77°F), and loading (100 grams). The units of penetration are hundredths of a centimeter. Other conditions of temperature, load, and time that are used for special testing are given.

EQUIPMENT

Use the following equipment for this test:

- A hot-water bath.
- A copper beaker or frying pan.
- A stainless-steel box.
- An electric hot plate.
- A sieve pan, 8-inch diameter.
- An asphalt-testing penetrometer (see *Figure 3-9, page 3-28*).
- A thermometer (66° to 80°F).
- A stopwatch.

STEPS

The described test depends on the water bath being maintained as closely as possible to the standard temperature of 77°F. Since the penetration of an asphalt cement varies with temperature, maintain the bath at 77°F. If this is

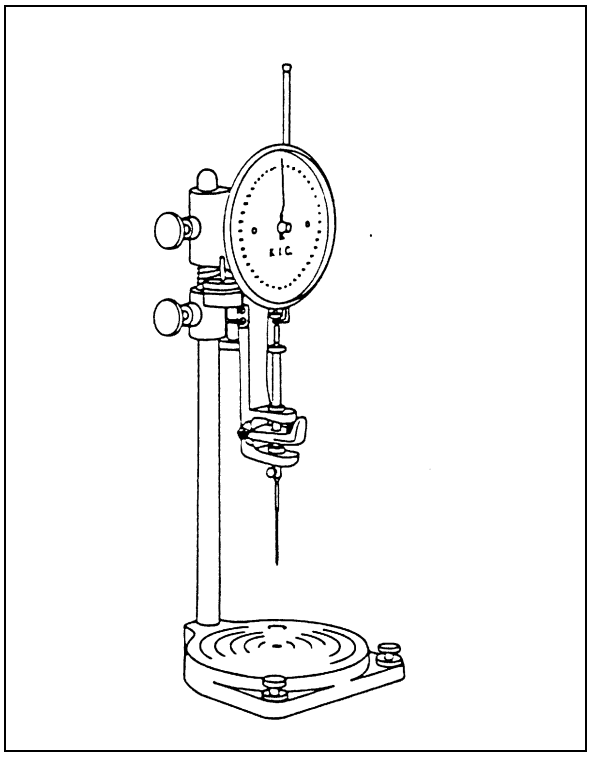


Figure 3-9. Asphalt penetrometer

impractical or less accuracy is acceptable, perform the test with the sample at room temperature. Perform the following steps:

Step 1. Melt the sample at the lowest possible temperature, using the electric hot plate and frying pan or copper beaker. Stir thoroughly until the sample is homogeneous and free of air bubbles.

Step 2. Pour the sample into the sample container (moisture-content box) to a depth of not less than 1.38 inch for the harder grades and 1.77 inch for the softer grades. Protect the sample from dust and allow it to cool in an atmosphere not lower than 65°F for 1 hour.

Step 3. Place the sample in its container in the sieve pan (or any other small, flat-bottomed pan or container that is 2 inches deep). Immerse the pan and sample for 1 hour in the water bath maintained at 77°F.

Step 4. Keep the sample in the pan filled with water from the water bath. The water should completely cover the sample container to maintain the temperature during the test. Place the transfer dish containing the sample in its container and the water on the stand of the penetrometer.

Step 5. Adjust the needle to make contact with the sample's surface of the sample. Place a light in a position so that the actual needle point and its image reflected on the specimen's surface are clearly defined. Contact may be judged with the point and its image touch on the surface.

Step 6. Note the reading of the dial or bring the indicator on the dial to zero.

Step 7. Release the needle for a period of 5 seconds. Read the distance penetrated on the thermometer. The needle and plunger are designed to have a standard weight of 100 grams. The dial is divided into 38 major divisions, each marked in 10 smaller subdivisions. Each of the smaller subdivisions represents a penetration by the needle of 1/100 centimeter. Thus, readings on the dial give penetration values without conversion.

Step 8. Test at least three points on the surface not less than 3/8 inch from the side of the container and not less than 3/8 inch apart. After each test, return the sample and pan to the water bath and carefully wipe the needle toward its point with a clean, dry cloth to remove all adhering asphalt.

RESULTS

The reported penetration is the average of at least three tests whose values do not differ by more than amounts shown in *Table 3-5*.

The penetration test, as pointed out previously, is used to classify asphalt cements for purchasing and identifying purposes, but it has other uses as well. It can be used to detect overheating or prolonged heating of asphalts in storage tanks. Also, when an asphalt is extracted from a pavement, the penetration test affords a means of estimating how the asphalt has changed with time and weathering.

Table 3-5. Penetration results

Penetration	0 to 49	50 to 149	150 to 249	250
Maximum difference between highest and lowest determination	2	4	6	8

DUCTILITY TEST

In the ductility test, dumbbell-shaped specimens of asphalt are molded under standard conditions. The dumbbell-shaped specimens are conditioned in a water bath to standard temperature (usually 77°F) then extended at the rate of 5 centimeters per minute until the threads connecting the two ends break. The difference in centimeters between the final length at the break and the original length is the ductility.

The ductility test is helpful in estimating an asphalt's ability to resist cracking and raveling. High-ductility asphalts have greater flexibility and tenacity. Conversely, low-ductility asphalts are considered more likely to crack under heavy loads or severe changes in temperature. Ductility is affected by various factors, such as method of refining and consistency. Blown asphalts (asphalts that have been hardened by blowing air through them, which causes oxidation) have low ductility. This is one reason why they are not used as paving asphalts. Within the group of asphalts produced by steam and vacuum distillation, ductility will vary according to the consistency at a given temperature. Note that the ductility test is also sensitive to other factors, such as imperfections in the specimens or impurities such as mineral filler in a sample of asphalt recovered from a pavement.

SOFTENING-POINT TEST

For the softening-point test, position a 3/8-inch-diameter steel ball on a brass ring filled with asphalt. Place the assembly in the beaker containing freshly boiled, distilled water and heat it slowly. As the asphalt becomes warmer, it begins to soften, and the weight of the ball forces the asphalt out of the ring. Record the temperature at which the asphalt touches the bottom of the beaker as the softening point.

The softening point is another consistency test and varies inversely with the penetration test. Like the penetration test, the softening-point test can be used to determine changes in an asphalt due to excessively high or prolonged heating. An abnormal increase in the softening point is an indication of excessive heating. The softening-point test is used in studies on asphalts recovered from pavements after extended service to determine effects of aging. If an asphalt shows an unusual increase in softening point, considerable aging and hardening have occurred.

VISCOSITY TESTS

There are two viscosity tests for identifying the qualities of bitumen—the Saybolt-Furor test and the kinematic-viscosity test.

SAYBOLT-FUROR TEST (ASTM D 244-89)

This test measures the time, in seconds, required to pass 60 cubic centimeters of asphalt-emulsion material, at a given temperature, through a tube of standard dimensions. Its purpose is to determine the viscosity of the material from which the spraying temperatures are established for field application of the bitumen.

KINEMATIC-VISCOSITY TEST (ASTM D 2170-85)

This test, like the Saybolt-Furor test, measures the time that a given amount of liquid-asphalt material will flow through a tube of standard dimensions under rigidly controlled conditions of temperature and pressure (or vacuum). The test establishes the viscosity of the liquid and, when correlated with the specific gravity of the material at the same temperature, results in a numerical designation called kinematic viscosity. The units used for kinematic viscosity are stokes (square centimeters per second) or centistokes (1/100 stoke). The kinematic-viscosity test requires special laboratory equipment that is not available in the field.

SOLUBILITY TEST (ASTM D 2042-81)

The solubility of asphalt cement can be determined using trichloroethylene. Trichloroethylene is toxic; therefore, protective equipment (including a ventilator, protective goggles, and protective gloves) must be worn while using it. Trichloroethylene waste is a hazardous waste and must be disposed of as such. Consult your installation environmental office for further guidance as to safe handling and disposal of trichloroethylene.

Dissolve 2 grams of the sample in 100 milliliters of solvent. Pour the mixture into a tared Gooch crucible and wash it through. Dry and weigh the crucible. The increase in the crucible's weight is the portion of the sample that is insoluble in the solvent.

The solubility test is a quality-control test used in specifications to ensure getting an asphalt cement that is not contaminated with mineral matter or is not improperly refined.

SPOT TEST

The spot test (often called the Oliensis spot test) is a solubility test that takes advantage of the selective solvent action of certain hydrocarbons; usually standard naphtha is specified. The test is applicable only to petroleum asphalts and should not be applied to natural asphalts containing nonbituminous matter insoluble in xylene.

Dissolve a 2-gram sample of asphalt in 10 milliliters of naphtha. Thoroughly stir the mixture with a stirring rod. Place a drop of the asphalt and solvent on a piece of Whatman No. 50 filter paper. Examine the filter paper after 5 minutes. If the drop forms a yellowish-brown stain with a darker nucleus, the test is positive. If the stain is uniformly brown, the test is negative. In the latter case, stopper the sample and set it aside for 24 hours, then repeat the test. If the stain with the darker nucleus again develops, the test is positive and is so reported. A negative result is an indication that the asphalt sample is a homogeneous material. A positive result may indicate that the sample is not a homogeneous material. A negative result is regarded as favorable to the sample; a positive result is unfavorable and may be used to reject the asphalt.

Considerable importance is attached to the spot test by some asphalt technologists and paving engineers. It is relied on principally as a means of detecting a cracked asphalt, which is a nonhomogeneous material not regarded as a good paving asphalt. The test can also be used to detect an asphalt that has been overheated or coked. Overheating or coking can occur in storage tanks or when the asphalt is added to aggregate that is too hot. In such cases, the asphalt is no longer a homogeneous substance, and the spot test will often show a nonuniform (positive) stain.

THIN-FILM OVEN TEST (ASTM D 1754-87)

The thin-film oven test was developed to overcome the deficiencies of the standard loss-on-heating test. The test uses the same oven as the loss-on-heating test except for a modification of the rotating shelf. The test has the same period and temperature of heating (5 hours at 325°F). The significant difference is in the sample. Instead of the 50-gram sample in a 3-ounce ointment can, a 1/8-inch-thick layer of asphalt is poured into a wide, shallow, circular aluminum dish. The dish has a flat bottom and is 5 1/2 inches in diameter and 3/8 inch deep. Weigh the sample before and after the heating period and compute the loss in weight. A penetration or viscosity test may also be conducted on the sample after the heating period to evaluate changes in the asphalt.

SECTION V. AGGREGATE AND FILLER TESTING

The aggregate transmits the load, takes the abrasive wear of traffic, and provides a nonskid surface. Desired aggregate characteristics include angular shape, rough surface, hardness, and gradation. Some of these

characteristics (such as shape, surface, and cleanliness) are determined visually. Durability and hardness cannot be seen but require knowledge based either on experience or some form of abrasion testing. Rocks that soak up water will eventually reach the condition where the binder is forced from the surface pores and the cementing action breaks down. Gradation may be established to some extent by observation. However, the grain-size distribution (sieve) tests will define the particle sizes and amounts much more accurately.

In bituminous paving, the aggregate constitutes the bulk of the pavement. Common practice subdivides the bituminous aggregates into a coarse aggregate, a fine aggregate, and a mineral filler. The No. 10 sieve separates coarse from fine aggregate, and the No. 200 sieve size is the lower limit for fine aggregate. Usually 65 percent or more of the mineral filler will pass the No. 200 sieve. The distribution of the different sizes determines how many voids will remain and helps determine how much bitumen will be needed.

Bituminous pavement specifications define acceptable gradation limits. The bitumen content for the mix is then determined from the trial-mix properties that are defined in the specifications.

SIEVE ANALYSIS

A sieve analysis of the aggregates to be used in a paving mixture is required to determine the particle-size distribution.

MINERAL FILLER (ASTM D 242-85)

In bituminous paving, particles finer than the No. 200 sieve are referred to as a mineral filler. To measure the amount of filler in a selected sample, perform a washed sieve analysis using the No. 40 and No. 200 sieves. Discard the material that has passed the No. 200 sieve, then return the material on the sieves to the original washed sample, oven-dry it, and weigh it. The amount of mineral filler is computed as—

$$\textit{percent finer than No. 200} = \frac{\textit{original dry weight} - \textit{washed dry weight}}{\textit{original dry weight}} \times 100$$

FINE AND COARSE AGGREGATE (WASHED) (ASTMS D 1073-88, 448-86, AND 692-88)

When definite amounts or limits of coarse and fine aggregates are specified, the sieve analysis with prewashing must be made using suitable sieves. If no limits have been designated, select a range of sieves to give adequate information about gradation. Record the results on DD Form 1206 (see *Figure 2-39, page 2-74*) and plot them as a gradation curve on DD Form 1207 (see *Figure 2-42, page 2-78*). When testing aggregates, obtain a representative sample by quartering, if necessary. The minimum size of the sample depends on the maximum size of particles in the material (see *Table 3-6*).

SPECIFIC GRAVITY

The specific gravities of aggregates and mineral filler used in bituminous paving mixtures are required to compute the percent of air voids and percent of voids filled with bitumens. Apparent specific gravity used with aggregate blends showing water absorption of less than 2 1/2 percent is based on the apparent volume of the material, which does not include those port spaces in

Table 3-6. Aggregate sizes and weights

Approximate Aggregate Size	Approximate Dry Weight of Sample (in Grams)
Fine Aggregate	
At least 95 percent finer than No. 10*	100
At least 90 percent finer than No. 4 and more than 5 percent coarser than No. 10*	500
Coarse Aggregate	
3/8-inch maximum size	1,000
1/2-inch maximum size	2,000
3/4-inch maximum size	3,000
1-inch maximum size	4,000
1 1/2-inch maximum size	5,000
2-inch maximum size	8,000
2 1/2-inch maximum size	12,000
3-inch maximum size	18,000
3 1/2-inch maximum size	25,000
*** ASTM specifies Numbers 8, 16, 30, and 50 instead of Numbers 10, 40, and 60. Tests based on ASTM standards identify the appropriate sieve sizes.**	

the aggregate which are permeable to water. Bulk-impregnated specific gravity is used for aggregate blends with 2 1/2 percent or greater water absorption. The methods for determining absorption of aggregates are described in Chapter 4 of this manual.

APPARENT SPECIFIC GRAVITY OF COARSE AGGREGATE

Apparent specific gravity can be determined using the method described for apparent and bulk specific gravity, or it may be determined using the Dunagan apparatus furnished with the concrete test set. Additional information for course-aggregate testing can be found in ASTM C 127-88.

Equipment

Use the concrete test set to determine the apparent specific gravity. The test set includes—

- The Dunagan apparatus (see *Figure 3-10, page 3-34*).
- Sieves (2-, 1 1/2-, 1/2-, and 3/8-inch and Numbers 4, 10, 40, 60, 80, 100, and 200).
- Evaporating dishes.
- An electric oven.
- Pans.

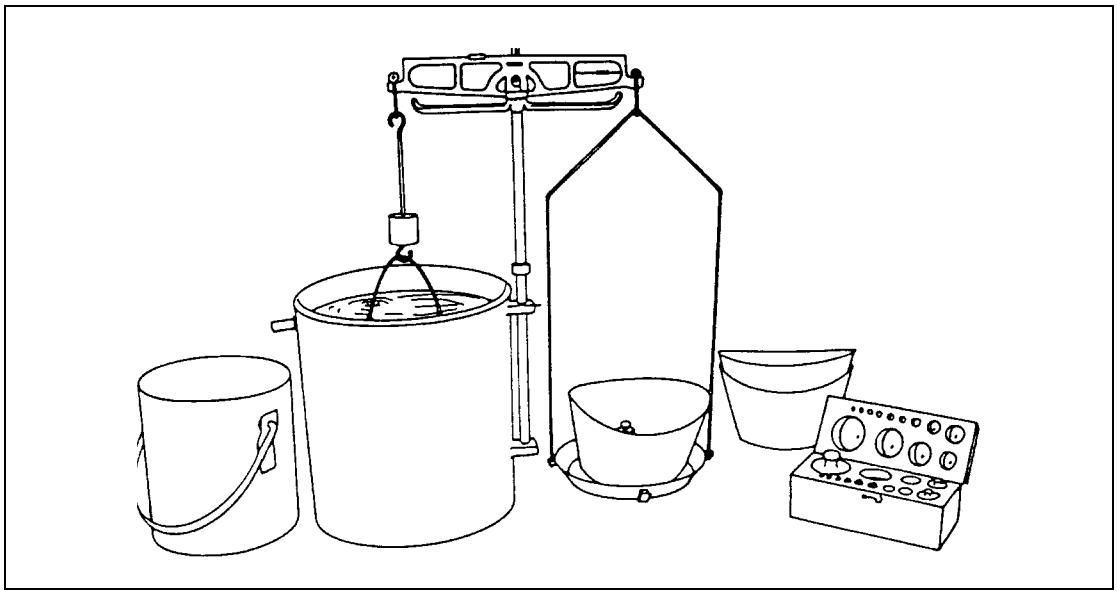


Figure 3-10. Specific-gravity test; Dunagan apparatus

Steps

Perform the following steps to determine the apparent specific gravity:

Step 1. Select about 5,000 grams of aggregate from the sample, not including particles smaller than the 3/8-inch sieve.

