CRD-C 649-95

Standard Test Method for Unit Weight, Marshall Stability, and Flow of Bituminous Mixtures*

1. Scope.

1.1 This test method is applicable for evaluation of all well-graded hot-mix bituminous pavement mixtures in which not more than 10 percent of the aggregate is retained on a 25.0.mm (l-in.) sieve. This test method is intended to be used for the determination of stability and flow of laboratory-prepared samples.

2. Apparatus.

2.1 A Marshall compaction mold and holder meeting the requirements shown in Figure 1. The mold holder shall be mounted on the compaction pedestal so that the center of the compaction mold is over the center of the post. The holder shall hold the compaction mold, collar, and baseplate securely in position during compaction of the specimen.

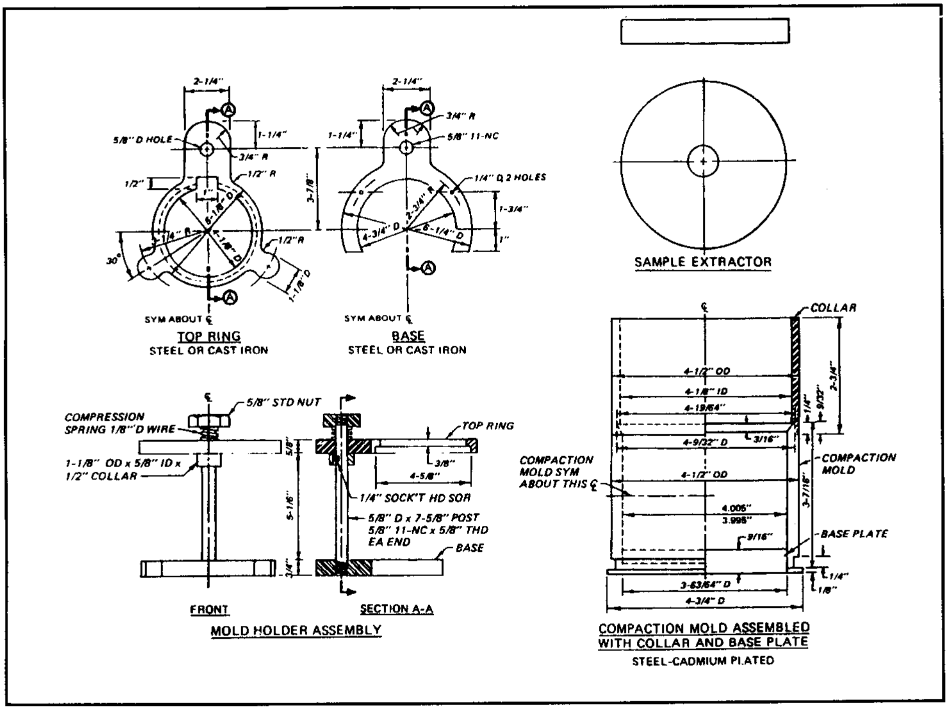

Figure 1. Marshall compaction mold and mold holder

*Formerly MIL-STD-620A, Method 100, 13 January 1996.

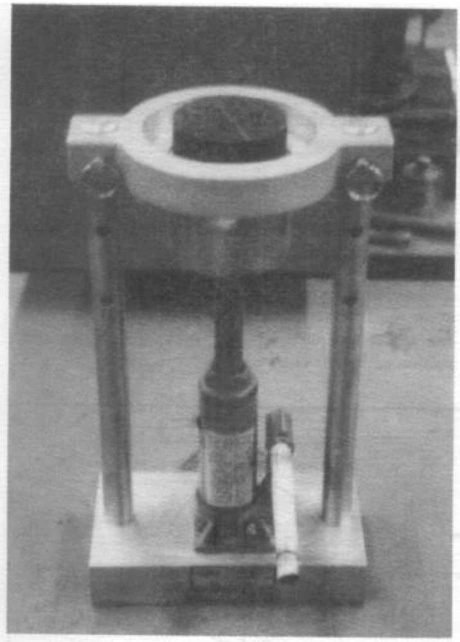

Figure 2. Specimen extractor

2.2 A specimen extractor (Figure 2) for removing the compacted specimen from the mold cylinder.

2.3 A compaction hammer (Figure 3) having a flat, circular tamping face and a 10 ± 0.0l-lb sliding mass with a free fall of 18 ± 0.025 in. For quality control or assurance work, it is recommended that two compaction hammers be available in case one is damaged.

