Designation: D6926 – 10

Standard Practice for Preparation of Bituminous Specimens Using Marshall Apparatus[1]

This standard is issued under the fixed designation D6926; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers preparation and compaction of 102 mm (4 in.) diameter by nominal 64 mm (2.5 in.) high cylindrical bituminous paving mixture specimens by means of the original manual Marshall method and subsequent variations of the method (Test Method D6927). This practice is intended for use with laboratory and plant produced bituminous mixtures with aggregate up to 25 mm (1 in.) maximum size and for recompaction of asphalt pavement samples.

1.2 There are three types of Marshall compaction apparatus in use. The following types of hammer arrangements are included in this practice:

1.2.1 Manually held hammer handle attached to a flat compaction foot through a spring loaded swivel and is hand operated (original standard developed by the Corps of Engineers).

1.2.2 Hammer handle restrained laterally (fixed) but not vertically attached to a flat compaction foot through a spring loaded swivel and is either mechanically or hand operated. There may or may not be a constant surcharge on top of the hammer handle. Mechanical hammers are available that operate at *(1)* nominal 55 blows per minute and *(2)* equal to or greater than 75 blows per minute.

1.2.3 Hammer handle restrained laterally (fixed) with constant surcharge on top of hammer, a slanted compaction foot, rotating mold base, and is mechanically operated.

1.3 Although the mass and height of mass drop for each apparatus are the same, density achieved in compacted specimens with the same number of blows will be different. It is up to the user to establish the specific required number of blows to be used for compaction of the specimen in relation to the field.

1.4 *Units*—The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.5 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D2493 Standard Viscosity-Temperature Chart for Asphalts

D3666 Specification for Minimum Requirements for Agencies Testing and Inspecting Road and Paving Materials

D6927 Test Method for Marshall Stability and Flow of Bituminous Mixtures

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

3. Significance and Use

3.1 Compacted bituminous mixture specimens molded by this procedure are used for various physical tests such as stability, flow, indirect tensile strength, fatigue, creep, and modulus. Density and voids analysis are also conducted on specimens for mixture design and evaluation of field compaction.

NOTE 1—Uncompacted mixtures are used for determination of theoretical maximum specific gravity.

4. Apparatus

4.1 *Specimen Mold Assembly*—Mold cylinders, base plates, and extension collars shall conform to the details shown in Fig. 1.

4.2 *Specimen Extractor*—The specimen extractor shall have a steel disk that will enter the mold without binding and not be less than 3.95 in. (100 mm) in diameter and ½ in. (12.5 mm) thick. The steel disk is used for extracting compacted specimens from molds with the use of the mold collar. Any suitable extraction device such as a hydraulic jack apparatus or a lever arm device may be used, provided the specimens are not deformed during the extraction process.

4.3 *Compaction Hammers*:

4.3.1 *Compaction Hammers with a Manually Held (Type 1) or Fixed (Type 2) Handle*, either mechanically or hand operated

[1] This practice is under the jurisdiction of ASTM Committee D04 on Road and Paving Materials and is the direct responsibility of Subcommittee D04.20 on Mechanical Tests of Bituminous Mixtures.

