

**METHODS OF SAMPLING AND TESTING**  
**MT 311-04**  
**MARSHALL METHOD FOR FIELD CONTROL**  
**OF HOT MIX ASPHALT PAVING**  
*(Montana Test Method)*

**1 Scope:**

- 1.1 This method of test is to be used for specifying, obtaining, and maintaining the best possible physical or structural properties of asphalt hot mix paving.
- 1.2 The method is applicable to hot mix asphalt paving mixtures using penetration grades of asphalt cement and containing aggregates with maximum sizes of 25.4 mm (one inch).

**2 Compaction Equipment:**

- 2.1 *Compaction pedestal* - consisting of a 203.2 x 203.2 x 457.2 mm (8 inch x 18 inch) wooden post capped by a 304.8 x 304.8 x 25.4 mm (12 inch x 12 inch x 1 inch) steel plate. The post should be placed on a 609.6 x 609.6 x 101.6 mm (24 inch x 24 inch x 4 inch) concrete block so it is plumb, the top is level and the entire assembly is free from movement during use. Double or triple hammer compactors will require an appropriately larger base.
  - 2.1.1 Prior to compaction, a quantity of the bituminous mixture shall be obtained in order to form a pad upon which to place the compaction pedestal or the jack used to support the floor of the test trailer beneath the compaction pedestal.
- 2.2 *Compaction mold* - consisting of a base plate, forming mold and collar extension. The forming mold shall have an inside diameter of 101.6 mm  $\pm$  0.13 mm (4  $\pm$  0.005 inches) and a height of approximately 76.2 mm (3 inches); the base plate and collar are designed to be interchangeable with either end of the forming mold.
- 2.3 *Compaction hammer* - consisting of a flat, circular, tamping face 98.425 mm (3.875 inches) in diameter and equipped with a 4,536  $\pm$  9 g (10  $\pm$  0.02 lb.) sliding weight constructed to obtain a specified 457.2 mm (18 inch) height of drop.
- 2.4 *Mold holder* - consisting of a spring tension device designed to hold compaction mold in place on compaction pedestal.
- 2.5 *Extrusion jack* - or arbor press, for extruding compacted specimens from the mold.
- 2.6 *Jack* - for supporting floor of test trailer beneath compaction pedestal.

**3 Securing Sample:**

- 3.1 Samples of the bituminous paving mixtures shall be obtained in accordance with MT-303.
- 3.2 The sample should be large enough to provide sufficient material to mold a minimum of two specimens (approximately 1150 gms, each).
- 3.3 Record on the work sheet the stationing, lift, and lane where the load, representing the sample, was placed.

**4 Preparation of the Mold and Hammer:**

- 4.1 Thoroughly clean the specimen mold assembly and the face of the compaction hammer and heat them in boiling water or on the hot plate to a temperature between 93.3 and 148.8°C (200 and 300°F). Place a piece of filter paper or paper toweling, cut to size, in the bottom of the mold before the mixture is placed in the mold.

**5 Compaction Temperature:**

- 5.1 Place a thermometer in the sample until the reading stabilizes and record the reading.
- 5.2 Select the compaction temperature so that the viscosity of the asphalt is  $280 \pm 30 C_{st}$ , as obtained by using the temperature viscosity charts in MT-308.

**6 Compaction of Specimen:**

- 6.1 Place a sufficient amount of the mixture, at approximately the temperature prescribed in paragraph 5.2 (Note 1) in the mold to produce a compacted briquette approximately  $63.5 \pm 1.27$  mm ( $2.5 \pm 0.05$  inches) high. Spade the mixture vigorously with a heated spatula or trowel 15 times around the perimeter and 10 times through the interior. Care should be taken so that an excess of coarse aggregate is not segregated to the surface or the face of the specimen will be rough and have higher voids than the interior of the specimen.