Note: Mechanical hammers may be used when properly correlated with the standard hand hammer by determining the number of blow necessary with the mechanical hammer to produce the same density as that produced by the specified number of blows with the hand hammer. Some mechanical hammers marketed cannot reproduce the compactive effort of the hand hammer regardless of the number of blows applied.

2.4 A pedestal, on which to anchor the mold during compaction of the test specimen, consisting of a timber post having a minimum cross section of 8 by 8 in. and a height of 18 ± 1 in. capped with a 12- by 12- by l-in. steel plate. Arrangements shall be made for placing the compaction mold directly over the 8- by 8-in. post. The compaction pedestal must be securely anchored to a concrete slab resting on the ground, or directly over an interior building column or similar location. Wooden floors or unsupported areas of concrete floors are unsuitable supports for the compaction pedestal. The use of a pedestal in accordance with these requirements is very important; otherwise, the

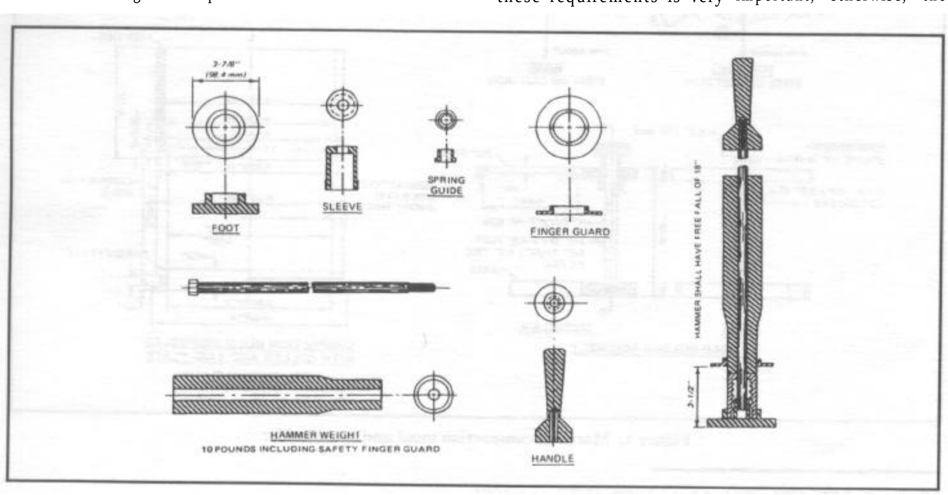

Figure 3. Compaction hammer

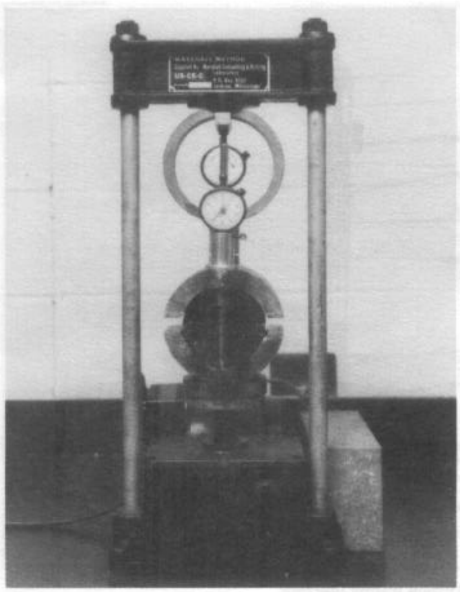

Figure 4. Marshall stability test apparatus

compaction obtained will not establish the proper density requirements for field compactton.