Step 2. Wash the aggregate to remove any dust or other coating and dry it to constant weight in the oven. Record the total weight of the oven-dry aggregate on DD Form 1216 (see *Figure 3-6, page 3-23*).

Step 3. Immerse the aggregate in water at 59° to 77°F for a period of 24 hours.

Step 4. Soak the sample and place it in a copper bucket filled with water. Turn the bucket and aggregate sharply back and forth to remove any air.

Step 5. Suspend the bucket from the brass hanger and bring the water level to the overflow pipe.

Step 6. Determine the submerged weight using weights placed in the scoop on the right-hand pan. Record the weight.

Calculations

The calculations required to determine the apparent specific gravity of coarse aggregate are shown on DD Form 1216 and are self-explanatory (see *Figure 3-6*).

APPARENT SPECIFIC GRAVITY OF FINE AGGREGATE (CALIBRATED FLASK)

Perform the procedure below to determine the apparent specific gravity when a calibrated flask is available.

Equipment

Use the following items (see *Figure 3-11*) to determine the apparent specific gravity of fine aggregate (calibrated flask):

- A balance; 2,000 grams, sensitive to 0.1 gram.
- An evaporating dish.
- A battery filler.
- A volumetric flask; 500-milliliter.
- An electric oven.
- A pan.
- A thermometer (0° to 300°F, in 1° gradations).
- An absorbent paper or cloth.

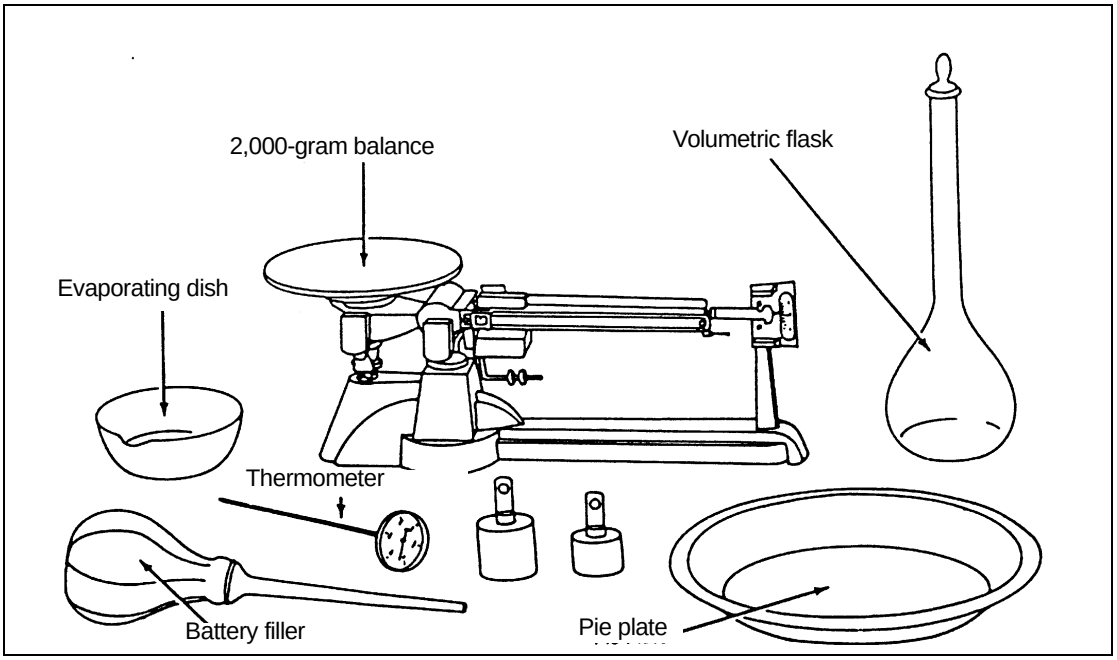


Figure 3-11. Calibrated-flask apparatus for determining apparent specific gravity of fine aggregate

Steps

Perform the following steps for particles finer than the No. 4 sieve (the data is recorded on DD Form 1208—see *Figure 2-36, page 2-65*):

Step 1. Calibrate a 500-milliliter volumetric flask.

Step 2. Dry a representative sample weighing about 500 grams to constant weight in the electric oven.

Step 3. Determine the oven-dry weight of the cooled sample and record in on DD Form 1208 (see *Figure 2-36)*.

Step 4. Transfer the sample to the 500-milliliter flask, being careful not to lose any of the material.

Step 5. Add clean water until the level just reaches the neck of the flask. Allow the sample to soak for 24 hours.

Step 6. Hold the flask containing the soaked sample by the neck, and roll it back and forth on a smooth surface until air bubbles stop coming from the sample (see *Figure 3-12*).

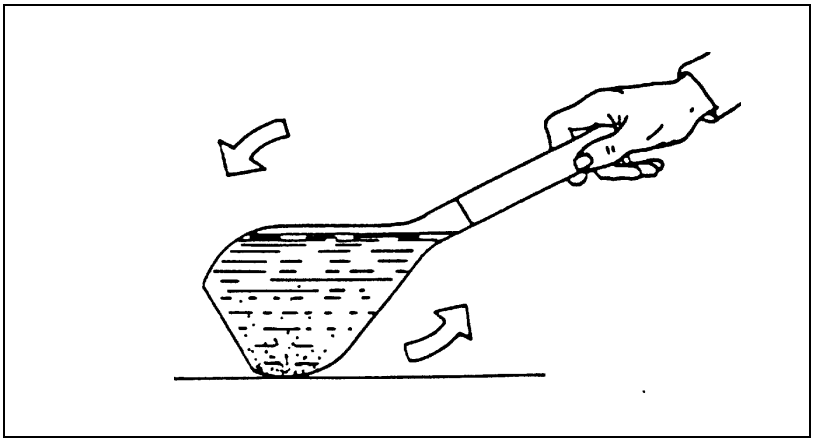


Figure 3-12. Manipulation of calibrated flask to remove air

Step 7. Use the battery filler to bring the water level up in the neck of the flask until the bottom of the meniscus coincides with the calibration mark on the flask. Use absorbent paper or cloth to remove any drops of water from the inside of the neck and on the outside of the flask.

Step 8. Determine the weight of the flask, aggregate, and water. Record the weight on DD Form 1208 (see *Figure 2-36, page 2-65*).

Step 9. Measure and record the temperature.

Calculations

The calculations for apparent specific gravity are the same as those indicated for soil in Figure 2-36.

APPARENT SPECIFIC GRAVITY OF FINE AGGREGATE (UNCALIBRATED FLASK)

Perform the procedure below to determine the apparent specific gravity when a calibrated flask is not available.

Equipment

Use the same equipment as for the calibrated-flask test, with the addition of a water bath maintained at 68°F. Do not use this procedure unless the temperature can be maintained.

Steps

Perform the following steps to determine the apparent specific gravity:

Step 1. Obtain a representative sample of aggregate passing the No. 4 sieve weighing about 500 grams. Dry it to constant weight in the electric oven maintained at a temperature of 230°F ± 9°.

Step 2. Obtain and record the dry weight after the sample has cooled in air.

Step 3. Transfer the sample to the flask, being careful not to lose any of the material.

Step 4. Add clean water until its level just reaches the neck of the flask. Allow the sample to soak for 24 hours.

Step 5. Roll the flask back and forth on a smooth surface until air bubbles stop coming from the sample (see *Figure 3-12*).

Step 6. Use the battery filler to bring the water level up in the neck of the flask to slightly above the calibrated mark.

Step 7. Place the flask with water and aggregate in the water bath maintained at a temperature of 68°F. Use the glass thermometer to check the temperature of the water in the flask from time to time.

Step 8. Bring the water in the flask to a uniform temperature of 68°F. Use the battery filler and absorbent paper to adjust the bottom of the meniscus to coincide with the calibration mark. Remove any drops of water inside the neck of the flask.

Step 9. Remove the flask from the bath and dry the outside thoroughly. Determine and record the weight of the flask plus the aggregate, plus the water at 68°F. It does not matter if the level of the water in the neck of the flask changes after removal from the bath. The proper adjustment was made at 68°F, and the total weight is not affected by the subsequent change in volume.

Step 10. Repeat the procedure in steps 6 through 9 above using water only. Enter the weight of the flask filled with water at 68°F on DD Form 1216 (see *Figure 3-6, page 3-23*). This needs to be done only once for a given flask; this value can be tabulated and used in subsequent tests. The weight of the flask filled only with water at 68°F must be known.

Calculations

Indicate the calculations necessary to determine the apparent specific gravity of fine aggregate using an uncalibrated flask on DD Form 1216 (see *Figure 3-6*).

SPECIFIC GRAVITY OF BULK-IMPREGNATED AGGREGATE

This test is used for determining the specific gravity of the blended aggregates (including filler) used in hot asphaltic mixtures. This method is to be used only when the water absorption for the entire blend of aggregate selected for the job-mix formula exceeds 2 1/2 percent. The method is not applicable to determine specific gravity of mineral filler except when included in the blended aggregate. See Military Standard (MIL-STD) 620A, method 105, for additional testing details.

Equipment

Use the following items to perform this test:

- The Dunagan apparatus.
- An electric oven (sensitive to ± 5° in the range of 275° to 325°F).
- Gallon-capacity pails.
- A balance; 5-kilogram capacity sensitive to 0.1 gram.
- Baking pans.
- A heavy sheet-metal strip for stirring the contents of the pail.
- A wire handle. **NOTE: A wire handle is convenient for handling the pail, but is not essential, since the container will be placed in the copper bucket of the Dunagan apparatus to determine the weight submerged in water. A No. 10 can (an empty fruit or vegetable can) with the top smoothly cut out is satisfactory, but care must be taken to eliminate air trapped under the bottom when the can is submerged.**

Samples should consist of 1,500 grams of blended aggregate (ensuring that the sample represents prototype grading) and 85 to 100 penetration-grade asphalt cement.

Steps

Perform the following steps to determine the specific gravity of bulk-impregnated aggregate:

Step 1. Dry the aggregate sample to constant weight at a temperature not less than 230°F nor greater than 290°F. After cooling the sample in air, weigh it to the nearest 0.1 gram.

Step 2. Heat the asphalt to 280°F ± 5°, using care to ensure that the temperature never exceeds 285°F. Add a sufficient amount to the 1-gallon pail to fill it about 1/3 full.

Step 3. Insert the sheet-metal stirrer and allow the pail and its contents to cool to room temperature. Allow 8 hours for cooling (preferably overnight).

Step 4. Weigh the pail plus the asphalt and stirrer in air at room temperature and submerged in water at 72°F ± 2°.

Step 5. Place the pail of asphalt with stirrer and also the sample of aggregate in an oven at 280°F ± 5° until temperatures of both are equalized. (A minimum of 4 hours is usually required.)

Step 6. Remove the aggregate and asphalt from the oven and gradually add aggregate to the asphalt, stirring thoroughly. After all of the aggregate is added, continue stirring until the total elapsed time from the start of mixing to the end of stirring is 2 minutes. During the cooling period, apply a flame to the surface to remove air bubbles. Cool the sample to room temperature (preferably overnight).

Step 7. Weigh the sample in air and in water at 72°F ± 2°.

Calculations

Calculate the bulk-impregnated specific gravity as follows:

$$\textit{bulk-impregnated specific gravity} = \frac{A}{(D-E)-(B-C)}$$

where—

A = weight of oven-dry aggregate, in grams

B = weight of pail + stirrer + asphalt in air, in grams

C = weight of pail + stirrer + asphalt in water, in grams

D = weight of pail + stirrer + asphalt + aggregate in air, in grams

E = weight of soil + stirrer + asphalt + aggregate in water, in grams

Duplicate determinations should check within 0.04 gram. If the values are within the 0.04 tolerance, use an average value. If the initial duplicate tests are not within the 0.04 tolerance, repeat the tests in duplicate. If the second set of test values is within the tolerance, discard the first two test values and use an average value of the second two tests.

SPECIFIC GRAVITY OF MINERAL FILLER

The specific gravity of mineral filler used in bituminous mixes is required for void computation. The methods described in the specific-gravity test apply (including procedures, calibration, testing, and calculations). Note that when the bulk-impregnated specific gravity is used, the mineral filler is included in the blended aggregate. Details can be found in ASTM D 854-92.

LOS ANGELES ABRASION TEST

The Los Angeles abrasion test requires a special machine consisting of a revolving drum rotated at the rate of 30 to 33 revolutions per minute (rpm) by an electric motor. Inside the drum is a shelf that picks up the aggregate sample along with a charge of steel balls and drops them together on the opposite side of the drum. Details can be found in ASTM C 131-89.

Conduct the test using various numbers of drum revolutions, sizes of samples, and numbers of steel balls, depending on the grading of the sample. For a sample that passes the 3/4-inch sieve and is retained on the 3/8-inch sieve, use 5,000 grams of material with 11 balls and 500 revolutions. Wash and dry the sample to constant weight before placing it in the machine. After the 500 revolutions are completed, remove the sample from the drum and sieve it over a No. 12 sieve. Wash, dry to constant weight, and weigh the portion retained on the No. 12 sieve. The difference between the original weight and the final weight of the sample is expressed as a percentage of the original weight of the sample

Job specifications usually require that the loss in weight as determined in the Los Angeles abrasion test shall not be greater than 40 percent for pavement aggregates and 50 percent for base and subbase aggregates.

SECTION VI. BITUMINOUS-MIX DESIGN

Hot-mix bituminous concrete for pavements is a mixture of blended aggregate filled with bituminous cement binder. The materials are heated when mixed so that the bitumen becomes fluid and thoroughly covers the aggregate particles. The design of a bituminous concrete mix is an economical blend and gradation of aggregates with bituminous cement. This produces a mixture that is durable, has the stability to withstand traffic loads, and is workable for placement and compaction with the construction equipment available.

The procedures described in this section are performed during the design of a hot-mix bituminous concrete. They include testing, plotting the results on graphs, and checking the readings against values from the design tables. Testing of the ingredients and the mix is started before and continued throughout the paving operations. FM 5-430-00-1 covers the design considerations in more detail. The paving operations and the blending and bitumen-content criteria are explained in TM 5-337. The testing phases are described in this manual.

The selection of the mix ratios of materials is tentative. The bitumen should be the same as the one used in the construction. The aggregates and fillers must meet definite requirements. In general, several blends should be considered for laboratory mix-design tests.

At times it will be necessary to shorten the design procedures to expedite military construction. Suggestions for expediting design mix are given at the end of this chapter. The final step is the preparation of a job-mix formula to be furnished to the construction unit.

HOT-MIX DESIGN CONSIDERATIONS

The objective of designing a hot mix is to determine the most economical blend of components that will produce a final product that meets specifications.

STEPS

Perform the following steps for determining the most economical blend of components:

Step 1. Prepare a sieve analysis of the aggregate available.

Step 2. Determine the aggregate blend that will achieve the specified gradation (see TM 5-337). Plot the selected blend proportions on a graph with the allowable limits to see that the blend conforms.

Step 3. Determine the specific gravity of the components

Step 4. Use selected percentages of bitumen (see TM 5-337), make trial mixes, and determine the mix's design test properties.

Step 5. Plot the test properties on individual graphs using the selected bitumen percentages. Draw smooth curves through the plotted points.

Step 6. Select the optimum bitumen content for each test property from the curves (as explained in the criteria tables).

Step 7. Average the bitumen content values from step 6 and from the graphs. Read the test-property value corresponding to this average.

Step 8. Check these values read in step 7 with the satisfactoriness-of-mix criteria.