Current edition approved June 15, 2010. Published September 2010. Originally approved in 2004. Last previous edition approved in 2004 as D6926–04 DOI: 10.1520/D6926-10.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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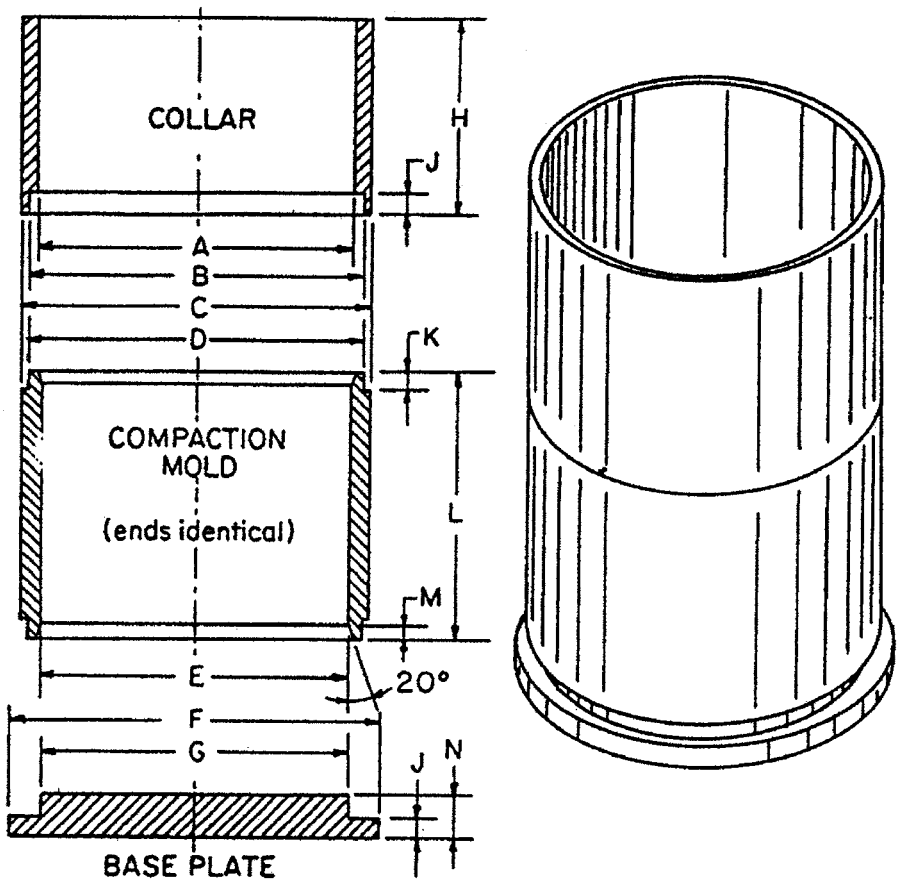

	in.	(mm)
A	4.100 to 4.150	(104.1 to 105.4)
B	4.295 to 3.439	(109.1 to 110.2)
C	4.490 to 4.560	(114.0 to 115.8)
D	4.211 to 4.320	(107.0 to 109.7)
E	3.990 to 4.005	(101.3 to 101.7)
F	4.720 to 4.780	(119.9 to 121.4)
G	3.980 to 3.990	(101.1 to 101.3)
H	2.730 to 2.770	(69.3 to 70.4)
J	0.235 to 0.285	(7.0 to 7.2)
K	0.235 to 0.265	(6.1 to 6.7)
L	3.420 to 3.460	(86.9 to 87.9)
M	0.120 to 0.190	(3.0 to 4.8)
N	0.485 to 0.585	(12.3 to 14.9)

FIG. 1 Compaction Mold

as generally shown in Fig. 2, shall have a flat, circular compaction foot with spring loaded swivel and a 10 ± 0.02 lb (4.54 ± 0.01 kg) sliding mass with a free fall of 18 ± 0.06 in. (457.2 ± 1.5 mm) (see Fig. 2 for hammer tolerances). A typical mechanical hammer is shown in Fig. 3.

NOTE 2—Manual compaction hammers should be equipped with a finger safety guard.

4.3.2 *Compaction Hammers with a Fixed Hammer Handle*, surcharge on top of handle, constantly rotating base, and mechanically operated (Type 3) shall have a slanted, circular tamping face and a 10 ± 0.02 lb (4.54 ± 0.01 kg) sliding weight with a free fall of 18 ± 0.06 in. (457.2 ± 1.5 mm) (see Fig. 2 for hammer and tamping face bevel angle and tolerances, respectively). A rotating mechanism is incorporated in the base. The base rotation rate and hammer blow rate shall be 18 to 30 rpm and 64 ± 4 blows per minute, respectively.

NOTE 3—Type 3 Marshall hammer apparatus are available in versions with more than one hammer. Multiple hammer operation will affect specimen density and is not recommended. Best comparative results will be obtained by compacting all specimens with the same hammer and with no other hammers operating.

4.4 *Compaction Pedestal*—The compaction pedestal shall consist of a nominal 8 by 8 in. (203.2 by 203.2 mm) wooden post approximately 18 in. (457 mm) long capped with a steel plate approximately 12 by 12 in. (304.8 by 304.8 mm) and 1 in. (25.4 mm) thick. The wooden post shall be oak, yellow pine, or other wood having an average dry density of 42 to 48 lb/ft^3 (670 to 770 kg/m^3). The wooden post shall be secured by