2.5 A breaking head (Figures 4 and 5) consisting of upper and lower cylindrical segments or test heads that have an accurately machined inside radius of curvature of 2.0000 ± 0.0025 in. The lower segment shall be mounted on a base having two perpendicular guide rods or posts extending upward. Guide sleeves in the upper segment shall be positioned so that the two segments are directed together without appreciable binding or loose motion on the guide rods.

2.6 A loading devise (Figures 4 and 6) consisting of a motor, mounted in a testing frame, that will produce a uniform vertical movement of 2.00 ± 0.05 in. per minute.

Note: A mechanical or hydraulic testing machine (Figure 7) may be used if the rate of movement can be maintained at 2.00 ± 0.05 in. per minute while the load is applied.

2.7 The proving ring (Figures 4 and 6) of 5,000 lbf capacity and sensitivity of 10 lbf for loads up to 1,000 lbf and 25 lbf for loads between 1,000 and 5,000 lbf. The micrometer dial on the proving ring shall be graduated in 0.00001-in. increments. Upper and lower proving ring attachments are required for fastening the

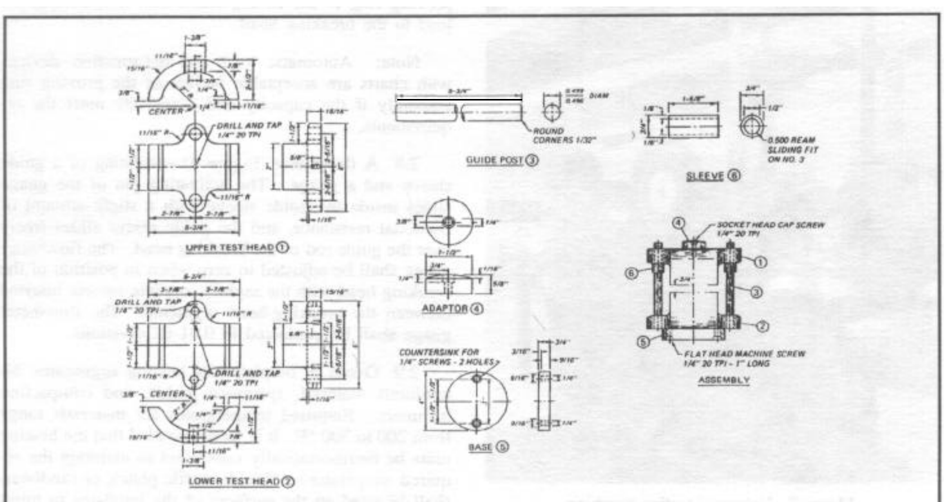

Figure 5. Marshall breaking head

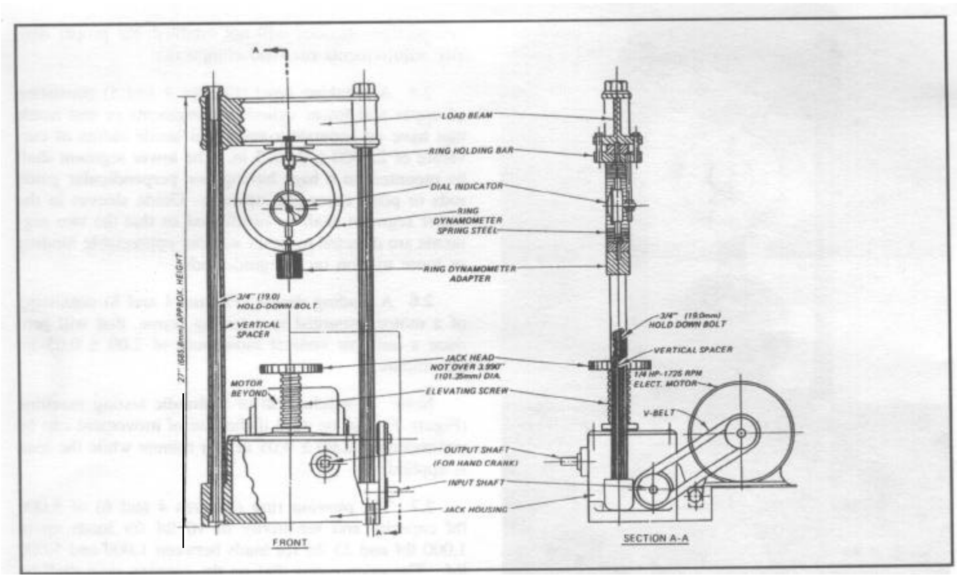

Figure 6. Marshall compression testing machine

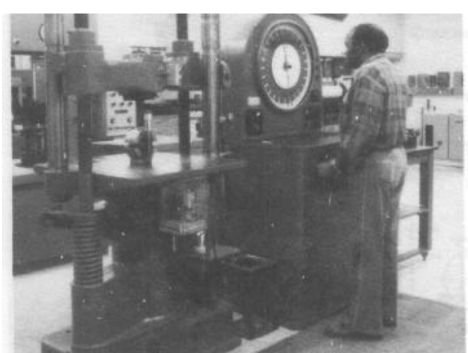

Figure 7. Universal testing machine

proving ring to the testing frame and transmitting the load to the breaking head.

Note: Automatic load and deformation devices with charts are acceptable in lieu of the proving ring assembly if the capacity and sensitivity meet the requirements.

2.8 A flowmeter (Figure 4) consisting of a guide sleeve and a gauge. The activating pin of the gauge slides inside the guide sleeve with a slight amount of frictional resistance, and the guide sleeve slides freely over the guide rod of the breaking head. The flowmeter gauge shall be adjusted to zero when in position of the breaking head with the asphalt concrete sample inserted between the breaking-head segment% The flowmeter gauge shall be graduated in 0.01-in. divisions.