VARIABLES

Gradation specifications are based on limits established as satisfactory by the Corps of Engineers. Within these limits, the following variables will affect the final mix design:

- The use of the mix (surface course, binder course, or road mix).
- The binder (asphalt, cement, or tar).
- Loading (low tire pressure [100 psi and under] or high tire pressure [over 100 psi]).
- The maximum size of the aggregate (in a stockpile or based on the thickness of the pavement course).

BLENDS

Once the gradation specifications have been selected, check the available materials to determine how to proportion the blend to meet these specifications. Study the sieve analysis of the available aggregates, and compute a series of trial blends. Make any necessary adjustments of the blend after testing the design and prepared mix. The considerations for establishing and adjusting the blend are explained in TM 5-337.

OPTIMUM BITUMEN CONTENT

The determination of optimum bitumen content is based on the gyratory test method or the Marshall test method.

GYRATORY TEST METHOD

The purposes of the gyratory test are to—

- Prepare specimens by kneading compaction at a pressure equal to the tire pressure for which the pavement is designed.
- Indicate optimum bitumen content directly by plasticity indicators called gyragraph recordings and by direct readings of shear resistance. The gyragraph recordings begin to widen, and the shearing resistance begins to decrease when the maximum permissible bitumen content is exceeded.
- Measure shear at the applied tire pressure which is used to calculate a shear-strength factor. This factor is used to predict whether the paving mixture will withstand the proposed tire-contact pressure.
- Obtain (by direct measurement) unit weight values required to minimize settlement under the design loads. Unit weight calculations are based on direct measurement of the sample height and the known sample diameter.

Definitions

The following terms are used for the gyratory test:

- Gyragraph. A recording of shear strain experienced by the bituminous mixture during the compaction test.
- Gyratory angle. A measure of the magnitude of the gyratory strain. Three pertinent angles are defined as follows:
  - — Initial gyratory angle or shear strain (machine setting) 0_o.
  - — Minimum gyratory angle or shear strain (minimum gyragraph band width) 0_1.
  - — Maximum gyratory angle or shear strain (maximum gyragraph band width) 0_{max}.
- Gyratory stability index (GSI). The ratio of the maximum gyratory angle to the minimum gyratory angle.
- Gyratory compactibility index (GCI). The ratio of the unit mass (total mix) at 30 revolutions of the gyratory testing machine (GTM) to the unit mass (total mix) at 60 revolutions of the GTM.
- Gyratory shear strength (S_G). The shear resistance of the specimen under the imposed loading conditions.
- Gyratory shear factor (GSF). The ratio of the measured gyratory shear strength to the approximate theoretical maximum induced shear stress.

Equipment

Use the following items to perform the gyratory test:

- A GTM and appurtenances (the primary equipment for this test).
- Spacer blocks. Two metal spacer blocks used to zero the equipment that measures the specimen height. They are 2 inches in diameter with one each of the following lengths: 2.50 $\pm$ 0.005 inches and 3.75 $\pm$ 0.005 inches.
- An oven, thermostatically controlled to maintain the required temperature within 5°.
- An electric hot plate.
- An electric mixer. A heavy-duty commercial food mixer complete with mixing bowl and beaters.
- Balances. Two balances are required, one having a capacity of 5 kilograms or more, sensitive to 1.0 gram; and one having a capacity of 2 kilograms or more, sensitive to 0.1 gram.
- Thermometers, armored glass or dial-type with metal stems are recommended. A range from 50° to 400°F with sensitivity to 5° is required.
- A metal beaker, about 1,000-milliliter capacity.

- Tongs for the beaker.
- A metal cooking pan, 12 inches in diameter.
- A kitchen scoop.
- Paper disks, 4 inches and 6 inches in diameter.
- Work gloves.
- Rags or paper towels.
- Kerosene (asphalt solvent).
- Creosote (tar solvent).

Steps

The gyratory method is applicable to mixtures containing asphalt cement, asphalt cutback, asphalt emulsion, tar or rubberized tar, and aggregate up to 1-inch maximum size in the 4-inch-diameter specimen and 1.5-inch maximum size in the 6-inch-diameter specimen. Perform the following procedures for the gyratory test:

Select the Bitumen Content

The bitumen content is expressed as a percent of the mixture's total weight. Using the procedures outlined in the following paragraphs, conduct preliminary tests with one specimen each at a minimum of three bitumen contents: one above, one below, and one at the estimated optimum. Once the range of bitumen contents for the design test has been selected, test at least four specimens at each of the selected bitumen contents. The formulas listed in the surface-area method may be used to make a rough estimate of optimum bitumen content. The GTM indicates excessive bitumen by the widening of the gyragraph and the reduction in upper-roller pressure during the compaction test. In these preliminary tests, bracket the optimum bitumen content by tests in which these phenomena occur at the higher bitumen contents.

The incremental change of the bitumen content should be generally 0.5 percent. For extremely critical mixes, lower the incremental change of bitumen content to 0.3 percent. For highly absorptive aggregate, increase the incremental change of bitumen content to 1.0 percent. The gyratory method does not use voids criteria to select the optimum bitumen content. However, the mix must be sufficiently dense (low in voids) to widen the gyragraph and reduce the roller pressure since these indicate overfilled voids. For this reason, the gyratory method selects mixtures with the most desirable durability properties, the maximum permissible bitumen content, and the minimum acceptable voids content.

Prepare the Aggregate

Procedures for determining particle-size distribution and blending to meet specification requirements have been discussed. The amount of aggregate required is discussed below.

Prepare the Mixture

For mixes employing penetration grades of bitumen, the temperature of the aggregate and asphalt at the time of mixing should correspond to the temperatures anticipated at the plant while manufacturing the paving mix. These temperatures will be in the range of 200°F for rubberized tar mixes.

For tar and rubberized tar, the temperature of the aggregate and the binder at the time of mixing should correspond to the temperature to be used at the plant during manufacture of the paving mix. This temperature will usually not exceed 225°F for tar mixes and 250°F for rubberized tar mixes.

For mixtures employing liquid asphalts (cutbacks or emulsions), the aggregate should be dried to the moisture content expected during construction (up to a maximum of 2 percent by dry weight). Combine the liquid asphalt with the aggregate at the temperature recommended for field application. Following mixing, cure the loose mixture in a ventilated oven maintained at 140°F ± 5° for at least 12 hours before compaction at this temperature. Occasionally stir the mix during curing to accelerate the loss of volatiles.

Combine the aggregates into batches large enough to make specimens about 2.50 inches long in the 4-inch-diameter mold and 3.75 inches long in the 6-inch-diameter mold. For normal aggregates, this will require about 1,200 grams for the 4-inch-diameter specimen and about 4,050 grams for the 6-inch-diameter specimen. Heat the aggregate to the proper mixing temperature, then weigh the required amount of bitumen at the proper temperature into the aggregate mixture. Mix the aggregate and bitumen as thoroughly and rapidly as possible. Mechanical mixing is recommended.

Perform the Compaction and Shear Test

For this test, set the initial gyratory angle, 0_o, at 1°. Roller positions 2 and 4 are used to set the initial gyratory angle, T. Use a trial batch of mix in making the 0_o adjustment. Ensure that the specimen molds are thoroughly clean and free of defects. Excessive wear or grooving in the molds in the area of contact with the upper and lower plates will have an adverse effect on the compaction as well as the gyragraph (shear strain) recording. (Instructions for the compaction temperatures for the laboratory specimens are presented above.) Set the GTM at 140°F at least 15 minutes before starting the compaction test. Preheat the mold and baseplate at 140°F. Place paper disks in the bottom of the mold and on top of the loose mix to prevent the bitumen from adhering to the end plates. Place the entire batch in the mold. Avoid hand troweling or tamping so that the compaction process will be completely controlled mechanically and will be the most precise and reproducible. Place the wall-friction yoke in position, then use the mold-carrying tray to load the mold containing the mixture into the machine. Raise the ram and use just enough pressure to retain the specimen while tightening the front of the mold chuck securely in position. When the mold chuck is securely tightened, increase the vertical pressure to the full compaction test pressure. Bring the gyragraph recorder pin into contact, actuate the roller carriage, and continue until 29 revolutions have been applied. After 29 revolutions, stop the carriage and record the specimen height and roller-pressure readings at three positions: 1, 3, and 4 (29 to 30 revolutions), thus completing 30 revolutions. Continue to apply additional revolutions until a total of 59 are reached. Again, record the

height and roller pressure readings at three positions: 1, 3, and 4 (59 to 60 revolutions), thus completing 60 revolutions.

Perform the Wall-Friction Test

Immediately following the compaction and shear test, lower the vertical ram slightly to relieve the pressure on the bottom roller. Lower the bottom roller enough turns to ensure that it will be out of contact with the mold chuck. (Keep account of the exact number of turns so that the roller can be reset to exactly the same position.) Reapply the compaction pressure to the ram, and cycle the roller carriage several times to level the specimen. With the compaction pressure still acting on the specimen, loosen the mold-chuck bolts and remove the front of the chuck so that the specimen mold is no longer restrained by the chuck. Install the two wall-friction apparatus jacks beneath the wall-friction yoke.

With the vertical load acting on the specimen, determine the force required to overcome wall friction and move the mold by observing the pressure gauge of the jack while actuating the jack. The pressure reading will increase with each thrust of the jack until there is enough force to move the mold. The pressure reading will then stabilize to about the same minimum value after each thrust of the jack. Record the low reading of the wall-friction gauge in the space provided. Remove the test specimen from the GTM immediately after the wall-friction test is completed, and bring the lower roller back to the 1° setting so that the machine is ready for the next test specimen.

Calibrate the Machine

When conducting shear tests with the GTM, it is necessary to make machine corrections for the gyratory shear value S_G. For this correction, shift the Mohr's diagram for test results on a cohesionless material enough to cause the envelope to pass through the origin of the Mohr's diagram. The cohesionless material used for this test is standard dry ottawa sand, all passing a No. 20 sieve and retained on a No. 40 sieve. A correction is needed for each combination of compaction pressure and gyratory angle used in the GTM compaction and shear tests. This correction is determined only once for any combination of vertical pressure and gyratory angle. The dry ottawa sand is first compacted under the same pressure, gyratory angle, and number of revolutions as scheduled for the compaction and shear tests on a given bituminous mixture. The shear test on the dry sand is then conducted for at least three different magnitudes of vertical pressure: starting at some lower value; including an intermediate value; and finally, using the same value that was used for compaction. The roller carriage is cycled once after each incremental adjustment in vertical pressure and before reading the upper roller values under that pressure.

Calculations and Presentation of Results

Perform the following calculations for the gyratory method:

Compaction Calculations

Calculate the following compaction properties for each specimen:

- Unit mass, total mix.

- Unit mass, aggregate only.
- GCI.

Shear Calculation

Calculate the following gyratory shear properties:

- GSI.
- Gyratory shear strength (S_G).
- GSF.

Graphical Presentation

For convenience of analysis, the calculations above are plotted against the bitumen content. The graphs may be to any convenient arithmetic scales.

Application of the Gyratory Method

The bitumen content must be as high as possible when using the gyratory method to select the optimum bitumen content and judge the satisfactoriness of the mix. The GSI must not be significantly greater than 1, and the GSF at this bitumen content must exceed 1.

MARSHALL TEST METHOD (ASTM D 1559-89)

The purposes of the Marshall test method are to—

- Prepare specimens by drop-hammer compaction. The number of drop-hammer blows used on the specimens is based on empirical correlations with two different traffic conditions: 50 blows on each end of the specimen for tires with less than 100-psi pressure and 75 blows on each end of the specimen for tires with greater than 100-psi pressure.
- Find the optimum bitumen content by averaging four measured properties: the peak of the compaction curve, the peak of the stability curve, the percent of the voids of the total mix at a specified amount, and the percent of the voids filled with bitumen at a specified amount. These values for total mix and bitumen vary with the aggregate's gradation, absorption properties, and compaction effort. There are ten separate sets of criteria to cover these variations. A special exception is made to use only voids total mix when the overall average falls outside the voids total-mix limits. This occurs for open-graded mixes or highly porous aggregates. There are no standards for sand-asphalt mixes at 75-blow compaction.
- Measure maximum breaking load (stability) and corresponding deformation (flow) for specimens prepared according to the compaction procedure. These values of stability and flow are empirically correlated for conditions outlined in the paragraph above.
- Obtain the unit weights of specimens from calculations based on weighing the specimens in air and in water. Porous specimens are coated with paraffin before weighing them in water.

Equipment

Use the following items to perform the Marshall test (see *Figure 3-13*):

- A mixing pan.
- A hot plate.

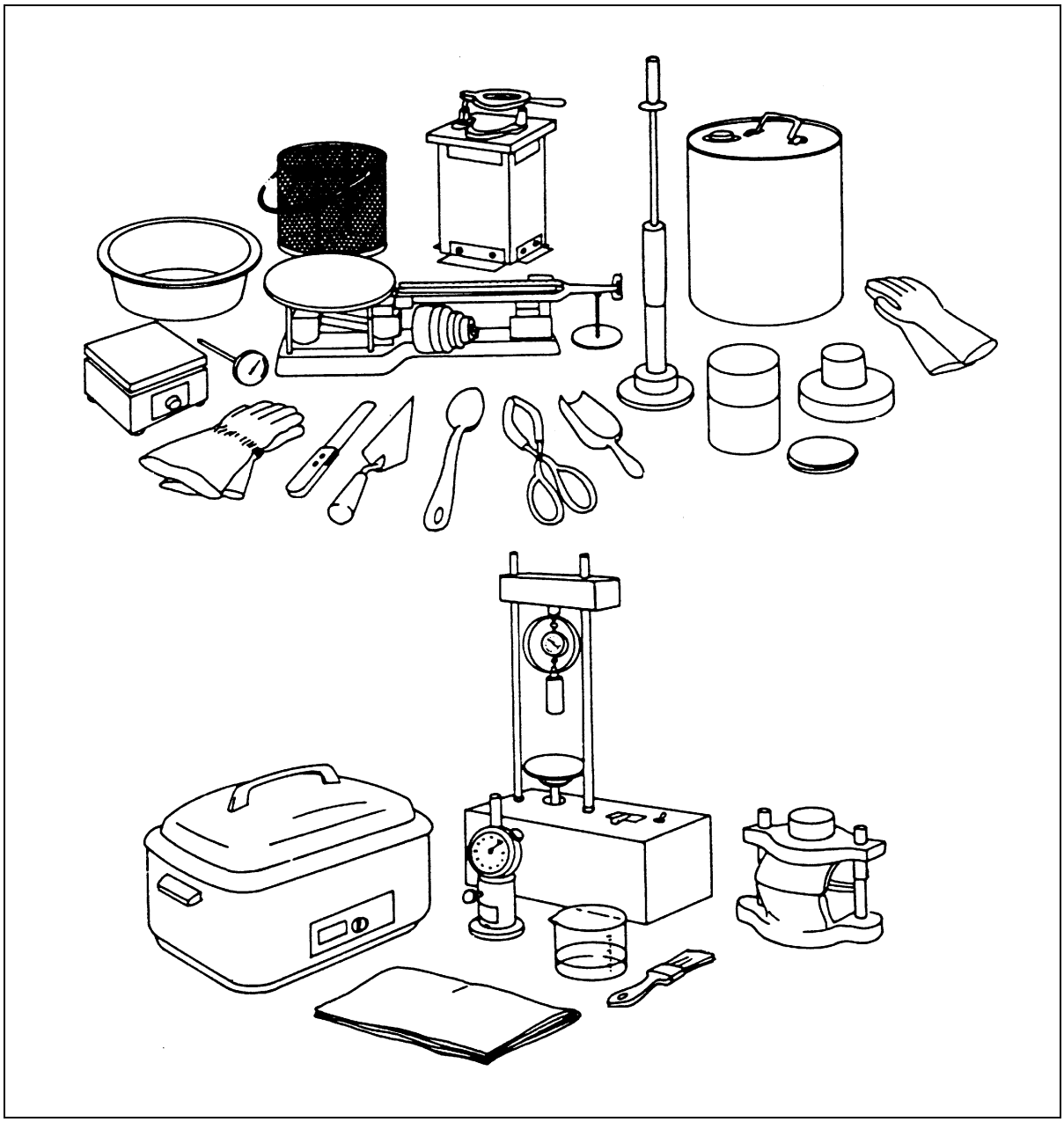


Figure 3-13. Apparatus for bituminous mix design—Marshall method

- Insulated gloves.
- A laboratory spatula.
- A trowel.
- A spoon.
- Insulated tongs.
- A scoop.
- A compaction hammer.
- A compaction mold.
- An extractor.
- Chemical-resistant gloves.
- Trichloroethane technical.
- A holder, compaction mold.
- A compaction pedestal.
- A triple-beam scale.
- A wire basket.
- A thermometer.
- A hot-water bath.
- A Marshall stability-testing machine.
- A flow indicator.
- Lab towels.
- A beaker with oil.
- A brush.
- A stability mold.