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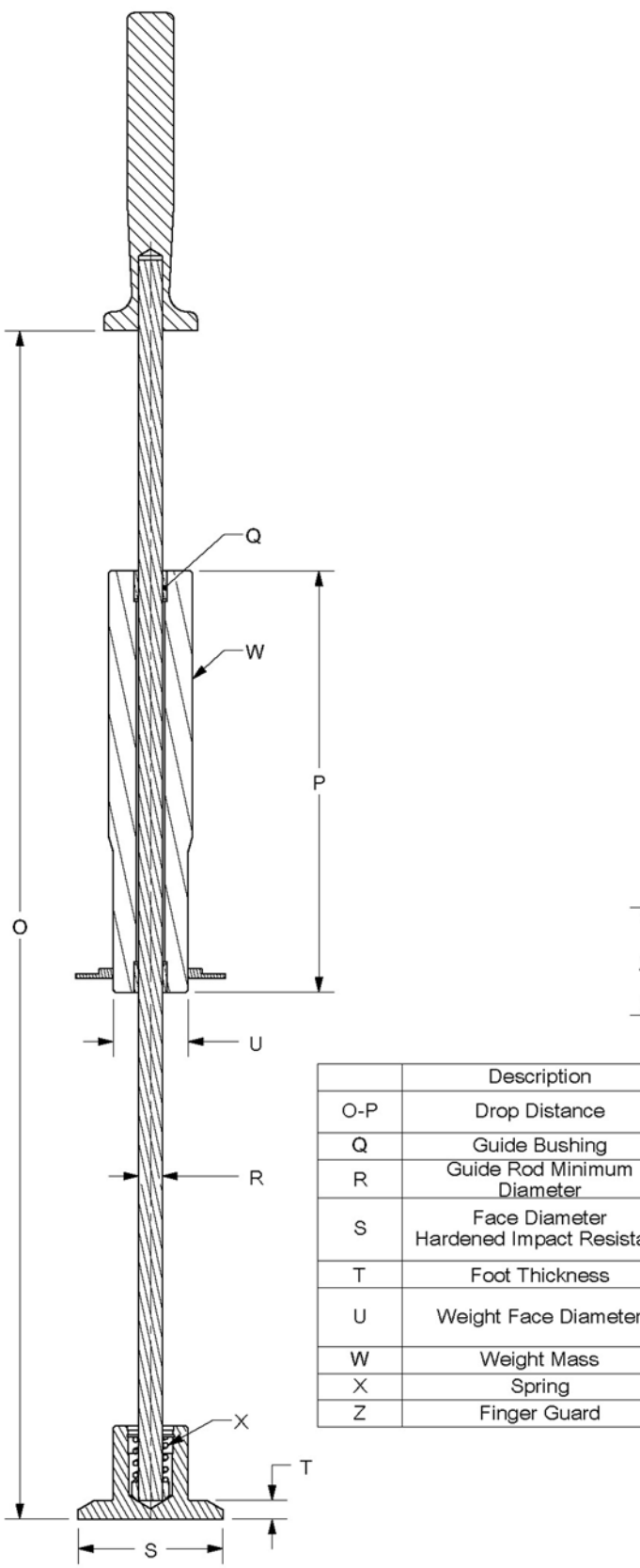

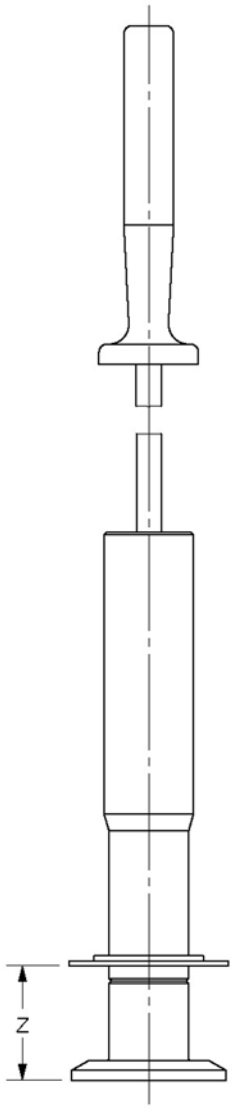

	Description		
O-P	Drop Distance	456.57 - 457.84 mm	(17.975 -18.025 in)
Q	Guide Bushing	-	-
R	Guide Rod Minimum Diameter	15.875 mm	(.625 in)
S	Face Diameter Hardened Impact Resistant	100.08 - 100.58 mm	(3.950 - 3.960 in)
T	Foot Thickness	11.43 - 13.97 mm	(0.450 - 0.550 in)
U	Weight Face Diameter	49.78 - 51.82 mm	(1.960 - 2.040 in)
W	Weight Mass	4.527 - 4.545 kg	(9.98 - 10.02 lb)
X	Spring	-	-
Z	Finger Guard	75 mm	(2.95 in)