2.9 Ovens or hotplates for heating aggregates, bituminous material, specimen molds, and compaction hammers. Required temperatures for materials range from 200 to 300 °F. It is recommended that the heating units be thermostatically controlled to maintain the required temperatures. Shields, baffle plates, or sandbaths shall be used on the surfaces of the hotplates to minimize localized overheating.

Figure 8. Mechanical mixer

2.10 *A metal pan or bowl.* Hand mixing may be used: however, mechanical mixing is recommended (Figure 8). Any type of mechanical mixer may be used if the required mixing temperature can be maintained and a well-coated homogeneous mixture can be produced in the allowable time. Two 10-qt mixing bowls and two wire stirrers are recommended.

2.11 A water bath (Figure 9) at least 6 in. deep provided with mechanical water agitator, heating elements, and thermostatic controls capable of maintaining the bath water at temperatures ranging from 100 to 140 °F. The bath shall have a perforated false bottom or be equipped with a shelf for supporting specimens 2 in. above the bottom of the bath.

Note: Some water baths marketed are not equipped with agitators and will not maintain the 140 ± 1 °F temperature requirement.

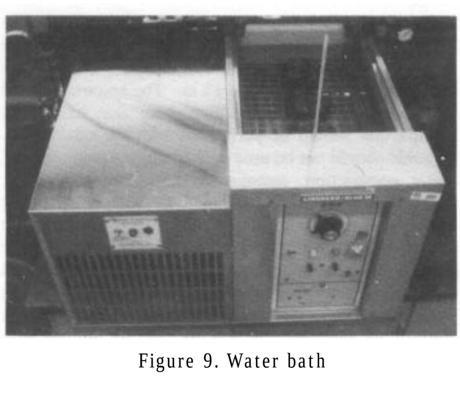

Figure 9. Water bath

2.12 Any type of mechanical sieve shaker provided it has a capacity of six full-height, 8-in.-diameter sieves.

2.13 *Sieves.* Sieves of 8-in. diameter and of the following sizes are required: 25.0-mm, 19.0-mm, 12.5-mm, 9.5-mm, 4.75-mm, 2.36-mm, 1.18-mm, 600-µm, 150-µm, 300-µm, and 75-µm (l-in., 3/4-in., 1/2-in., No. 4, No. 8, No. 16, No. 30, No. 50, No. 100, and No. 200). The sieves shall conform to the requirements of ASTM E Il. Large, rectangular-shaped screens and shaking facilities are recommended for preparation of large samples.