Steps

The Marshall method is applicable to hot-mix mixtures using penetration grades of asphalt cement and containing aggregate with not more than 10 percent of the aggregate larger than the 1-inch sieve. The procedure for handling large aggregate as well as for cold mix is described later. Use the following procedure and example to determine the optimum asphalt content for one particular blend of aggregates:

Select the Bitumen Content

Start the laboratory tests by estimating the optimum amount of bitumen for the aggregate to be tested. Continue the tests until results show at least two bitumen contents above and two below what would be the optimum content. Since the optimum is not determined until after the results are plotted, specimens are usually prepared for each of six different contents. Prepare at least three specimens at each bitumen content. You may use 1 percent incremental changes of bitumen content for preliminary work. However, use

increments of 1/2 or 1 percent for final tests. Express the percent of bitumen as a percent of the total weight of the batch of paving mix. The procedure for establishing the estimated optimum content is explained in TM 5-337.

Prepare the Aggregate

Procedures for determining the particle-size distribution and blending to meet specification requirements have already been presented. Dry 50 pounds of the selected blend to constant weight at 221° to 230°F. This amount of material provides for 1,220 grams per specimen for 18 specimens (three in each of six bitumen contents) with allowance for some loss. The Marshall method uses a 4-inch-diameter mold and is not applicable, without special handling, when more than 10 percent of the aggregate is larger than 1 inch. The previously given total amounts of aggregate required assume less than 10 percent of the particle will exceed 1 inch. (Special handling of oversize aggregates is covered later.)

Prepare the Hot Mixture

Heat the bitumen and the aggregates to specified temperatures for mixing. These temperatures are based on the bitumen that will be used (see *Table 3-7*). Bitumen should not be held at the mixing temperature for more than 1 hour before using. Therefore, plan the preparation so that the mixing will be done within this time limit. Preheat the mixing pans to a temperature about 50° above the mixing temperature. Pour the heated dry aggregate fractions into the pans and mix thoroughly. Form a crater in the mixed aggregate, and pour the required amount of bitumen at the proper temperature into the crater. At this point, the temperature of the ingredients should be within the limits specified above. Mix the aggregates and bitumen as rapid and as thorough as possible to ensure that the bitumen is uniformly distributed throughout the aggregate.

Table 3-7. Temperatures for mixing bitumens and aggregates

Bitumen Type	Mixing Temperature (°F)	
	Aggregate	Bitumen
Asphalt cement	300 ± 5	270 ± 5
Tar (RT-10, -11, or -12)	225 ± 5	200 ± 5
Rubberized tar	250 ± 5	225 ± 5

Compact the Hot Mixture

Prepare three specimens at each bitumen content, and prepare the molds to receive the specimens as soon as they are mixed. Thoroughly clean and heat the striking face of the compaction hammers and the compaction molds to 200° to 300°F. Oil the mold and other metal in contact with the mix before the mixture is introduced to facilitate removing the specimen after compaction. A silicone spray is convenient for this use. Wipe the parts with a rag or paper towel before using. Place the mix in the mold (rodding the material as it is added). Remove the collar and, with a trowel, smooth the top surface of the mix to a slightly rounded shape. The thickness of the compacted specimen should be 2.5 ± .05 inches. One or two trials will indicate the quantity of mix required to produce such a specimen. Replace the collar and place the mold

assembly on the compaction pedestal. The temperature at this point must be as specified in *Table 3-8* for compaction.

Table 3-8. Temperatures for compacting bitumens and aggregates

Bitumen Type	Compaction Temperature (°F)
Asphalt cement	300 ± 5
Tar (RT-10, -11, or -12)	225 ± 5
Rubberized tar	250 ± 5

Apply the required number of blows with the compaction hammer (see *Figure 3-14*). Remove the baseplate and collar, and reverse and reassemble the mold. Apply the required number of blows to the other side of the specimen. For example, roads, streets, and facilities for an airfield designed for aircraft whose tires carry 100 psi or less should be compacted by 50 blows on each end of the specimen. If the pavement is being designed for aircraft which carry tires with pressure greater than 100 psi, the compactive effort should be 75 blows per side.

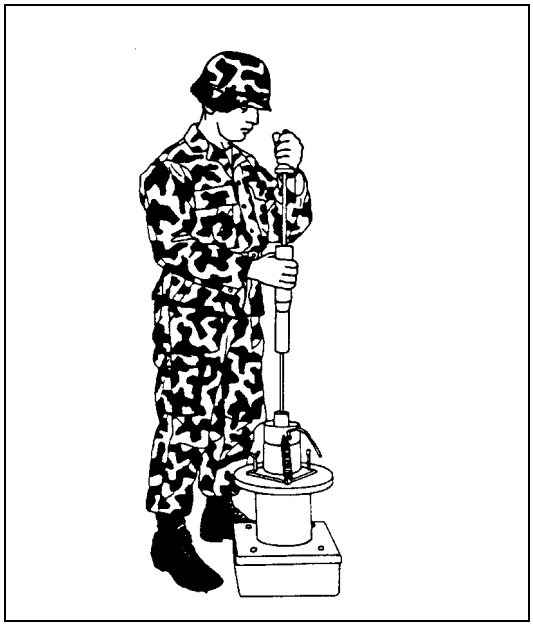


Figure 3-14. Compaction of bituminous trial-mix specimens

Cool the Hot Specimen

After compacting, remove the baseplate and collar, and either air cool the mold and specimen (normally overnight) or place them in cold water for a minimum of 2 minutes for fast cooling. Remove the cooled specimen from the mold with an extension jack or by placing the collar on the floor (with the mold and specimen on top) and forcing the specimen out with blows from the compaction hammer. The specimen is easier to remove if the mold is placed in a 140°F

oven for a few minutes just before ejecting the specimen. Place the specimen (carefully handled and suitably identified) on a smooth surface until it is ready for testing as described below.

Weigh the Specimen in Air and in Water

Weigh each specimen in air and in water to obtain the weight and volume measurements used in calculating the unit weight of the compacted mix (see *Figure 3-15*).

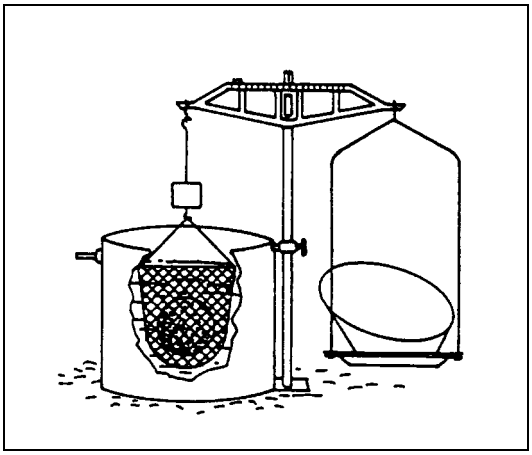


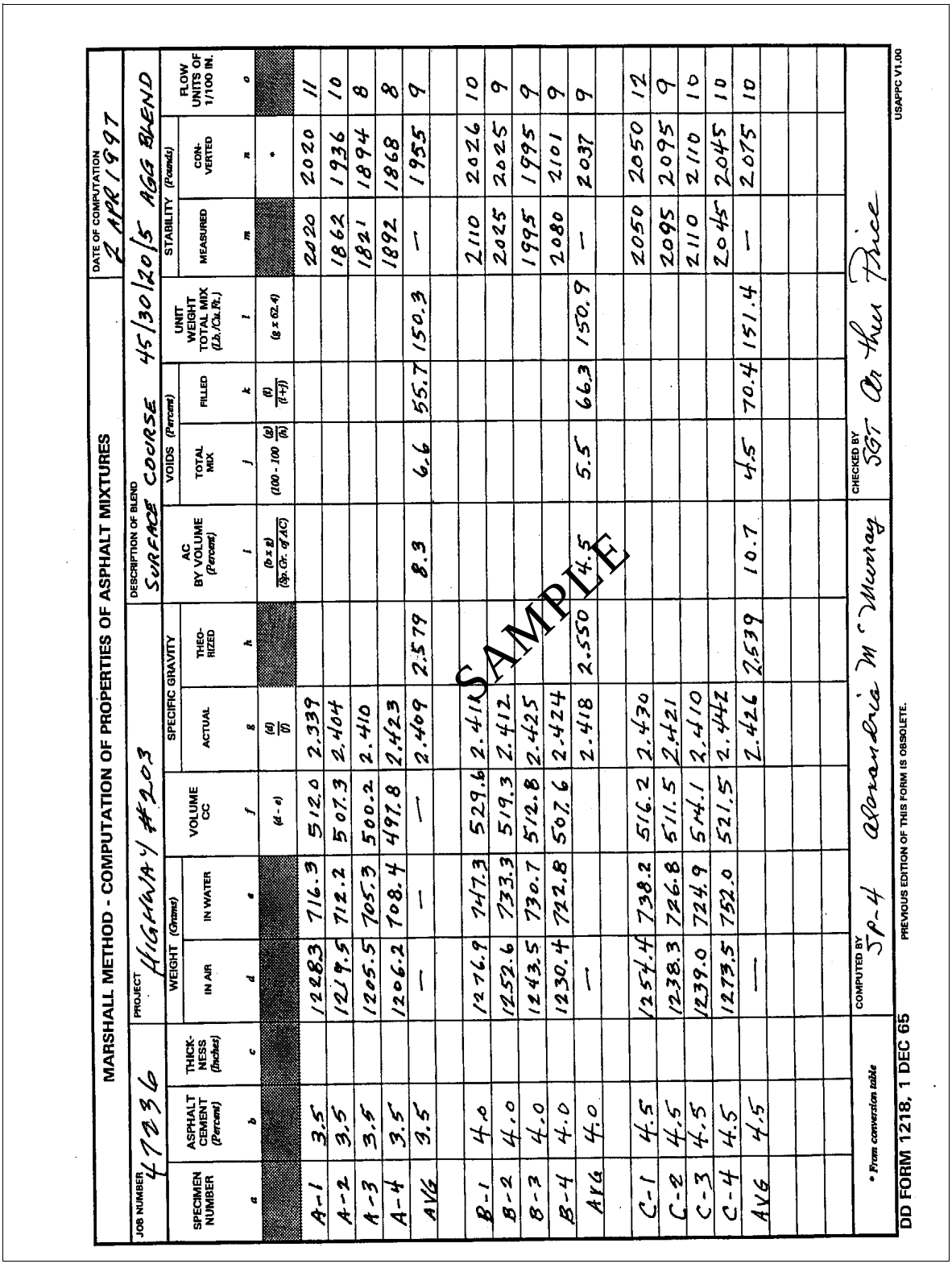
Figure 3-15. Weighing compacted bituminous specimen in water

DD Form 1218 provides space for recording those measurements made at room temperature (see *Figure 3-16, pages 3-52 and 3-53*). A direct weight in water of open-textured or porous specimens will give erroneous results because of water penetration and absorption. For such specimens, you must use other means to determine the volume. One means of measuring the volume of the porous specimens is to coat it with paraffin to seal all the voids and then weigh the coated specimens in air and in water.

Measure Stability and Flow

Bring the test specimens to the desired temperature for the test by immersing them in an oven for at least 2 hours. The bath temperature for asphalt samples is 140°F ± 1.8° and 100°F ± 1.8° for tar samples (RT-10 to RT-12). Record test measurements on DD Form 1218 (see *Figure 3-16*).

Clean the inside surfaces of the test heads and the guide rods thoroughly before performing the stability test, and lubricate the guide rods so the upper test head will slide easily over the guide rods on the lower test head. Remove the specimen from the water bath and place it on its side in the lower section of the breaking head. Position the upper section of the breaking head on the guide rods and on the specimen, then place the complete assembly in position in the testing machine (see *Figure 3-17, page 3-54*). To prevent excessive cooling of this specimen with a resulting increase in stability value, perform the entire procedure as quickly as possible (within 30 seconds) from the time the specimen is removed from the water bath.



MARSHALL METHOD - COMPUTATION OF PROPERTIES OF ASPHALT MIXTURES

DATE OF COMPUTATION: 2 APR 1997

JOB NUMBER: 47236 | PROJECT: HIGHWAY #203 | DESCRIPTION OF BLEND: SURFACE COURSE 45/30/20/5 AGG BLEND

SPECIMEN NUMBER	ASPHALT CEMENT (Percent)	THICKNESS (Inches)	WEIGHT (Grams) IN AIR	WEIGHT (Grams) IN WATER	VOLUME CC	SPECIFIC GRAVITY ACTUAL	SPECIFIC GRAVITY THEORIZED	AC BY VOLUME (Percent)	VOIDS (Percent) TOTAL MIX	VOIDS (Percent) FILLED	UNIT WEIGHT TOTAL MIX (Lb./Cu. Ft.)	STABILITY (Pounds) MEASURED	STABILITY (Pounds) CONVERTED	FLOW UNITS OF 1/100 IN.
a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
					(d - e)	(d) / (f)		(b x g) / (Sp. Gr. of AC)	(100 - 100 (g) / (h))	(f) / (7+j)	(g x 62.4)		•	
A-1	3.5		1228.3	716.3	512.0	2.399						2020	2020	11
A-2	3.5		1219.5	712.2	507.3	2.404						1862	1936	10
A-3	3.5		1205.5	705.3	500.2	2.410						1821	1894	8
A-4	3.5		1206.2	708.4	497.8	2.423						1892	1868	8
AVG	3.5		—	—	—	2.409	2.579	8.3	6.6	55.7	150.3	—	1955	9
B-1	4.0		1276.9	747.3	529.6	2.411						2110	2026	10
B-2	4.0		1252.6	733.3	519.3	2.412						2025	2025	9
B-3	4.0		1243.5	730.7	512.8	2.425						1995	1995	9
B-4	4.0		1230.4	722.8	507.6	2.424						2080	2101	9
AVG	4.0		—			2.418	2.550	4.5	5.5	66.3	150.9	—	2037	9
C-1	4.5		1254.4	738.2	516.2	2.430						2050	2050	12
C-2	4.5		1238.3	726.8	511.5	2.421						2095	2095	9
C-3	4.5		1239.0	724.9	514.1	2.410						2110	2110	10
C-4	4.5		1273.5	752.0	521.5	2.442						2045	2045	10
AVG	4.5		—			2.426	2.539	10.7	4.5	70.4	151.4	—	2075	10

SAMPLE

* From conversion table

COMPUTED BY: SP-4 Alexandria M Murray

CHECKED BY: SGT Arthur Price

DD FORM 1218, 1 DEC 65 PREVIOUS EDITION OF THIS FORM IS OBSOLETE. USAPPC V1.00

Figure 3-16. Sample DD Form 1218

MARSHALL METHOD - COMPUTATION OF PROPERTIES OF ASPHALT MIXTURES

DATE OF COMPUTATION: 3 APR 1997

JOB NUMBER | PROJECT | DESCRIPTION OF BLEND

SPECIMEN NUMBER	ASPHALT CEMENT (Percent)	THICK-NESS (Inches)	WEIGHT (Grams) IN AIR	WEIGHT (Grams) IN WATER	VOLUME CC	SPECIFIC GRAVITY ACTUAL	SPECIFIC GRAVITY THEO-RIZED	AC BY VOLUME (Percent)	VOIDS (Percent) TOTAL MIX	VOIDS (Percent) FILLED	UNIT WEIGHT TOTAL MIX (Lb./Cu.Ft.)	STABILITY (Pounds) MEASURED	STABILITY (Pounds) CON-VERTED	FLOW UNITS OF 1/100 IN.
a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
					(d - e)	(d) / (f)		(b x g) / (Sp. Gr. of AC)	(100 - 100 (g)/(h))	(i)/(i+j)	(g x 62.4)		*	
D-1	5.0		1237.9	727.0	510.9	2.423						1875	1875	14
D-2	5.0		1300.0	763.6	536.3	2.424						2130	1981	10
D-3	5.0		1273.6	746.9	526.7	2.418						1900	1824	12
D-4	5.0		1247.9	731.8	516.1	2.418						1855	1855	12
AVG	5.0		—			2.421	2.519	11.9	3.9	75.3	151.5	—	1884	12

SAMPLE

* From conversion table

COMPUTED BY: SP4 M C Marrero

CHECKED BY: SGT. Price

DD FORM 1218, 1 DEC 65 PREVIOUS EDITION OF THIS FORM IS OBSOLETE. USAPPC V1.00

Figure 3-16. Sample DD Form 1218 (continued)

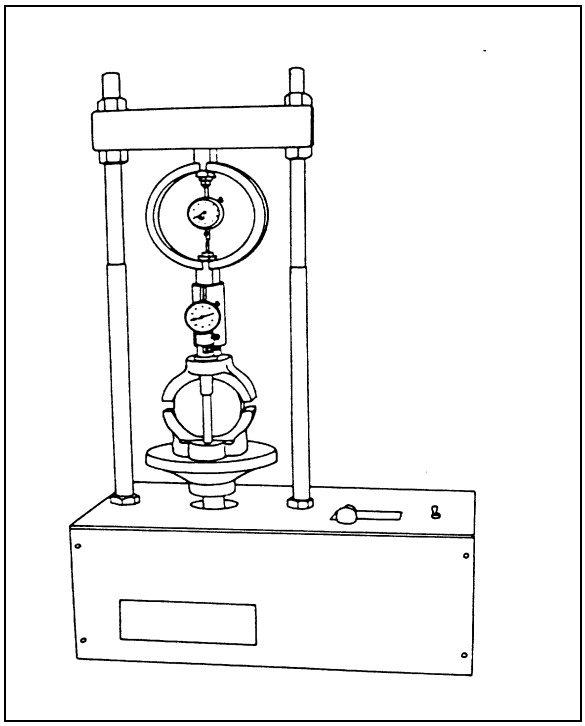


Figure 3-74. Stability-test assembly

Place the flowmeter over one of the guide rods and take an initial reading, estimated to 0.01 inch. Hold the flowmeter firmly over the guide rod while loading the specimen. Read or remove the flowmeter from its position over the guide rod just when the load first begins to decrease, as indicated by the dial gauge in the proving ring. DD Form 1218 provides space for recording the flow valve, which is the difference between the initial reading and the final reading (see *Figure 3-16, pages 3-52 and 3-53*).