*Note 1 - Do not attempt to increase the temperature of the mixture by heating. If mixture is below temperature required, a new sample must be taken.*

- 6.2 Remove the collar and smooth the surface to a slightly rounded shape.
- 6.3 Replace the collar and place a filter on top of the mixture prior to compaction.
- 6.4 Place the mold assembly on the compaction pedestal in the mold holder, and, unless otherwise specified, apply 50 or 75 blows with the compaction hammer with a free fall of 457.2 mm (18 inches). Hold the axis of the compaction hammer perpendicular to the base of the mold assembly during compaction.
- 6.5 Remove the base plate and collar, and reverse and reassemble the mold.
- 6.6 Apply the same number of compaction blows to the face of the reversed specimen.
- 6.7 After compaction is completed, air cool the specimen by the use of fans for 30 minutes.
- 6.8 Remove the specimen from the mold by means of an extrusion jack or other compression device, and place on a smooth, level surface until ready for testing.
- 6.9 Form a second specimen, as rapidly as possible, in the same manner as described in paragraph 6.1 through 6.8

**7 Test Procedure:**

- 7.1 Each finally compacted test specimen is subjected to the following tests and analysis in the order listed:

Bulk Specific gravity Determination  
Stability and Flow Test  
Density and Voids Analysis

**8 Equipment Necessary for Testing Specimens:**

- 8.1 Marshall Testing Machine – An electrically powered testing device, for determining the compressive strength and a Marshall flow meter for determining the maximum strain at the maximum load for test.
- 8.2 Water Bath – At least 152.4 mm (6 inches) deep and thermostatically controlled to  $60 \pm 1^{\circ}C$  ( $140 \pm 1.8F$ ).

## 9 Bulk Specific Gravity of a Compacted Bituminous test Specimen:

9.1 The bulk specific gravity of a compacted specimen may be obtained by computing the ratio of its weight in air to its bulk in volume (including both permeable and impermeable voids normal to the material). The bulk volume may ordinarily be determined by weighing the specimen in water, then weighing the saturated surface-dry specimen in air, and calculating the difference. The equipment necessary to conduct this test is as follows:

9.2 *Balance* – A balance having a minimum capacity of 2 kg and sensitive to 0.1 g or less.

9.3 *Wire Basket* – A wire basket constructed to hold the test specimen while it is being weighed while immersed in water.

9.4 *Container* – sufficient to contain specimen with overflow device, for immersing the wire basket in water and maintaining a constant water level.

9.5 *Suspension Apparatus* – for suspending the wire basket from the center of a scale pan of the balance.

9.6 *Cloth Towel* – for blotting excess water from the specimen after weighing in water.

9.7 Weigh the specimen in air on the balance to the nearest 0.1 g and record this weight as “A”. Weigh the specimen suspended in the basket and immersed for three to five minutes in a water bath at  $25 \pm 1^\circ\text{C}$  ( $77 \pm 1.8^\circ\text{F}$ ). Weigh to the nearest 0.1 g and designate this weight as “C”. Remove the specimen from the water, surface dry by blotting with a damp towel, weigh the surface-dry specimen in air to the nearest 0.1 g, and designate this weight as “B”.

9.8 Calculate the bulk specific gravity of the test specimen as follows:

$$\text{Bulk Specific Gravity} = \frac{A}{B - C}$$

where:

A = weight of specimen in air,

B = weight of saturated surface dry specimen in air, and

C = weight of specimen in water

## 10 Stability and Flow Equipment:

10.1 *Breaking Head* - consisting of upper and lower cylindrical segments or test heads having an accurately machined radius of curvature of 50.8 mm (2 in.). The lower segment will be mounted on a base having two perpendicular guide rods or posts extending upward. Guide sleeves in the upper segment will position the two segments together without appreciable binding or loose motion on the guide rods.

10.2 *Loading Jack* - consisting of a screw jack mounted in a testing frame to produce a uniform vertical movement of 50.8 mm (2 in.) per minute. An electric motor may be attached to the jacking mechanism.

**Note 2** – *Instead of the Loading Jack, a mechanical or hydraulic testing machine may be used provided the rate of movement can be maintained at 50.8 mm (2 in.) per minute while the load is applied.*

10.3 *Ring Dynamometer Assembly* - of 22.2 KN (5,000 lbf) capacity and sensitive to 44.5 N (10 lbf) up to 4.45 (1,000 lbf) and 111.2 N (25 lbf) between 4.45 and 22.2 KN (1,000 and 5,000 lbf) and equipped with a micrometer dial. The micrometer dial will be graduated in 0.0025 mm (0.0001 in.). Upper and lower ring dynamometer attachments are required for fastening the ring dynamometer to the testing frame and transmitting the load to the breaking head.