2.14 One sink with cold running water is required to cool molded specimens prior to extrusion from the mold cylinder.

2.15 *Appurtenant equipment.*

(a) Containers for heating aggregates, such as flat-bottom metal pans, or other suitable containers.

(b) Containers for heating bituminous material, such as metal cups, beakers, or pouring pots.

(c) Mixing tools, either steel trowel (garden type) or spatula, for spading and handmixing.

(d) Thermometers for determining temperatures of aggregates, bitumen, and bituminous mixtures. Armored glass thermometers or dial-type with metal stem are recommended. They must have a range of 50 to 400 °F with a sensitivity of 5.0 °F.

(e) Thermometers for water bath with a minimum range of 99 to 141 °F and graduated to 0.5 °F.

(f) Balance, 2-kg capacity, sensitive to 0.1 g, for weighing molded specimens.

(g) Balance, 20-kg capacity, sensitive to 1.0 g, for preparing bitumen and aggregate mixtures.

(h) Wire basket and water bucket suitable for weighing molded specimens in water.

(i) Gloves for handling hot equipment.

(j) rubber gloves for removing specimens from water bath.

(k) Marking crayons for identifying specimens.

(l) Scoop, 2-qt size, for handling hot aggregates.

(m) Scoop, flat bottom, for placing mixture in specimen molds.

3. Preparation of Specimens.

3.1 *Preparation of aggregates.* Dry aggregates to constant weight at 230 ± 9 °F and separate the aggregates by sieving into the desired sieve fractions. The following separations are recommended for paving mixtures having 19.0-mm (3/4-in.) nominal maximum size aggregate: 19.0-9.5-mm (3/6 3/8-in.). 9.5.mm 4.75-mm (3/8-in. to No. 4), 4.75-mm 2.36-mm (No. 4 to No. 8), and finer than 2.36-mm (No. 8). Aggregate separation may be accomplished in a large, processing-type sieve shaker, a standard mechanical sieve shaker, or a rocker-type hand shaker.

3.2 *Preparation of mixtures.* Weigh into individual pans the amount of each size fraction required to produce a batch that will result in the desired number of compacted specimens, each 2.5 ± 0.125 in. in height. This will require approximately 1,200 g of blended aggregate per specimen. Figure IO illustrates the form recommended for recording these laboratory batch weights. Place the pans on the hotplate or in the oven, and heat to the temperatures indicated in this tabulation.

Bituminous Mixture Weights

Job No.: | W/R No.: | Date: 3 June 1994

Project: Typical Mix

Description of Blend Used: Stockpile Samples

Type of Bitumen: AC 20 Asphalt

Aggr Temp: 300°F | Bitumen Temp: 270°F | Comp Temp: 250°F

Blend No.						
Aggr Size	Per Cent	Weights		Per Cent	Weights	Accumulative Weights
Coarse	34.9	418.8				
			Aggregate	96.0	1200	1250
Fine	55.1	661.2	Bitumen	4.0	50	
N. Sand	10.0	120.0	Aggregate	95.5	1200	1256
			Bitumen	4.5	56	
			Aggregate	95.0	1200	1263
			Bitumen	5.0	63	
			Aggregate	94.5	1200	1270
			Bitumen	5.5	70	
			Aggregate	94.0	1200	1277
			Bitumen	6.0	77	
			Aggregate	93.5	1200	1283
			Bitumen	6.5	83	
			Aggregate			
			Bitumen			
			Aggregate			
			Bitumen			
			Aggregate			
			Bitumen			
Total	100.0	1200				

Computed by: RTG | Checked by: RRJ | Aggr blend prepared by: DR | Mix prepared by: JKS | Compacted by: JKS