Apply load to the specimen at a constant rate of strain of 2 inches per minute until specimen failure occurs. The load builds up on the typical test as movement occurs, until it reaches a maximum and falls off. The maximum reading of the dial, converted to pounds, is the stability value for the specimen. Record this reading on the form (see *Figure 3-16*).

Calculation and Presentation of Results

DD Form 1218 is used to summarize the measured and calculated Marshall test properties (see *Figure 3-16*). The specimen numbers—placed on each specimen with a marking crayon—are given for identification. Note that there are four duplicate tests for each bitumen content and that these four test values are averaged in each instance. Note also that the specimen's thickness is not indicated since the volume can be used to find the stability correlation ratio from *Table 3-9*. The theoretical specific gravity is transferred from DD Form 1218 to calculate the voids (see *Figure 3-16, pages 3-52 and 3-53*). Note that the stability value is shown directly in pounds. Unless the testing machine provides a load-measuring device that reads directly in pounds, it will be necessary to convert this value. Use the calibration factor

furnished with the ring dynamometer on the testing machine. The stability value varies directly with the specimen's thickness. Therefore, it is necessary to correct the stability values for specimens of a thickness greater or less than the standard 2 1/2 inches. *Table 3-9* shows the necessary conversion factors for specimens varying in thickness from 1 to 3 inches. *Table 3-9* also contains data whereby the stability conversion factor can be determined on the basis of the volume of the specimen, since the volume is a direct function of height for

Table 3-9. Stability correlation ratios, Marshall stability test

Volume of Specimen (in Cubic Centimeters)	Approximate Thickness of Specimen (in Inches)	Correlation Ratio
200 to 213	1	5.56
214 to 225	1 1/16	5.00
226 to 237	1 1/8	4.55
238 to 250	1 3/16	4.17
251 to 264	1 1/4	3.85
265 to 276	1 5/16	3.57
277 to 289	1 3/8	3.33
290 to 301	1 7/16	3.03
302 to 316	1 1/2	2.78
317 to 328	1 9/16	2.50
329 to 340	1 5/8	2.27
341 to 353	1 11/16	2.08
354 to 367	1 3/4	1.92
368 to 379	1 13/16	1.79
380 to 392	1 7/8	1.67
393 to 405	1 15/16	1.56
406 to 420	2	1.47
421 to 431	2 1/16	1.39
432 to 443	2 1/8	1.32
444 to 456	2 3/16	1.25
457 to 470	2 1/4	1.19
471 to 482	2 5/16	1.14
483 to 495	2 3/8	1.09
496 to 508	2 7/16	1.04
509 to 522	2 1/2	1.00
523 to 535	2 9/16	0.96
536 to 546	2 5/8	0.93
547 to 559	2 11/16	0.89
560 to 573	2 3/4	0.86
574 to 585	2 13/16	0.83
586 to 598	2 7/8	0.81
599 to 610	2 15/16	0.78
611 to 625	3	0.76

a constant 4-inch-diameter specimen. All other calculations are indicated directly on the form (see *Figure 3-16, pages 3-52 and 3-53*).

Graphical Presentation

The average Marshall test properties from the tabulation (see *Figure 3-16*) for each bitumen content are shown graphically on DD Form 1219 (see *Figure 3-18*). The average values for each property are plotted on their respective graphs using the bitumen content as ordinates. A smooth curve is drawn through the plotted points in each instance.

Application of the Marshall Test

Table 3-10, page 3-58, lists the criteria for determining the optimum bitumen content along with the Marshall specifications for a satisfactory mix. The optimum bitumen content is determined by averaging the bitumen content read from the curves in *Figure 3-18* at the four points indicated for determination of the optimum bitumen content in *Table 3-10*. Once this average bitumen content is obtained, the Marshall properties at this average are read from curves representing the mix, as in *Figure 3-18*. These values are compared with the specification limits in *Table 3-10* to evaluate the satisfactoriness of the mix. The exceptions allowed when the values obtained fail to conform with the specification limits given in the table are shown in notes at the bottom of *Table 3-10*.

Modified Marshall Test for Cold-Mix Pavement

This method is used as an aid in determining the asphalt content for cold-mix design of light-duty pavement. It can be used where asphalt cutbacks will be the binder. The procedure follows those used for hot-mix design in general, with the following modifications:

- Aggregates. These are dried to a moisture content expected during construction (up to a maximum of 2 percent by weight).
- Asphalt. The selected bitumen is mixed with the aggregates, but at the temperature recommended for field application. The aggregates remain at room temperature.
- Curing. Before compaction, the mixture is cured at least 12 hours in an oven set at 140°F ± 5°.
- Compaction. After curing, the mixture is compacted at 140°F using 50 blows of the hammer at each end of the specimen.
- Cooling. After molding, the specimens are cooled to room temperature in the molds. Care must be taken to remove the specimens, undisturbed and undamaged, from the molds.
- Testing. The specimens are heated in an oven to 100°F ± 2° and tested in the Marshall machine. Heating will normally take about 2 hours.
- Design amount of asphalt. The asphalt contents at maximum density and maximum stability, after averaging, are used as the design amount.

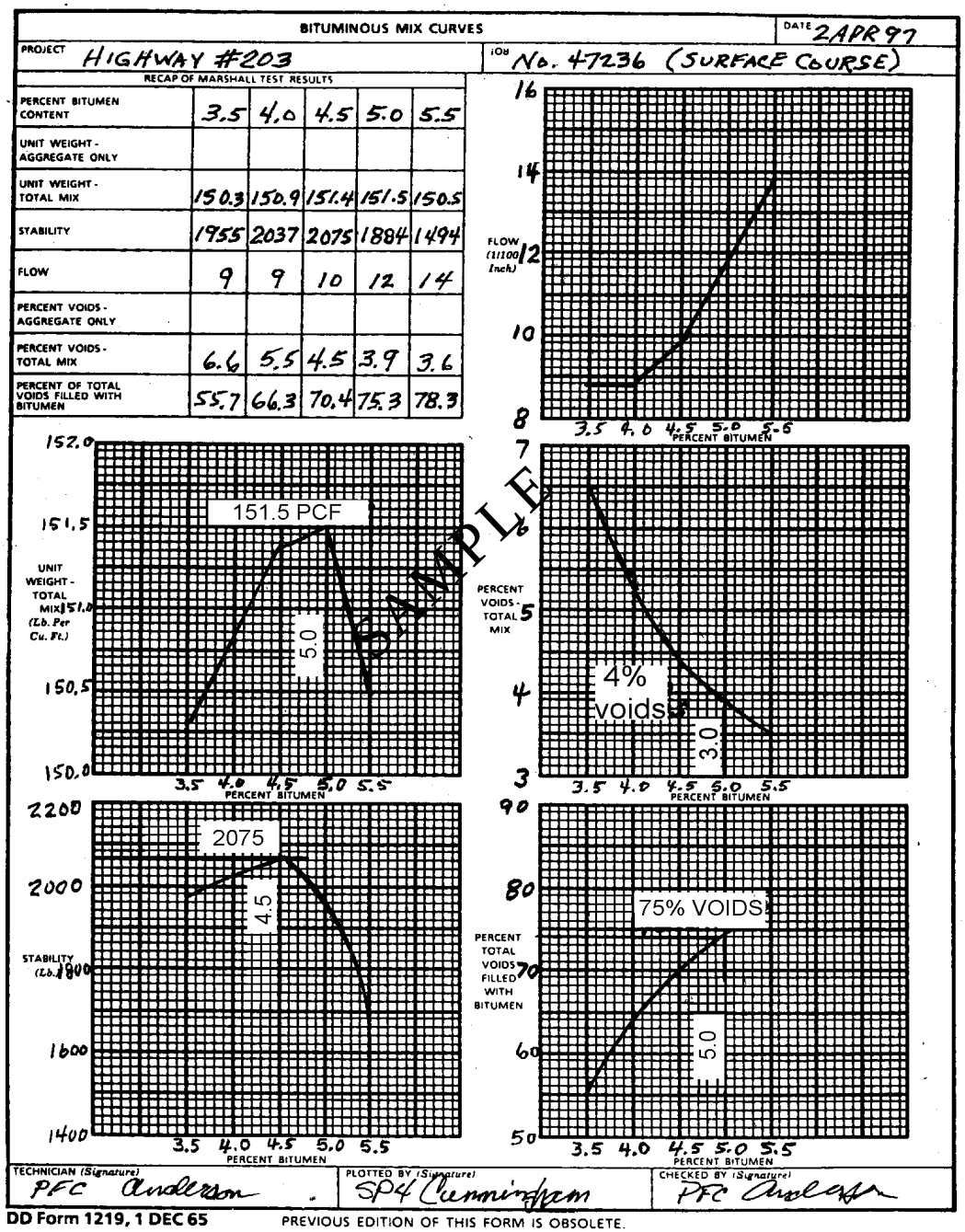


Figure 3-75. Asphalt mix curves, Marshall test properties

Table 3-19. Marshall test specifications and determination of optimum asphalt content

Property	Course	Criteria		Determination of OAC	
		75 Blows	50 Blows	High Press	Low Press
		**High Press	Low Press		
Aggregate blends showing water absorption up to 2 1/2 percent (used with ASTM apparent specific gravity)					
Stability	Surface	1,800 or higher	500 or higher	Peak of curve	Peak of curve
Unit weight	Surface	—	—	Peak of curve	Peak of curve
Flow	Surface	16 or less	20 or less	Not used	Not used
Percent voids total mix	Surface	3 to 5 percent	3 to 5 percent	4 percent	4 percent
Percent voids filled w/AC	Surface	70 to 80 percent	75 to 85 percent	75 percent	80 percent
Stability	Binder	1,800 or higher	500 or higher	Peak of curve*	Peak of curve*
Unit weight	Binder	—	—	Peak of curve*	Peak of curve*
Flow	Binder	16 or less	20 or less	Not used	Not used
Percent voids total mix	Binder	5 to 7 percent	4 to 6 percent	6 percent	5 percent
Percent voids filled w/AC	Binder	50 to 70 percent	65 to 75 percent	60 percent	70 percent*
Stability	Sand asphalt	**	500 or higher	**	Peak of curve
Unit weight	Sand asphalt	—	—	**	Peak of curve
Flow	Sand asphalt	**	20 or less	Not used	Not used
Percent voids total mix	Sand asphalt	**	5 to 7 percent	**	6 percent
Percent voids filled w/AC	Sand asphalt	**	65 to 75 percent	**	70 percent
Aggregate blends showing water absorption greater than 2 1/2 percent (used with bulk-impregnated specific gravity)					
Stability	Surface	1,800 or higher	500 or higher	Peak of curve	Peak of curve
Unit weight	Surface	—	—	Peak of curve	Peak of curve
Flow	Surface	16 or less	20 or less	Not used	Not used
Percent voids total mix	Surface	2 to 4 percent	2 to 4 percent	3 percent	3 percent
Percent voids filled w/AC	Surface	75 to 85 percent	80 to 90 percent	80 percent	85 percent
Stability	Binder	1,800 or higher	500 or higher	Peak of curve*	Peak of curve*
Unit weight	Binder	—	—	Peak of curve*	Peak of curve*
Flow	Binder	16 or less	20 or less	Not used	Not used
Percent voids total mix	Binder	4 to 6 percent	3 to 5 percent	5 percent	4 percent
Percent voids filled w/AC	Binder	55 to 75 percent	70 to 80 percent	65 percent	75 percent
Stability	Sand asphalt	**	500 or higher	**	Peak of curve
Unit weight	Sand asphalt	—	—	**	Peak of curve
Flow	Sand asphalt	**	20 or less	Not used	Not used
Percent voids total mix	Sand asphalt	**	4 to 6 percent	**	5 percent
Percent voids filled w/AC	Sand asphalt	**	70 to 80 percent	**	75 percent

***If the inclusion of bitumen contents at these points in the average causes the voids total mix to fall outside the limits, then the optimum bitumen should be adjusted so that the voids total mix are within the limits.**

****Criteria for sand asphalt to be used in designing pavement for high-pressure tires have not been established.**

Test Variations

These variations apply to aggregates with 10 percent or more larger than 1-inch maximum size. The procedure previously described is applicable where the amount of aggregate larger than the 1-inch sieve is less than 10 percent of the total. When the +1-inch material exceeds 10 percent of the total, the following variations are made in the procedure:

- Mix bitumen at the selected content with the entire aggregate, including the +1-inch portion.
- Pass the mixed hot batch through a 1-inch sieve. Discard the +1-inch portion.
- Make compacted specimens from the portion that passes the 1-inch sieve and perform the Marshall test. Do not calculate the voids of the compacted specimens at this time.
- Determine the bulk specific gravity of the +1-inch aggregate and, with the specific gravity of the compacted specimens, compute the adjusted specific gravity (G_A) as follows:

$$G_A = \frac{100}{\left(\frac{A}{C} + \frac{B}{D}\right) \times f}$$

where—

A = weight of dry, 1-inch material expressed as a percentage of the total batch weight (bitumen plus aggregate)

B = portion of the total batch remaining after the dry, +1-inch portion is removed (100 percent – A percent)

C = bulk specific gravity of the +1-inch aggregate

D = actual specific gravity of the compacted specimen

f = empirical factor = 0.995

- Calculate the voids by using the adjusted specific gravity and apply the design criteria for this value.
- Use stability and flow values as measured on the compacted specimens.

SURFACE-AREA METHOD

The following approximation formulas may be used for estimating the optimum bitumen content when the gradation of the aggregate blend is known. These estimates must be considered rough approximations since the optimum bitumen content is a function of the compaction effort as well as the gradation and surface area. The greater the anticipated pavement loading, the greater the compaction effort that must be used. The greater the compaction effort for a given aggregate, the lower the optimum bitumen content.

Asphalt Cement

Use the following formula for asphalt cement, based on the surface area of the aggregate:

$$P = 0.02a + 0.07b + 0.15c + 0.20d$$

where—

P = percent of asphalt material by weight of dry aggregate

a = percent of mineral aggregate retained on the No. 50 sieve

b = percent of mineral aggregate passing the No. 50 and retained on the No. 100 sieve

c = percent of mineral aggregate passing the No. 100 and retained on the No. 200 sieve

d = percent of mineral aggregate passing the No. 200 sieve

NOTE: Express all percentages as whole numbers.