FIG. 2 Manual Compaction Hammer

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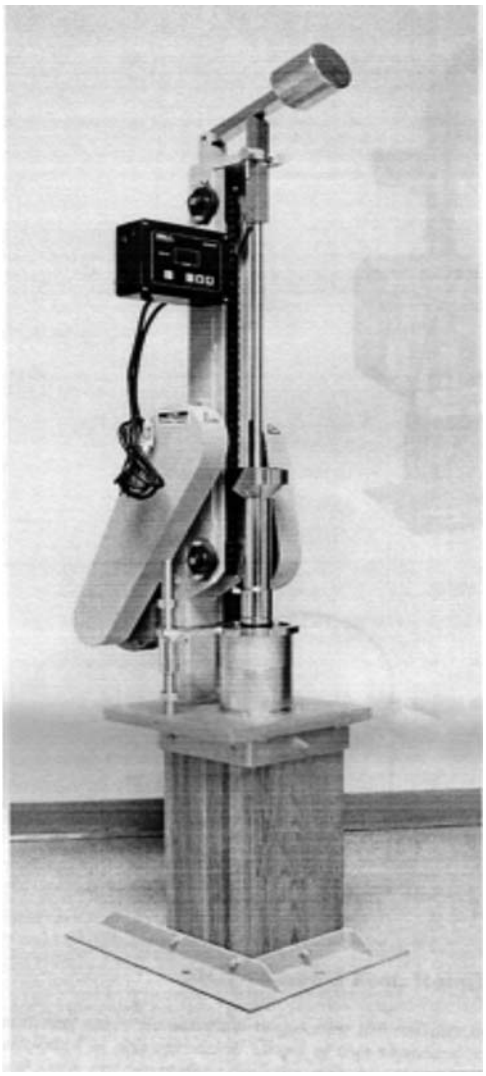

FIG. 3 Typical Mechanical Hammer

bolts through four angle brackets to a solid concrete slab. The steel cap shall be firmly fastened to the post. The pedestal assembly shall be installed so that the post is plumb and the cap is level.

4.5 *Specimen Mold-Holder*—With single hammer compactors, the holder shall be mounted on the compaction pedestal so as to center the compaction mold over the center of the post. Specimen mold-holders of multi-hammer compactors are not necessarily centered. The holders shall hold the compaction mold, collar, and base plate securely in position during compaction of the specimen.

4.6 *Ovens, Heating Pots or Hot Plates*—Circulating air ovens or thermostatically controlled heating pot and hot plates shall be provided for heating aggregates, bituminous material, specimen molds, compaction hammers, and other equipment to within 5°F (3°C) of the required mixing and compaction temperatures. Suitable shields, baffle plates, or sand baths shall be used on the surfaces of the hot plates to minimize localized overheating.

4.7 *Mixing Apparatus*—Mechanical mixing is recommended. Any type of mechanical mixer may be used provided the mix can be maintained at the required temperature and mixing will produce a well-coated, homogeneous mixture of the required amount in the allowable time, and further provided that essentially all of the batch can be recovered. A metal pan or bowl of sufficient capacity for hand mixing may also be used.

4.8 *Miscellaneous Equipment*:

4.8.1 *Containers for Heating Aggregates*, flat-bottom metal pans, or other suitable containers.

4.8.2 *Covered Containers for Heating Bituminous Material*, either gill-type tins, beakers, pouring pots, or saucepans may be used.

4.8.3 *Mixing Tools*, shall consist of a steel trowel (Mason's pointing trowel with point rounded), spoon or spatula, for spading and hand mixing.

4.8.4 *Thermometer(s)*—temperature measuring device(s) readable to 2°F (1°C) for checking mixing and compacting temperatures.

4.8.5 *Calibrated Thermometers*, for determining temperatures of aggregates, bitumen, and bituminous mixtures. Armored-glass or dial-type thermometers with metal stems are recommended. A range from 50 to 400°F (10 to 200°C) with sensitivity of 3°C (5°F) is required.

NOTE 4—Standardization practices specified in Specification D3666 are recommended for the thermometer used in this test method. Dial thermometer may exhibit inaccuracies due to frequently use or mishandling. It is recommended that the standardization of dial thermometers be conducted more frequently by a comparison to a reference thermometric device of equal or greater readability at a temperature within the range of intended use.