WES Form 965
May 1957

Figure 10. Bituminous mixture weights

	Mixing Temperature	
Type Bitumen	Aggregate	Bitumen
Asphalt cement	300 ± 5 °F	270 ± 5 °F
Tar, RT-10, -11, -12, or -14	225 ± 5 °F	200 ± 5 °F

Charge the heated aggregate into the heated mixing bowl, and mix the dry aggregate thoroughly. Form a crater in the dry blended aggregate, and add the required weight of bitumen at the required temperature. Mix the aggregate and the bituminous material rapidly until the aggregate is thoroughly coated. Mixing should be completed as quickly as possible to minimize heat loss.

3.3 *Compaction of specimens.* Thoroughly clean the specimen mold assembly and the face of the compaction hammer, and heat them either in hot water on a hotplate or in an oven to a temperature between 180 and 250 °F. Place a piece of filter paper, paper towel, or kraft paper cut to size in the bottom of the mold before the mixture is introduced. Place the mixture in the mold, and spade with a heated spatula or trowel around the perimeter. Remove the collar, and smooth the surface of the mix with a trowel to a slightly rounded shape. Temperatures of the mixtures immediately prior to compaction shall be:

Type Bitumen	Compaction Temperature
Asphalt cement	250 ± 5 °F
Tar, RT-10, -11, -12, or -14	180 ± 5 °F

Replace the collar, place the mold assembly on the compaction pedestal in the mold holder, and apply the appropriate number of blows with the compaction hammer using a free fall of 18 in. The hammer should be held in a vertical position with one hand, and compaction should be performed with the other hand. A guide should not be used to hold the hammer vertical. After compaction, remove the baseplate and collar, invert the sample, and reassemble the mold. Apply the same number of compaction blows to the face of the inverted specimen. Fifty blows on each side of the specimen are used for mix design for roads, streets, and facilities for aircraft with tires inflated to 100 psi or less; 75 blows on each side of the specimen are used for mix designs for facilities that will be used by aircraft with tire pressures greater than 100 psi and for heavy duty roads such as those carrying tank traffic. After compaction, remove the baseplate and immerse the mold containing the specimen in cool water for not less than 2 min. Remove specimen from mold by means of a sample extractor and a suitable jack and frame arrangement. After removal from the mold, carefully transfer the specimen to a smooth, flat surface and allow the sample time to dry and cool to approximately room temperature. Auxiliary cooling, such as an electric fan or water bath, may be used to reduce cooling time.

4. Test Procedures.

4.1 *Density determination.* Weigh the specimen in air and in clean water at a temperature of 77 ± 1.8 °F. The difference between the two weights in grams gives the volume in cubic centimeters. The specific gravity of the specimen (density in Mg/m^3) is determined by dividing the weight of the specimen (in air) in grams by the volume in cubic centimeters. The density (in lb/ft^3) is calculated by multiplying the specific gravity by 62.4. Open-textured or porous specimens will absorb water, giving an erroneous result when weighed in water. Therefore, it is recommended that the specimen be reweighed in air (after blotting excess water with a cloth or paper towel) directly after weighing in water and correction made for absorbed water (Figure 11). Figure 12 is the form recommended for recording density and other required data.

4.2 *Determination of stability and flow.* Bring the specimen to the test temperature indicated in the following tabulation by immersing in the water bath for 20 to 40 min. Thoroughly clean the guide rods and the inside surfaces of the test heads, and lubricate the guide rods so that the upper test head slides freely over them.