Asphalt Emulsion

Use the following formula for asphalt emulsion, based on the surface area of the aggregate:

$$P = 0.05A + 0.1B + 0.5C$$

where—

P = percent by weight of asphalt emulsion, based on weight of graded mineral aggregate

A = percent of mineral aggregate retained on the No. 8 sieve

B = percent of mineral aggregate passing the No. 8 sieve and retained on the No. 200 sieve

C = percent of mineral aggregate passing the No. 200 sieve

NOTES:

1. Express all percentages as whole numbers.

2. Absorptive aggregate, such as slag, lime rock, vesicular lava, and coral, will require additional asphalt.

JOB-MIX FORMULA

When the necessary laboratory tests have been completed and the optimum bitumen content has been determined, the job-mix formula must be established for use by plant personnel producing the paving mix. Setting up the job-mix formula involves the relative percentages of the available aggregate and the bitumen. In the mix-design test already illustrated, the optimum content was found to be 4.7 percent of the total mix. Accordingly, the aggregate portion of the mix will be 95.3 percent of the total mix. Referring to the aggregate-blend calculations on DD Forms 1217 (see *Figure 3-19*) and 1207 *(see Figure 3-20, pages 3-62 and 3-63)*, the portions were 45 percent coarse aggregate, 30 percent fine aggregate, 20 percent fine river-bar sand (FRBS), and 5 percent limestone dust or mineral filler.

The job-mix formula is then computed as follows:

Coarse aggregate = 95.3 x 45 = 42.9 percent

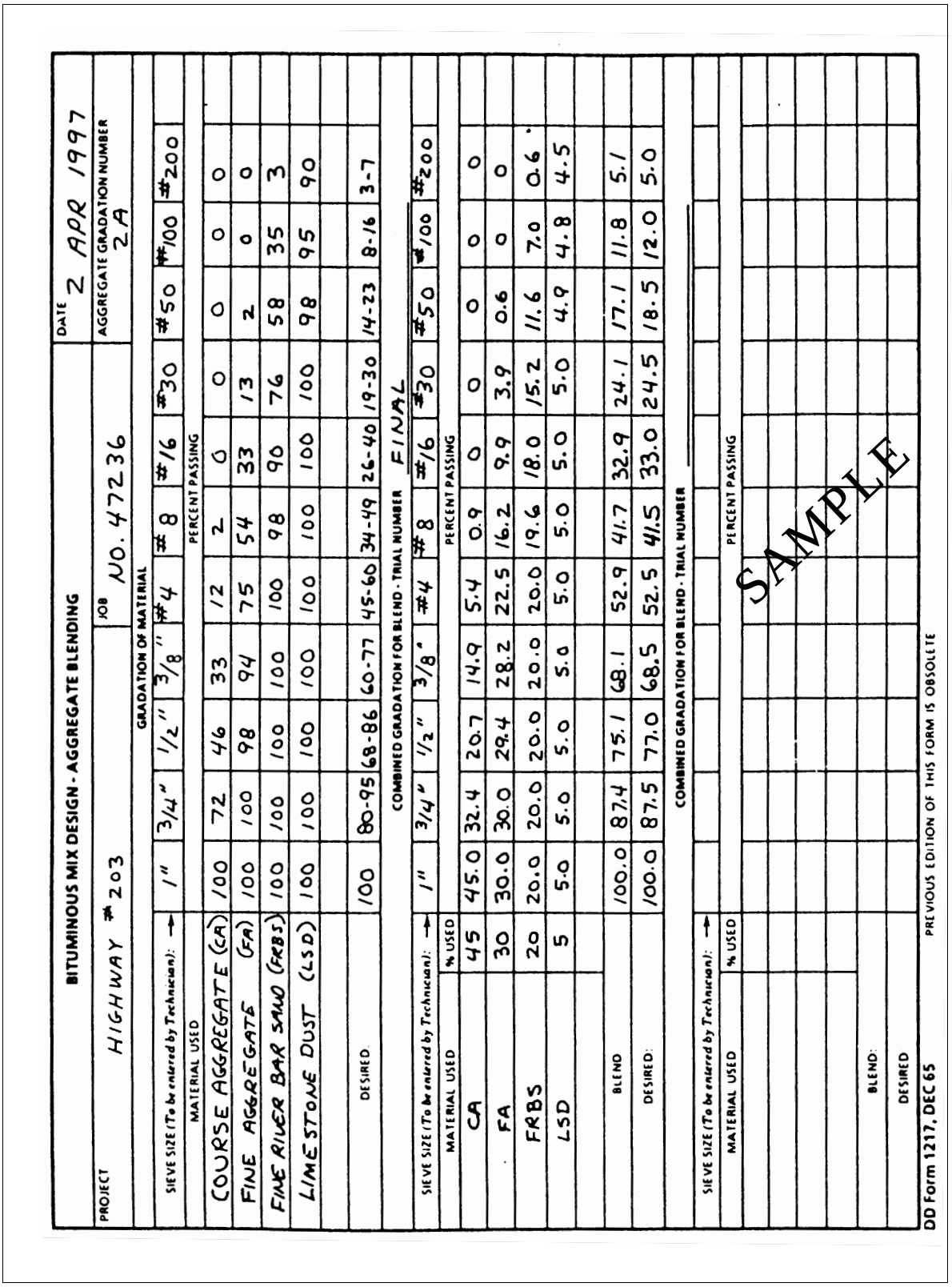
Fine aggregate = 95.3 x 30 = 28.6 percent

FRBS = 5.3 x 20 = 19.0 percent

Mineral filler = 95.3 x 5 = 4.8 percent

Bitumen = 4.7 percent

Total = 100.0 percent



BITUMINOUS MIX DESIGN - AGGREGATE BLENDING

DATE: 2 APR 1997

PROJECT: HIGHWAY # 203 JOB NO. 47236 AGGREGATE GRADATION NUMBER 2A

GRADATION OF MATERIAL

SIEVE SIZE (To be entered by Technician): →	1"	3/4"	1/2"	3/8"	#4	#8	#16	#30	#50	#100	#200
MATERIAL USED	PERCENT PASSING										
COURSE AGGREGATE (CA)	100	72	46	33	12	2	0	0	0	0	0
FINE AGGREGATE (FA)	100	100	98	94	75	54	33	13	2	0	0
FINE RIVER BAR SAND (FRBS)	100	100	100	100	100	98	90	76	58	35	3
LIMESTONE DUST (LSD)	100	100	100	100	100	100	100	100	98	95	90
DESIRED:	100	80-95	68-86	60-77	45-60	34-49	26-40	19-30	14-23	8-16	3-7

COMBINED GRADATION FOR BLEND - TRIAL NUMBER FINAL

SIEVE SIZE (To be entered by Technician): →	1"	3/4"	1/2"	3/8"	#4	#8	#16	#30	#50	#100	#200
MATERIAL USED	% USED	PERCENT PASSING									
CA	45	45.0	32.4	20.7	14.9	5.4	0.9	0	0	0	0
FA	30	30.0	30.0	29.4	28.2	22.5	16.2	9.9	3.9	0.6	0
FRBS	20	20.0	20.0	20.0	20.0	20.0	19.6	18.0	15.2	11.6	7.0
LSD	5	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.8
BLEND		100.0	87.4	75.1	68.1	52.9	41.7	32.9	24.1	17.1	11.8
DESIRED:		100.0	87.5	77.0	68.5	52.5	41.5	33.0	24.5	18.5	12.0

COMBINED GRADATION FOR BLEND - TRIAL NUMBER _____

SIEVE SIZE (To be entered by Technician): →											
MATERIAL USED	% USED	PERCENT PASSING									
BLEND:											
DESIRED											

SAMPLE

DD Form 1217, DEC 65 PREVIOUS EDITION OF THIS FORM IS OBSOLETE

Figure 3-19. Sample DD Form 1217

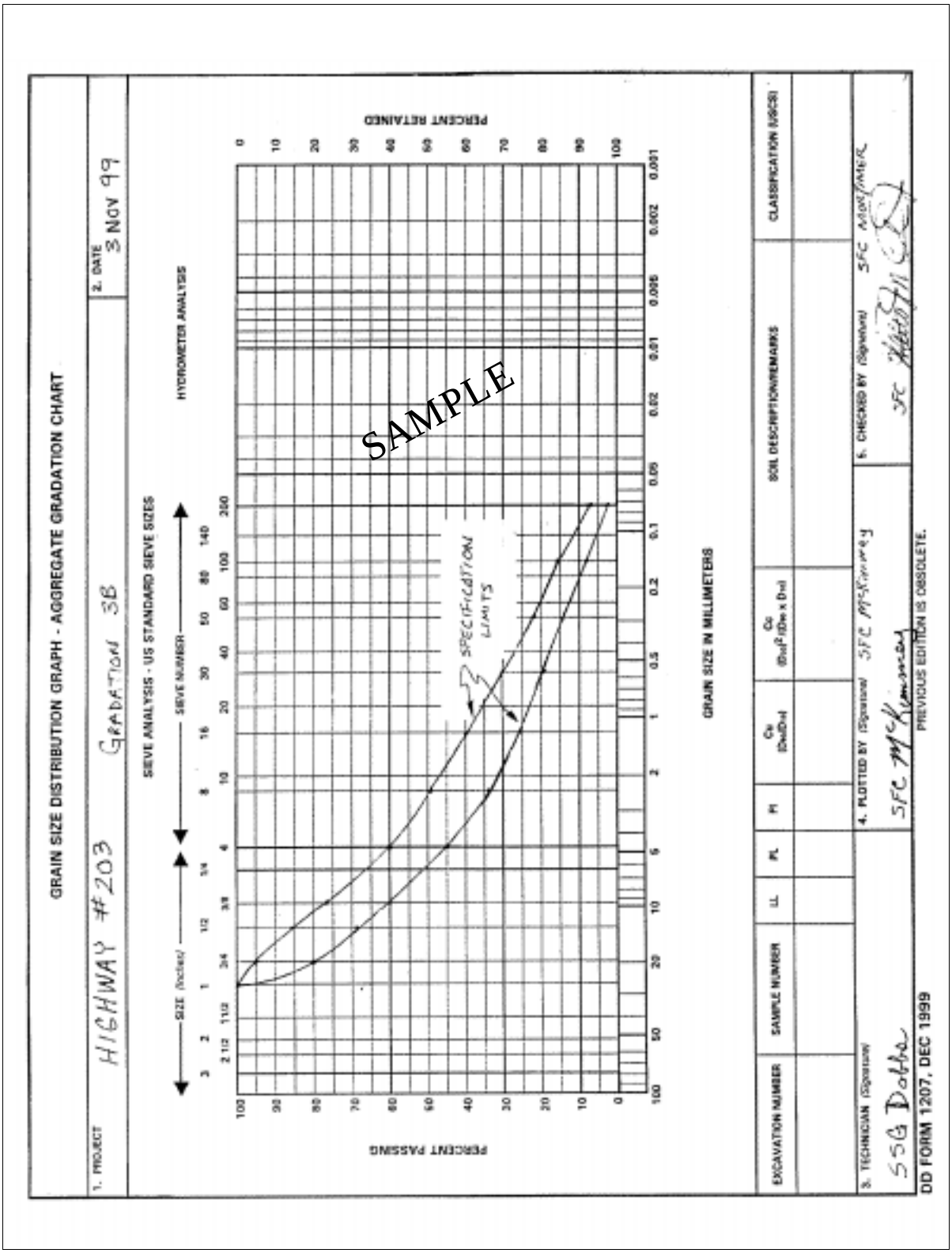


Figure 3-20. Sample DD Form 1207

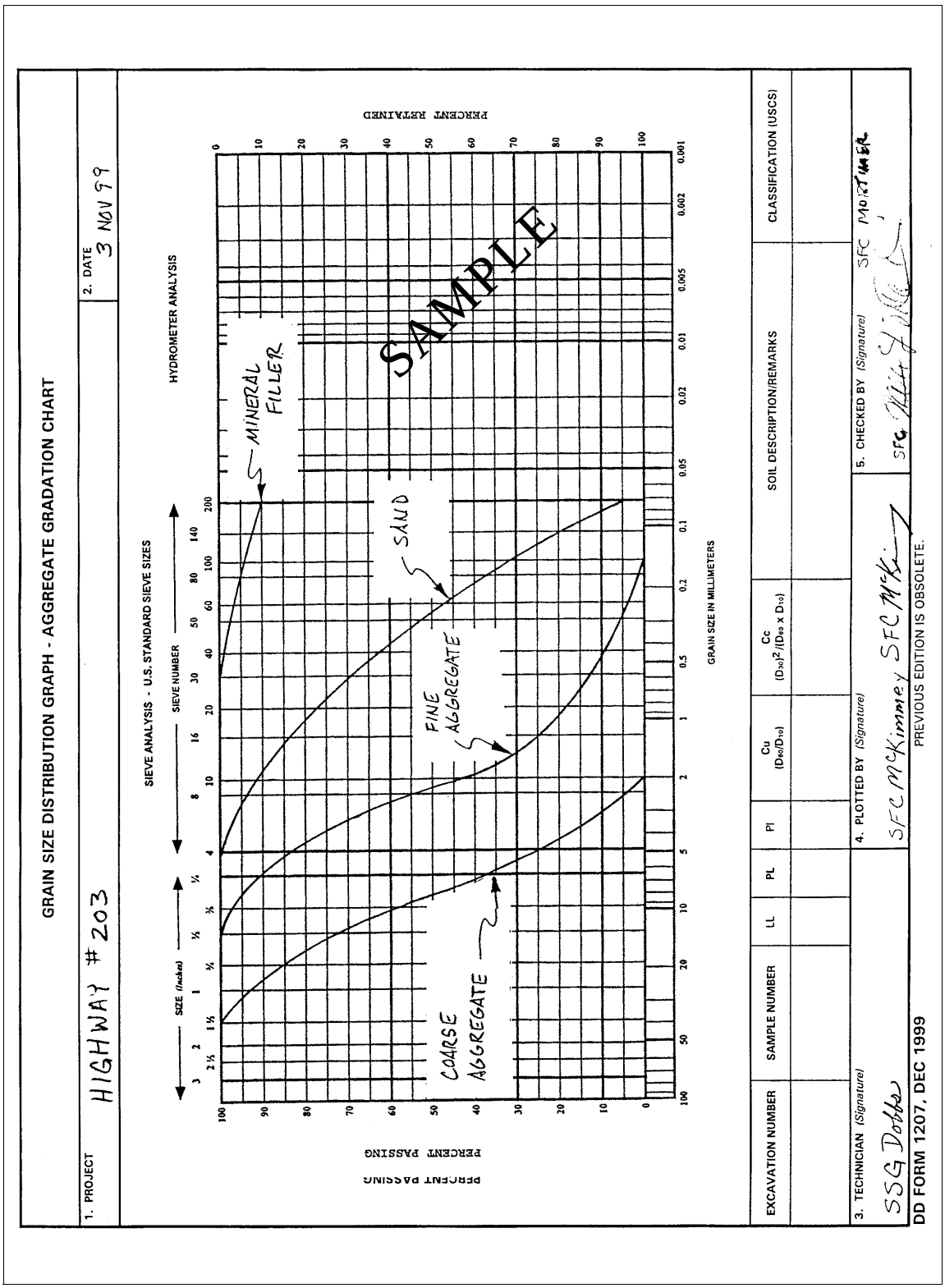


Figure 3-20. Sample DD Form 1207 (continued)

SECTION VII. PLANT CONTROL

Aggregate is mixed in correct proportions for specified construction in high-type bituminous paving plants and intermediate-type plants. The type of plant used depends on proximity and the requirements for the aggregate. Laboratory procedures must be done to obtain correct mixes and must be correlated with production procedures. Proper control over all procedures and equipment must be exercised to ensure quality for each aggregate specified.

PLANT TYPES

Figures 3-21 and 3-22 are schematic drawings of a batch plant and a drum-mix plant.