4.8.6 *Balance*, readable to at least 0.1 g (0.004 oz (avoir)) for batching mixtures.

4.8.7 *Gloves*, for handling hot equipment.

4.8.8 *Marking Crayons*, for identifying specimens.

4.8.9 *Scoop*, flat bottom, for batching aggregates.

4.8.10 *Spoon*, large, for placing the mixture in the specimen molds.

5. Test Specimens

5.1 *Preparation of Aggregates*—Dry aggregates to constant weight. Oven drying should be done at 105 to 110°C (221 to 230°F). After cooling, separate the aggregates by dry-sieving into the desired size fractions.[3] The following minimum size fractions are recommended:

1 to ¾ in. (25 to 19 mm)
¾ to ½ in. (19 to 12.5 mm)
½ to ⅜ in. (12.5 to 9.5 mm)
⅜ to No. 4 (9.5 to 4.75 mm)
No. 4 to No. 8 (4.75 to 2.36 mm)
Passing No. 8 (2.36 mm)

5.2 *Determination of Mixing and Compacting Temperatures*:

5.2.1 The asphalt cement used in preparing the samples must be heated to produce viscosities of 170 ± 20 cP (0.17 ± 0.02 Pa·s) and 0.28 ± 0.03 Pa·s (280 ± 30 cP) for mixing and compacting, respectively. An example of a viscosity temperature chart is given in Fig. 2 of D2493.

[3] Detailed requirements for these sieves are given in ASTM Specification E11.

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NOTE 5—Selection of mixing and compaction temperatures at viscosities of 170 ± 20 cP (0.17 ± 0.02 Pa·s) and 280 ± 30 cP (0.28 ± 0.03 Pa·s), respectively, may not apply to modified binders. The user should contact the manufacturer to establish appropriate mixing and compaction temperature ranges.

5.2.2 *Cutback Asphalt Mixture*—The temperature to which a cutback asphalt must be heated to produce a viscosity of 170 ± 20 cP (0.17 ± 0.02 Pa·s) shall be the mixing temperature. The compaction temperature for a cutback asphalt mixture is selected using a compositional chart of viscosity versus percent solvent for that cutback asphalt. From the compositional chart, determine the cutback asphalt's percentage of solvent by weight from its viscosity at 140°F (60°C) after it has lost 50 percent of its solvent (for rapid-cure and medium-cure cutbacks) or 20 percent of its solvent (for slow cure cutbacks). The compaction temperature is determined from the viscosity temperature chart as that to which the cutback asphalt must be heated to produce a viscosity of 280 ± 30 cP (0.28 ± 0.03 Pa·s) after losing the specified amount of original solvent.

5.2.3 *Recompacted Paving Mixtures*—Materials obtained from an existing pavement shall be warmed in covered containers in an oven to within 5°F (3°C) of the desired compaction temperature. Heating should only be long enough to achieve desired compaction temperature. If the compaction temperature for a specific mixture is not known, experience has shown that these mixes should be compacted at a temperature between 250°F (120°C) and 275°F (135°C). In preparation for heating to compaction temperature the material should be warmed and worked until a loose mixture condition is obtained. Any cut aggregate can be removed. Stability of reheated and recompacted mixtures from existing pavements is likely to be higher than the original mixture due to in service hardening of the binder. The reheating process will have only minor influence on binder hardening.

5.3 *Mixture Preparation*—Specimens may be prepared from single batches or multiple batches containing sufficient material for three or four specimens.

5.3.1 Weigh into separate containers the amount of each aggregate size fraction required to produce a batch that will result in one, two, three, or four compacted specimens 2.5 ± 0.1 in. (63.5 ± 2.5 mm) in height (about 1200, 2400, 3600 or 4800 g, respectively). Place aggregate batches in containers on a hot plate or in an oven and heat to a temperature above but not exceeding the mixing temperature established in 5.2 by more than 50°F (28°C) for asphalt cement and tar mixes and 25°F (14°C) for cutback asphalt mixes. Charge the mixing container with the heated aggregate and dry mix thoroughly (approximately 5 s) with scoop or spoon. Form a crater in the dry blended aggregate and weigh the required amount of bituminous material at mixing temperature into the mixture. For mixes prepared with cutback asphalt, introduce the mixing blade in the mixing bowl and determine the total weight of the mix components plus bowl and blade before proceeding with mixing. Care must be exercised to prevent loss of the mix during mixing and subsequent handling. At this point, the mixture temperature shall be within the limits of the mixing temperature established in 5.2. Mix the aggregate and bituminous material rapidly until thoroughly coated for approximately 60 s for single-specimen batches and approximately 120 s for multiple-specimen batches.