Type Bituminous Material	Marshall Stability Test Water Temperature
Asphalt	140 ± 1 °F
Tar	100 ± 1 °F

Remove the specimen from the water bath and place it in the lower segment of the breaking head. Between tests, the testing head temperature shall be maintained between 70 and 140 °F, using a water bath when necessary. Place the upper segment of the breaking head on the specimen, and place the complete assembly in position on the testing machine. Figures 4 and 7, respectively, show the Marshall test apparatus and the Universal testing machine using the Marshall breaking head. When using the marshal1 apparatus, place the flowmeter in position over one of the guide rods, and hold the sleeve firmly against the upper segment of breaking head while the load is applied. Adjust the flowmeter to 0 prior to the start of the test. When using the Universal machine, an extensometer is normally used. Apply load to the specimen at a constant rate of 2.00 in. per min. until the maximum load is reached and the load begins to decrease. Record the maximum load. Remove the flowmeter from its position over the guide rod the instant the load begins to decrease. Note and record the indicated flow value. Elapsed time for the test from removal of test specimen from the water bath to the maximum load determination shall not exceed 30 sec. Correct the load for variations from the standard 2.5-in. length by using the proper multiplying factor from Table I.

5. Calculations and Report.

A summary of computations, such as that shown in Figure 12, shall be prepared.

WEIGHT AND VOLUME DETERMINATION FOR SLIGHTLY POROUS BITUMINOUS PAVEMENT SAMPLES

JOB NO.: PROJECT: TYPICAL MIX DATE: 4 JUNE 1963

SPECIMEN NUMBER	BITUMEN CONTENT %	INITIAL WEIGHT IN AIR	WEIGHT IN WATER	SECOND WEIGHT IN AIR	ABSORPTION	CORRECTED WEIGHT IN WATER	VOLUME
		A	B	C	D (C - A)	E (B - D)	F (A - E)
L-10-7	4.5	1,248.6	741.6	1,257.8	9.2	732.4	516.2

TECHNICIAN: DR COMPUTER: JKS CHECKED: RTG

Figure 11. Correction for absorbed water in density calculations

6. Safety Precautions.

Local exhaust ventilation (e.g., lab hoods: must be provided when bituminous materials are heated, since heating may produce polynuclear aromatic compounds. Such compounds are known carcinogens.

COMPUTATION OF PROPERTIES OF BITUMINOUS MIXTURES

JOB NO.: | PROJECT: | DESCRIPTION OF BLEND: | DATE:

SPECIMEN NO.	BITUMEN CONTENT - %	THICKNESS IN.	WEIGHT - GRAMS IN AIR	WEIGHT - GRAMS IN WATER	VOLUME CC	SPECIFIC GRAVITY ACTUAL	SPECIFIC GRAVITY THEOR.	BITUMEN BY VOLUME - %	VOIDS - PER CENT TOTAL MIX	VOIDS - PER CENT AGG ONLY	VOIDS - PER CENT FILLED	UNIT WEIGHT LB/CU FT TOTAL MIX	UNIT WEIGHT LB/CU FT AGG ONLY	STABILITY PR.RING	STABILITY MEASURED LB	STABILITY CONVERTED LB	FLOW 1/100"
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	R	S
					(D-E)	(D)/(F)		B×G / SP. GR. OF BITUMEN *	(100-100 G/H)	I + J	I/K × 100	G×62.4	M(100-B)/100			**	
1	4.0		1231.0	717.4	513.6	2.397									1610	1610	10
2			1242.4	722.4	520.0	2.389									1760	1760	12
3			1223.5	710.5	513.0	2.385									1670	1670	10
Avg						2.390	2.565	9.3	6.8	16.1	57.8	149.1				1680	11
1	4.5		1236.8	722.9	513.9	2.407									2060	2060	12
2			1221.0	712.6	508.4	2.402									1990	2070	11
3			1232.5	720.9	511.6	2.409									1740	1740	10
Avg						2.406	2.545	10.5	5.5	16.0	65.6	150.1				1957	11
1	5.0		1185.1	695.3	489.8	2.420									1890	2060	12
2			1233.7	721.4	512.3	2.408									1840	1840	11
3			1239.9	727.6	512.3	2.420									1990	1990	12
Avg						2.416	2.525	11.8	4.3	16.1	73.3	150.8				1963	12
1	5.5		1243.7	732.4	511.3	2.432									2165	2165	13
2			1245.3	734.4	510.9	2.437									2100	2100	14
3			1241.2	732.8	508.4	2.441									2220	2339	14
Avg						2.437	2.506	13.0	2.8	15.8	82.3	152.1				2191	14