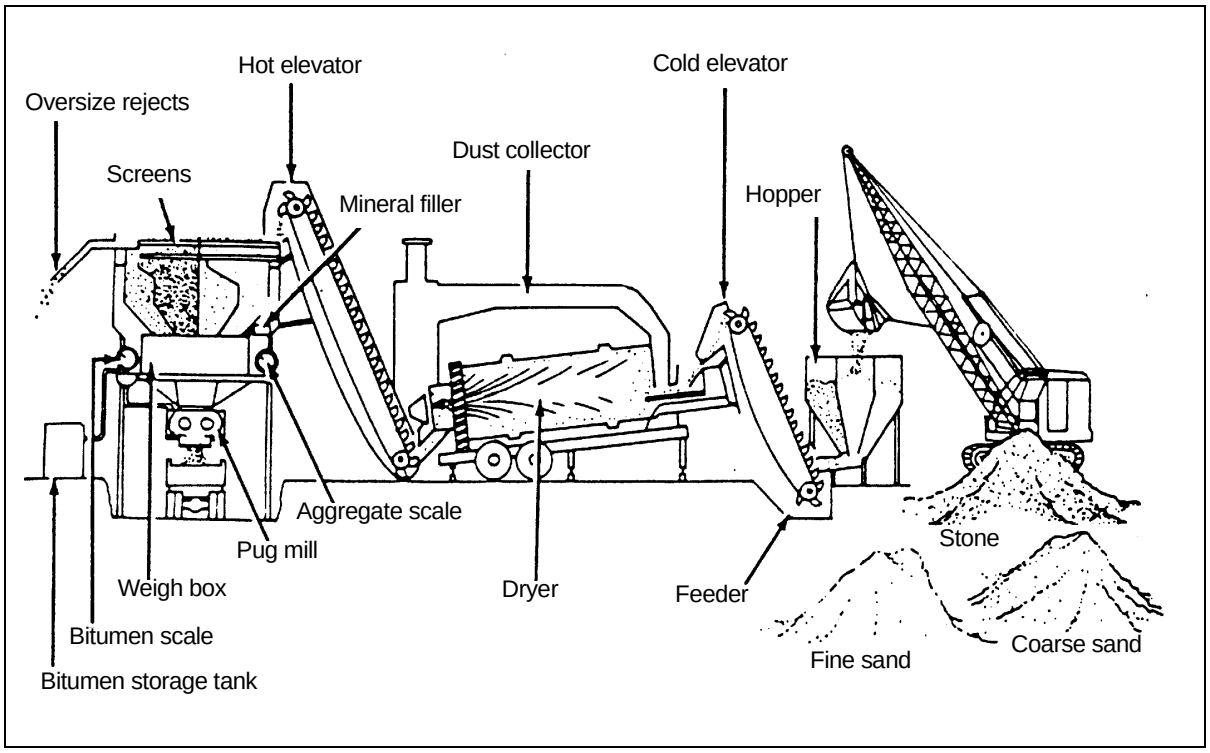


Figure 3-21. Bituminous hot-mix batch plant

HIGH-TYPE BITUMINOUS PAVING PLANT

In the operation of a high-type bituminous paving plant, aggregates from two or more sources are fed into the aggregate dryer in the approximate proportions required to produce the desired gradation. This initial proportioning usually is accomplished by means of a hopper-type feeder, operating from one or more bins, which feeds the aggregates into a cold elevator that delivers them to the dryer. The mechanical feeder is loaded by a clamshell or other suitable means.

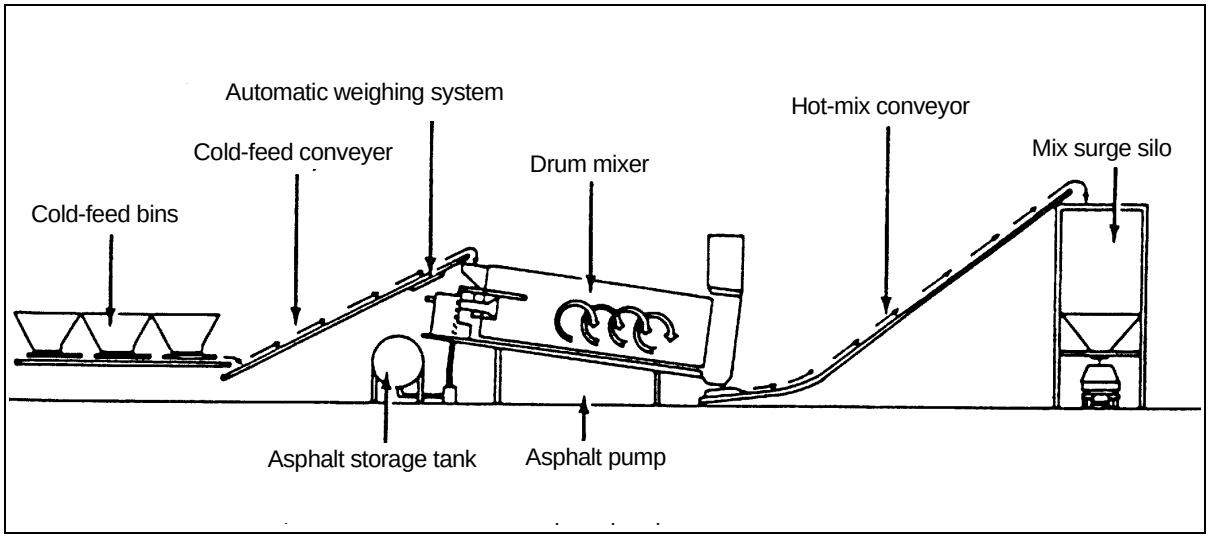


Figure 3-22. Bituminous hot-mix continuous-mix plant

They are heated to the desired temperature. Upon leaving the dryer, they pass over vibrating screens where they are separated according to size. The usual screening equipment for a three-bin plant consists of a rejection (scalping) screen for eliminating oversized material and screens for dividing the coarse aggregate into two separate sizes (bins). Fine aggregate goes into the third bin. An additional screen is provided for separating the coarse aggregate in a four-bin plant. Additional mineral filler, if required, usually is stored and weighed or proportioned into the mix separately. It may be obtained from the plant's dust collector or from an external source. Plant screens may be changed to provide a variation in the size of openings. The sizes used depend largely on the type of mixture being produced. In some cases, it may be necessary to change the size of the screens to obtain a proper balance of aggregate sizes in each bin.

The aggregates must be fed through the plant uniformly, preferably by a mechanical feeder, to obtain efficient plant operation and to produce a desired mixture. It is usually necessary to make some slight adjustments in the plant-bin proportions, since a screen analysis of the hot storage bins will not entirely duplicate the screen analysis used in the laboratory design. This may result from—

- Fines lost while passing through the dryer (unless the equipment includes an effective dust collector and the fines are returned to the mix).
- Aggregate degradation in the dryer.
- Plant screens that are not completely efficient in the separation of the aggregate, with the result that some fines are carried over into the coarser bins.
- Separation of material at hot bins into more or fewer fractions than represented at stockpiles.

INTERMEDIATE-TYPE PLANTS

An intermediate-type plant does not have the refinements of the high-type plant described above. Such items as the gradation control unit, the dryer unit, and even the storage hoppers or bins may not be components of this type of plant. The aggregates from stockpiles or trucks are added directly (in correct proportion) into the elevator and then fed into the mixer. Corrections or changes in the aggregate proportions must be made during the feed. If a dryer is not part of the plant, adjustment to compensate for moisture must be anticipated and made externally.

INITIATING PLANT PRODUCTION

The heaviest demands on laboratory facilities arise at the beginning of plant production. Preliminary computations, which provide the gradation for the mixture design, may be made to determine the weight of material from each bin. The gradation of aggregate supplied by the plant according to computed bin weights may not reproduce precisely the desired gradation. The gradation of the plant-produced aggregates approximates the one used in design, within reasonable tolerances, if initial sampling has been done properly and if the plant is operated efficiently. Certain steps should be taken, however, to ensure that satisfactory mixtures are reproduced from the beginning and throughout the period of plant production. Procedures outlined in this section will ensure satisfactory paving mixtures.

SIEVE ANALYSIS

A sieve analysis is made on material from each plant bin. Samples for these sieve analyses are obtained after a few tons of aggregate have been processed through the dryer and screens so that the sample will be representative. Final bin proportions may be based on these sieve analyses.

MIX REDESIGN

The aggregates from the bins sometimes cannot be proportioned to satisfactorily reproduce the gradation of the aggregate used in the laboratory design. It is then necessary to redesign the mix, using plant-produced aggregates. Specimens are prepared and tested for the new design in the same manner as for the original. This gives optimum asphalt content and a satisfactory mix produced by the plant. Occasions may arise in which the gradation of the plant-produced aggregate will differ from the laboratory design so that part of the aggregates may be wasted. The mix should be redesigned to use all of the available aggregate. Sufficient additional tests should be performed to establish optimum asphalt requirements and ensure that the mix meets applicable criteria.

CONTROLLING PLANT PRODUCTION

Obtain from each of the first four truckloads enough paving mix for the preparation of four test specimens. Prepare the four specimens from each of these samples and compact and test them according to standard procedures described previously. Conduct the tests as rapidly as possible, and delay plant production until data from these tests are available. The data must conform to final design data at the same asphalt content, within reasonable tolerances, before plant production is resumed. If necessary, make adjustments to secure

a conforming mix. Such procedures will delay plant production generally less than 2 hours and assure production of satisfactory mixes. As soon as the data from the testing of the plant-produced mix are obtained, compare it with corresponding design data for further adjustments of the mix, if necessary. Probable causes of paving-mixture deficiencies for both batch and continuous mixing plants are shown in *Figure 3-23*. These deficiencies are observed at the plant. Other imperfections and their causes that may be encountered in placing the mix in the pavement are given in *Figure 3-24, page 3-68*.

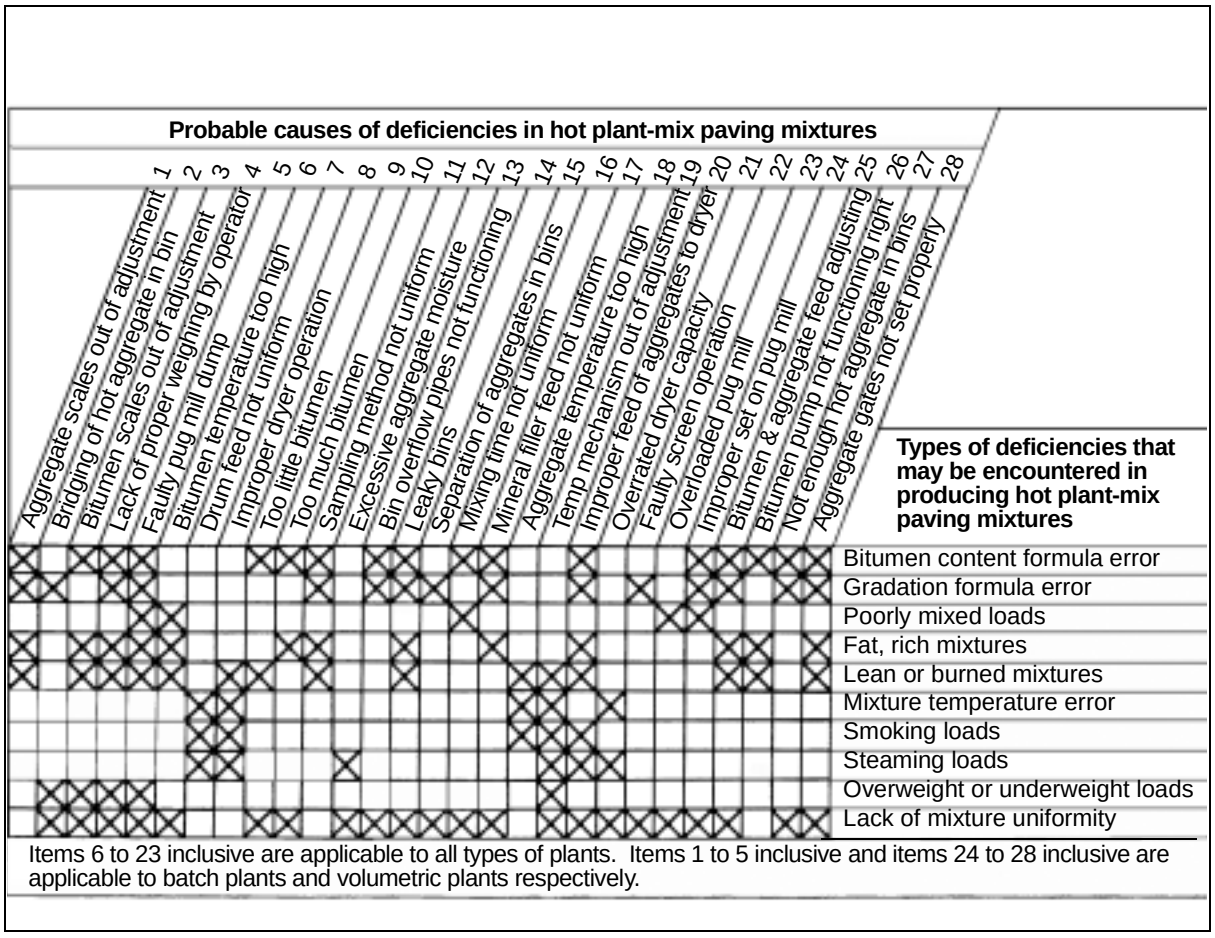


Figure 3-74. Probable causes of paving-mixture deficiencies detected at plant

GYRATORY TEST CONTROL

The GSI of the individual test specimens should never exceed 1.05. The GSF of the individual test specimens should never be less than 1.0. The average value of the other test properties for the four test specimens from any given truckload should not deviate from the final design values by more than the following amounts:

- Unit weight total mix ± 1.5 pcf.
- Gyratory shear (S_G) ± 15 percent.

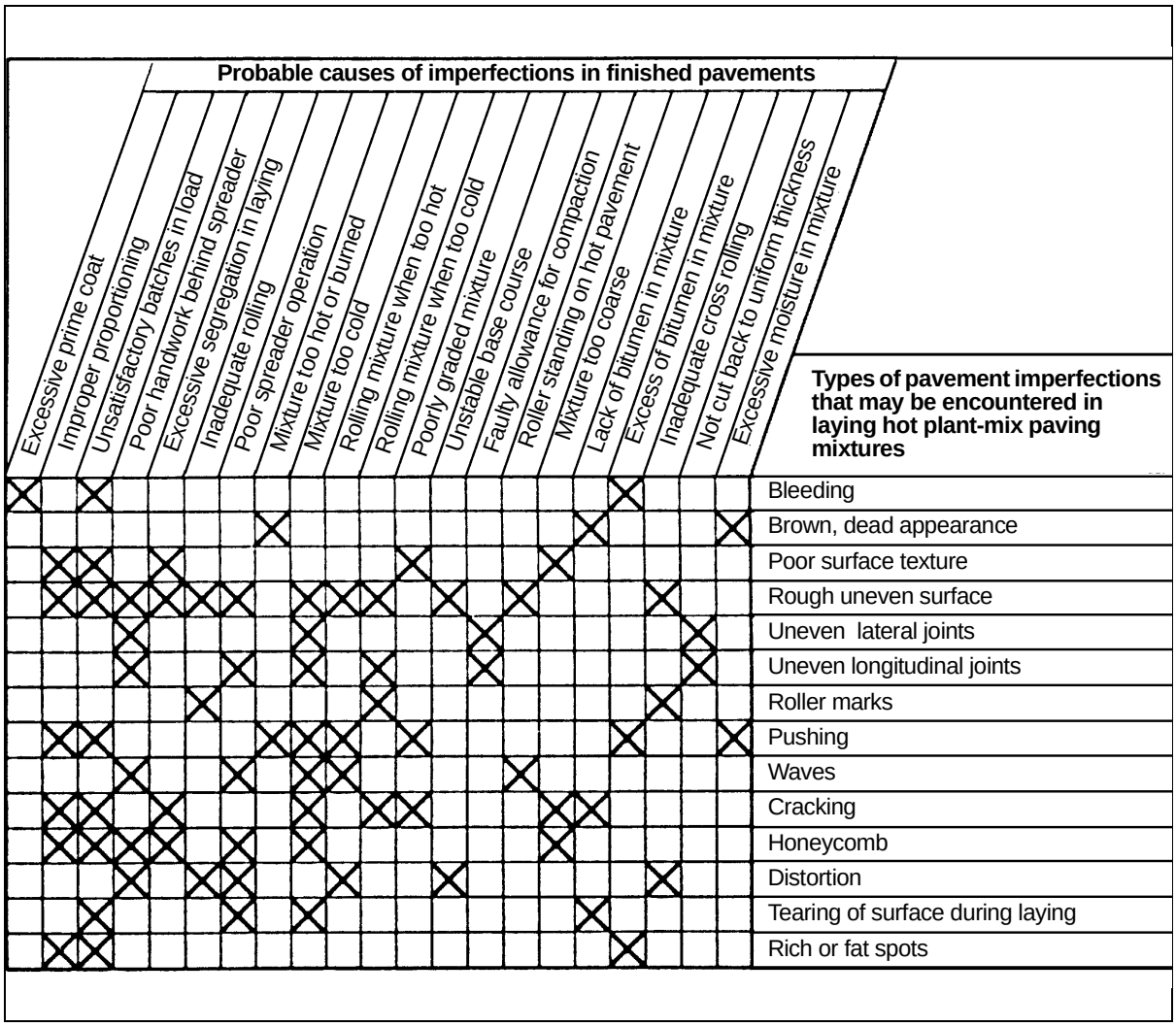


Figure 3-74. Probable causes of imperfections encountered in laying pavement

MARSHALL TEST CONTROL

The flow value of the individual test specimens should never exceed the specification limits and should not vary more than two points between specimens. The average value of the other test properties for the four test specimens from any given truckload should be within the specification limits and not vary from the final design values by more than the following amounts:

- Unit weight total mix ± 1.5 pcf
- Marshall stability ± 5 percent.
- Voids total mix ± 0.5 percent.