5.3.2 Condition single batches in covered metal containers in an oven at a temperature 15°F (8°C) to 20°F (11°C) above the compaction temperature established in 5.2 for a minimum of 1 h and a maximum of 2 h.

5.3.3 For multiple batched sample, place the entire batch or sample on a clean non-absorptive surface. Hand mix to ensure uniformity and quarter into appropriate sample size to conform to specimen height requirements. For asphalt cements and tar mixtures, put the samples into metal containers and cover. Place the covered metal containers in a ventilated oven at the temperature established in 5.3.2 to condition for a minimum of 1 h and a maximum of 2 h. Cure cutback asphalt mixture in the mixing bowl in a ventilated oven maintained at approximately 20°F (11°C) above the compaction temperature. Curing is to be continued in the mixing bowl until precalculated weight of 50 % solvent loss or more has been obtained. The mix may be stirred in the mixing bowl during curing to accelerate the solvent loss. However, care should be exercised to prevent mix loss. Weigh the mix during curing in successive intervals of 15 min initially and less than 10 min intervals as the weight of the mix at 50 % solvent loss is approached.

5.3.4 Other bituminous or plant-produced materials may require special curing techniques.

NOTE 6—Heating mixtures for a period of time prior to compaction may result in specimens having properties that are different from those that are compacted immediately after mixing (original Marshall criteria are based on a no-cure procedure).

5.4 *Compaction of Specimens*:

5.4.1 Thoroughly clean the specimen mold assembly and the face of the compaction hammer and heat them either in boiling water, in an oven, or on a hot plate to a temperature between 200 and 300°F (90 and 150°C). Place a piece of nonabsorbent paper, cut to size, in the bottom of the mold before the mixture is introduced. Place the mixture in the mold, spade the mixture vigorously with a heated spatula or trowel 15 times around the perimeter and 10 times over the interior. Place another piece of nonabsorbent paper cut to fit on top of the mix. Temperature of the mixture immediately prior to compaction shall be within the limits of the compaction temperature established in 5.2.

5.4.2 Place the mold assembly on the compaction pedestal in the mold holder and apply the required number of blows with the specified compaction hammer. Remove the base plate and collar and reverse and reassemble the mold. Apply the same number of compaction blows to the face of the reversed specimen. After compaction, remove the collar and base plate. Allow the specimen to cool sufficiently to prevent damage and extract the specimen from the mold. Cooling specimens in the mold can be facilitated by immersion in cold water. To facilitate extraction, the mold and specimen can be briefly immersed in a hot water bath to heat the metal mold and reduce specimen distortion. Carefully transfer specimens to a smooth, flat surface and allow to cool at room temperature (this may be overnight). A fan can be used to facilitate cooling.

5.4.2.1 When compaction is accomplished with a manually held and operated hammer, hold the axis of the compaction

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hammer by hand, as nearly perpendicular as possible to the base of the mold assembly during compaction. In this original Marshall procedure, no mechanical device of any kind shall be used to restrict the handle of the hammer in the vertical position during compaction.

NOTE 7—Hammer shaft should be clean and lightly oiled.

6. Report

6.1 The report shall include at least the following information:

6.1.1 Sample identification (number, laboratory mixed, or plant mixed, and so forth),

6.1.2 Type of bituminous material, source, and content,

6.1.3 Type(s) of aggregate, source, and grading,

6.1.4 Type and time of curing prior to compaction,

6.1.5 Type of hammer (that is, manually held or fixed and mechanically or manually operated hammer and flat or slanted foot),

6.1.6 Number of blows/side,

6.1.7 Mixing temperature,

6.1.8 Compaction temperature, and

6.1.9 Type and time of cooling.

7. Precision

7.1 A precision statement is not applicable to this practice. Specimens should be accepted or rejected for further testing based on requirements of the criteria being applied. For Marshall stability, and flow determination according to Practice D6926, use only those replicate specimens which have bulk specific gravities within ±0.020 of the mean.

NOTE 8—For two specimens prepared by laboratories participating in a AMRL reference testing program, the single operator 1s and the acceptable difference of two results, d2s, for the bulk specific gravity were 0.007 and 0.020, respectively Results of these tests are available as a research report.

8. Keywords

8.1 bituminous mixtures; laboratory compaction; Marshall test

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