** FROM CONVERSION TABLE | COMPUTED BY: RTG | CHECKED BY: RRJ

WES FORM 883 — *SP. GR. OF BITUMEN 1.028

Figure 12. Computation of properties of bituminous mixtures

COMPUTATION OF PROPERTIES OF BITUMINOUS MIXTURES

JOB NO.: | PROJECT: | DESCRIPTION OF BLEND: | DATE:

SPECIMEN NO.	BITUMEN CONTENT - %	THICKNESS IN.	WEIGHT - GRAMS IN AIR	WEIGHT - GRAMS IN WATER	VOLUME CC	SPECIFIC GRAVITY ACTUAL	SPECIFIC GRAVITY THEOR.	BITUMEN BY VOLUME - %	VOIDS - PER CENT TOTAL MIX	VOIDS - PER CENT AGG ONLY	VOIDS - PER CENT FILLED	UNIT WEIGHT LB/CU FT TOTAL MIX	UNIT WEIGHT LB/CU FT AGG ONLY	STABILITY PR.RING	STABILITY MEASURED LB	STABILITY CONVERTED LB	FLOW 1/100"
A	B	C	D	E	F	G	H	I	J	K	I	M	N	O	P	R	S
					(D-E)	(D)/(F)		B×G / SP. GR. OF BITUMEN *	(100-100 G/H)	I + J	I/K × 100	G×62.4	M(100-B)/100			**	
1	6.0		1244.7	730.8	513.9	2.422									1975	1975	13
2			1244.1	731.8	512.3	2.428									1890	1890	14
3			1248.7	735.1	513.6	2.431									2090	2090	15
Avg						2.427	2.487	14.2	2.4	16.6	85.4	151.5				1985	14
1	6.5		1126.6	721.1	505.5	2.427									1470	1529	19
2			1213.7	713.3	500.4	2.425									1500	1560	18
3			1224.8	719.5	505.3	2.424									1275	1846	18
Avg						2.425	2.468	15.3	1.7	17.0	89.5	151.3				1645	18

** FROM CONVERSION TABLE | COMPUTED BY: RTG | CHECKED BY: RRJ

WES FORM 883 — *SP. GR. OF BITUMEN 1.028

Figure 12. (Concluded)

Table I. Stability-correlation ratio

Volume[1] of specimen in cubic centimeters	Approximate thickness of specimen, in.	Correlation ratio
200-213	1.00	5.56
214-225	1.06	5.00
226-237	1.13	4.55
238-250	1.19	4.17
251-264	1.25	3.85
265-276	1.31	3.57
277-289	1.38	3.33
290-301	1.44	3.03
302-316	1.50	2.78
317-328	1.56	2.50
329-340	1.63	2.27
341-353	1.69	2.08
354-367	1.75	1.92
368-379	1.81	1.79
380-392	1.88	1.67
393-405	1.94	1.56
406-420	2.00	1.47
421-431	2.06	1.39
432-443	2.13	1.32
444-456	2.19	1.25
457-470	2.25	1.19
471-482	2.31	1.14
483-495	2.38	1.09
496-508	2.44	1.04
509-522	2.50	1.00
523-535	2.56	0.96
536-546	2.63	0.93
547-559	2.69	0.89
560-573	2.75	0.86
574-585	2.81	0.83
586-598	2.88	0.81
599-610	2.94	0.78
611-625	3.00	0.76
626-637	3.06	0.74
638-649	3.13	0.71
650-662	3.19	0.69
663-676	3.25	0.68

Note: The measured stability of a specimen multiplied by the correlation ratio determined for the thickness of the specimen equals the corrected stability for a 2.5-in. specimen.

[1]Volume-thickness relation is based on a specimen diameter of 4 in. Thicknesses shown in Table I are for use when tests are conducted on specimens whose dimensions vary from the desired 2.5 ± 0.125 in. in height.