No limit is placed on voids filled since control is ensured by the limitations on voids total mix.

PLANT-CONTROL EXECUTION

Stop plant production if the measured test properties fail to comply with the limitations cited above. Resume production on a trial basis until the problem has been isolated and corrective measures have been taken. Small variations in aggregate quantities usually do not change test properties significantly, while small changes in bitumen content (a few tenths of a percent) can have a very significant effect on test properties. If trouble is indicated, check all calculations as a first step. Check the total of the batch weights dumped into the truck against the total load on the truck. These total weights should not vary from each other by more than 2 percent.

Improper weighing or faulty scales may be detected readily. Take corrective measures by maintaining a close check on load weights. Check plant scales and gate openings and recalibrate them as necessary. Adjust scales and proportioning devices found to be inaccurate. After checking the plant components and making the necessary adjustments, obtain, sample, and test four additional truckloads of plant mix. Do not place the plant in continuous operation until the test properties conform to the specifications and allowable tolerance. Once the plant has been placed in continuous operation, prepare test specimens from approximately each 400 tons of mix produced.

CENTRIFUGAL-EXTRACTION METHOD (ASTM D 2172-88)

The procedure for control of plant production (based on the test properties obtained by using the Marshall apparatus or the GTM) may be supplemented by the determination of asphalt content using a centrifugal-extraction apparatus. The measured asphalt content is compared with the optimum asphalt content previously established. Discrepancies may be corrected by plant adjustments, if necessary. After the asphalt has been extracted, the remaining aggregates may be subjected to a sieve analysis for comparison with the previously selected aggregate gradation. Corrections again may be made in the operation of the plant, as necessary. The method is also used to test tar or tar-rubber mixes.

PURPOSE

Use the centrifugal-extraction-device method to determine the asphalt content of a bituminous plant mixture.

EQUIPMENT

Use the following items for this method:

- A balance; 2,000-gram capacity.
- A beaker; 600-milliliter capacity.
- A varnish brush.
- A graduate; 1,000-milliliter glass.
- Evaporating dishes.
- A centrifugal extractor, hand-driven with pad.
- A filter ring (paper-basket type).
- An electric hot plate.

- An electric oven.
- A baking pan.
- Solvent (trichloroethane); 5-gallon can.
- A spatula.
- A cooking spoon.
- Crucible tongs.

The Dulin-Rotarex centrifugal-extraction device and related equipment are shown in *Figure 3-25*.

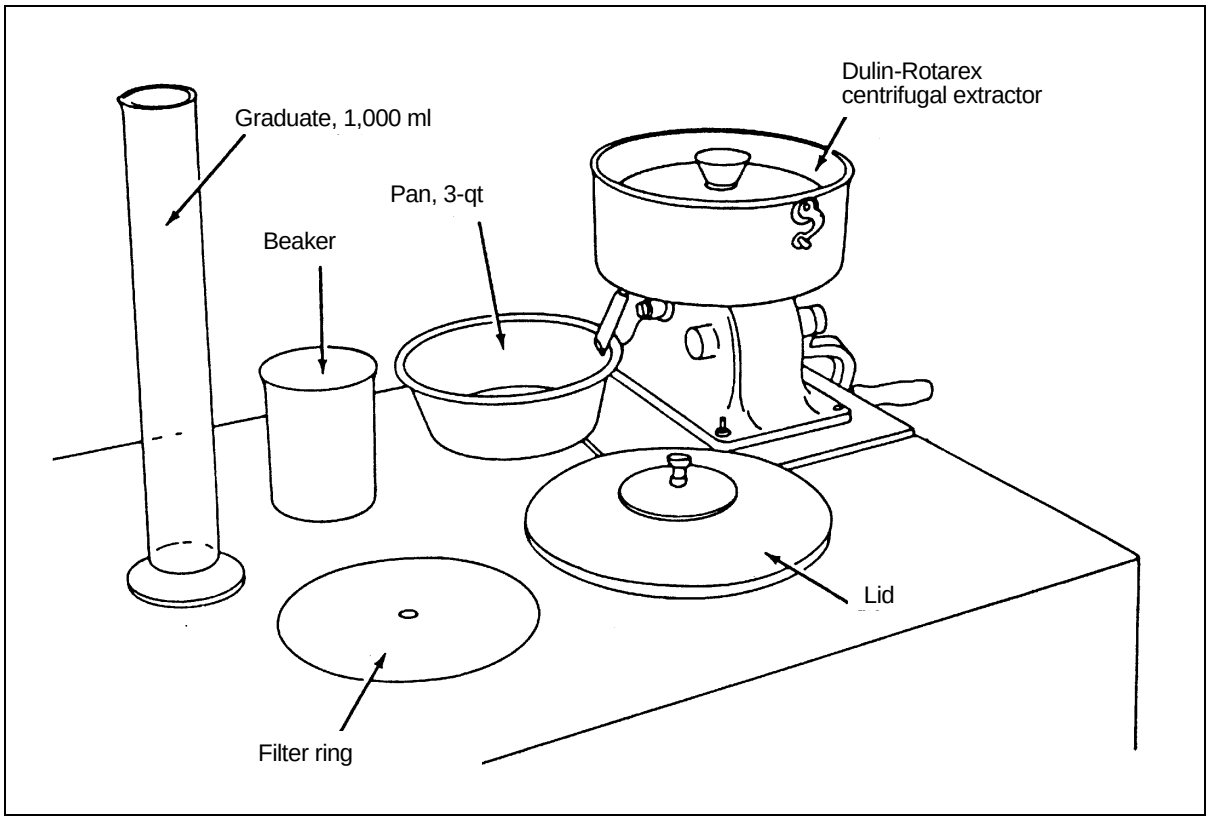


Figure 3-75. Dulin-Rotarex extraction equipment

STEPS

The centrifugal-extraction test may be performed on a representative sample taken from an individual batch or on a composite sample representing several batches. Perform the following steps:

Step 1. Take four samples upon initiation of the asphalt plant operation, one from each of the first four trucks to leave the plant. Delay plant production until the test is complete. After the plant is in normal operations, obtain a suitable composite sample by combining samples taken every 4 hours or every 400 tons of production, whichever comes first. Do this by using a shovel and cutting completely across the stream of hot mixture as it is discharged from

the mixer. Place the hot samples in a tin pail or other container with a tight-fitting lid until the last sample for the day is taken.

Step 2. Heat the sample in a pan on the hot plate or in the oven until it is soft enough to be easily disintegrated with a large spoon. Ensure that the individual particles of aggregate are not crushed.

Step 3. Prepare a representative sample by the quartering method and allow it to cool. Weigh not less than 650 grams of a sample containing particles smaller than 1/2 inch and place it in the bowl of the extraction device. Record the initial weight of the sample.

Step 4. Weigh an oven-dried, gasket-type, filter-paper ring and record the weight. Fit the filter paper on the rim of the bowl. Position the cover plate on the bowl and securely lock it in place. Place the bowl on the shaft of the extractor and fasten it securely.

Step 5. Place the empty 1,000-milliliter glass graduate under the spout of the extraction apparatus. Pour about 200 milliliters of solvent into the bowl through the solvent funnel. Solvent flowing through the weep holes indicates a full bowl. Allow the solvent to set in the bowl for 10 to 15 minutes before operating the equipment.

Step 6. Put the lid on and rotate the bowl by turning the hand crank until the solvent discharges from the spout in a thin stream. After the first charge is drained, remove the lid and add more solvent. Replace the lid and rotate the bowl again. Repeat this operation several times until the discharged solvent is clean. With a little experience, the operator can soon judge exactly what treatment is necessary for any given material.

Step 7. Remove the bowl when the last addition of solvent has drained off. Carefully disassemble the bowl and allow the bowl, the cover plate, and the filter ring to air-dry. After air-drying, carefully brush the sample out of the bowl and off the cover plate into the preweighed tare. Oven-dry the sample and the filter ring at 230°F ± 9° to a constant weight. Allow the sample and filter ring to cool in a desiccator. Weigh the sample and record the weights.

Step 8. Subtract the weight of the clean aggregate, plus the weight of any mineral filler retained in the filter paper, from the weight of the original sample to determine the amount of asphalt extracted. This value for the amount of asphalt extracted is subject to correction, depending on the amount of mineral filler contained in the solvent, as indicated below.

Step 9. Determine the amount of mineral filler that passed through the filter paper and is contained in the solvent extract.

a. Measure and record the total amount of solvent extract (volume, in milliliters).

b. Agitate the solvent thoroughly, and measure 100 milliliters into a preweighed evaporating dish.

c. Place the evaporating dish on a hot plate and evaporate over low heat until all that remains in the dish is a black residue.

a. Heat the residue to a dull-red ash (932° to 1,112°F). A laboratory furnace or blow torch may be used to heat the residue. The heating process will burn off any organic matter (asphalt binder) remaining in the residue.

b. Allow the residue to cool to room temperature once it has become a dull-red glowing ash.

c. Prepare a saturated solution of ammonium carbonate and add it to the ash in the proportions of 5 milliliters of solution to 1 gram of ash remaining in the dish. (A saturated solution of ammonium carbonate is prepared by dissolving as much ammonium carbonate into water as the water can retain. At 60°F about 100 grams of ammonium carbonate will dissolve in 100 milliliters of water.)

NOTE: Prepare the solution at room temperature since ammonium carbonate decomposes at 135°F. Allow the ammonium-carbonate solution and ash mixture to stand for 1 hour. Oven-dry the mixture at 230°F to a constant weight. After oven-drying, allow the mixture to cool in a desiccator. Weigh the mixture (in the evaporating dish), and the record the weight.

CALCULATIONS

Perform calculations on DD Form 1793 as shown in *Figure 3-26*.

SIEVE ANALYSIS OF AGGREGATE

The clean aggregate may be subjected to sieve analysis. The amount of material passing the No. 200 sieve (mineral filler) in the sieve analysis must be increased by the weight of filler retained in the filter-paper gasket and in the solvent as determined in the calculations.

TESTING TAR OR TAR-RUBBER MIXES

For tar or tar-rubber mixes, the above procedure should be modified as follows:

- Soak the sample in crystal-free creosote overnight.
- Transfer the soaked sample and creosote to the centrifugal apparatus and centrifuge to remove the creosote.
- Wash the sample with benzene until the solvent is a light straw color.

DENSITY TESTS

Density test samples should be taken and tests performed as often as conditions require, but at least once for every 400 tons of mix placed. To obtain a satisfactory specimen, take the samples early in the morning when the pavement is cool. Perform any additional rolling required as a result of the tests during the heat of the day. Take the sample for testing from any portion of the bituminous pavement, provided the area is typical of placing and rolling conditions.

A coring machine or concrete saw may be used for cutting out the samples. Avoid chopped or jack-hammered samples, if possible, as these are likely to develop cracks or other disturbances which would lead to erroneous results. Cut samples completely through the thickness of the pavement and remove

DETERMINATION OF ASPHALT CONTENT
(Dulin - Rotarex Extractor)

PROJECT: HIGHWAY NO. 206 — DATE: 3 APR 1997

LINE NO	ITEM		UNIT	1	2
1.	Weight of original sample and tare		g	253.1	
2.	Weight of tare		g	53.1	
3.	Weight of original sample	(1-2)	g	200.0	
4	Weight of clean aggregate and tare		g	239.2	
5.	Weight of tare		g	53.1	
6.	Weight of clean aggregate	(4-5)	g	186.1	
7.	Final weight of filter paper		g	28.6	
8.	Initial weight of filter paper		g	27.2	
9.	Weight of filler in filter paper		g	1.4	
10.	Total amount of solvent		cm^3	927	
11.	Amount of solvent evaporated and ignited		cm^3	60	
12.	Final weight of evaporation dish and residue		g	33.3	
13.	Initial weight of clean evaporation dish		g	33.2	
14.	Amount of filler in evaporation dish	(12-13)	g	0.1	
15.	Amount of filler in total solvent	$\left(\frac{10}{11} \times 14\right)$	g	1.5	
16.	Total amount of aggregate in sample	(6-9-15)	g	189.0	
17.	Percentage asphalt	$\left(\frac{3 \cdot 16}{6} \times 100\right)$	%	5.5	

SAMPLE

REMARKS

SAMPLE 78

SPECIFICATION 55% CHECK, MIX OK

TECHNICIAN	COMPUTED BY	CHECKED BY
SP4 Cunningham	F. Dawnis	S. Mayo

DD Form 1793, FEB 71

Figure 3-74. Sample DD Form 1793

them carefully to avoid damage. In hot weather, it may be necessary to chill the area with ice for 15 to 30 minutes before cutting out the sample.

When density samples are taken from a surface course placed on a binder course, it is practically impossible to remove the specimen from the tacked binder-course surface. To assist in removing samples of the surface course from the binder course, select the spot for the test before laying the surface course. Place a piece of wrapping paper about 18 inches square on the spot selected. On the side of the project least subject to construction traffic, drive two nails into the base or pavement a convenient distance apart and an equal distance from the center of the paper so that you may readily locate the center of the paper after the surface course is laid. The roller should not treat the mix placed over the paper any differently than the remainder of the pavement. The area of pavement over the paper is small, and practice has demonstrated that specimen density secured by this method is about the same as the density in the surrounding pavement. You should not use frames or separators around the proposed sample.

Determine the bulk specific gravity for each specimen and use the following formula to calculate the specimen's density:

$$D = G_m \times 62.4$$

where—

D = density of specimen, in pcf

G_m *= bulk specific gravity of specimen*

62.4 = density of water, in pcf

Compare the calculated density of the bituminous pavement with the densities obtained during the bituminous-mix design and Marshall stability tests. Normally, the field density must be at least 95 percent of the maximum density calculated in the bituminous-mix design. However, individual project specifications do vary, and the acceptable density ranges must be verified for each project. When the density test on samples from the bituminous pavement show that the minimum specified field density has not been obtained, correct the deficiency by additional rolling or remove and replace the pavement. Where constant difficulty is experienced in meeting the specified density, check the job-mix formula thoroughly.

EXPEDITING THE DESIGN

When military expediency demands it, the preliminary laboratory mix designs are eliminated, and the mix is designed directly from plant-produced aggregates. In such cases, the engineering officer will, on the basis of sieve analysis or other information or judgment, select the most promising of the available aggregates and start the plant using this aggregate. As pointed out previously, in nearly all cases the aggregate will show some breakdown of the particles because of heating and screening. Consequently, the grading curve for the material that has passed through the plant will differ from the grading curve of the material before entering the plant. Laboratory tests using aggregate from the plant bins combined in the most desirable proportions must be conducted to determine the optimum asphalt content (OAC).

Manufacture of the paving mix then can be initiated. If the available aggregate must be used, regardless of whether it produces a mix that meets all the design criteria at OAC, the asphalt content should be selected to give a mix which meets the criteria for flow and percent of voids in the total mix. The criteria for stability and percent of voids filled with asphalt is given less consideration.