**Note 3** – *Instead of the ring dynamometer assembly, any suitable load measuring device may be used provided the capacity and sensitivity meet the above requirements.*

**10 Stability and Flow Equipment:** (continued)

**10.4** *Flowmeter* - consisting of a guide sleeve and gage. The activating pin of the gage shall slide inside the guide sleeve with a slight amount of frictional resistance. The guide sleeve must slide freely over the guide rod of the breaking head. When each individual test specimen is inserted between the breaking head segments, the flowmeter gage will be adjusted to zero when placed in position on the breaking head. Graduations of the flowmeter gage will be 0.25 mm (0.01 in.) divisions.

**Note 4** – *Instead of the flowmeter, a micrometer dial or stress-strain recorder graduated in 0.25 mm (0.01 in.) may be used to measure flow.*

**11 Stability and Flow Tests:**

**11.1** Place an old briquette in the 140°F water bath for five minutes. Place it in the breaking head and center breaking head in the loading device. Warm the Marshall Proving Ring by flexing it three times from 2.54 mm to 5.08 mm (0.100 to 0.200 inches) (approximately two complete revolutions of the dial).

**11.2** The flowmeter gage shall be adjusted to zero when placed in position on the breaking head when each individual test specimen is inserted between the breaking head segments. Graduations of the flowmeter gage shall be in 0.25 mm (0.01 in.) divisions.

**11.3** Immerse specimen in water bath at  $60 \pm 1^\circ\text{C}$  ( $140 \pm 1.8^\circ\text{F}$ ) for 30 to 40 minutes.

**11.4** Thoroughly clean inside surfaces of testing head. Lubricate guide rods with a thin film of oil so that the upper test head will slide freely.

**11.5** With testing apparatus in position, remove test specimen from water bath and carefully dry surface. Place specimen in lower testing head and center, then fit the upper testing head into position and center complete assembly in the loading device. Place flow meter over guide rod, adjust the flowmeter to zero and hold the sleeve firmly against the upper segment of the breaking head while the test load is being applied.

**11.6** Apply testing load to specimen at a constant rate of deformation of 50.8 mm (2 inches) per minute, until failure occurs. The point of failure is defined as the maximum load obtained. The total number of pounds required to produce failure of the specimen at 60°C (140°F) shall be recorded as the Marshall stability value.

**11.7** While stability test is in progress, hold the flow meter firmly in position over the guide rod and remove as soon as the load begins to decrease; take the reading and record. This reading is the flow value of the specimen, expressed in units of 0.01 inch. For example, if the specimen deformed 0.15 inches, the flow value is 15.

**11.8** The entire procedure, both stability and flow tests, starting with removal of the specimen from the water bath, shall be completed within a period of thirty seconds.

**12 Density and Voids Analysis for Each Specimen:**

**12.1** Average the bulk specific gravity values for all test specimens of a given asphalt content. Values obviously in error shall not be included in the average.

**12.2** Maximum mixture specific gravity ( $G_{cm}$ ) may be determined by:

**12.2.1** MT-321 - the Rice Method, which is an actual measurement of the maximum mixture specific gravity. The Rice Method is the preferred method and shall normally be used. (Rice gravity values will be furnished with each mix design by the materials Bureau and monitored on the project.

**12.2.2** If a situation arises where you elect to use the maximum theoretical density in the voids analysis, use the procedure described in MT-306, paragraph 14.2.

**12 Density and Voids Analysis for Each Specimen:** (continued)

**Note 5** - *The desirable ranges of test properties for Marshall design criteria is shown in MT-306, Table II.*

**12.3** The percentage of voids by volume is calculated for each specimen and is determined by use of the following formula:

$$V_v = \frac{G_{em} - G_{mb}}{G_{em}} \times 100$$

where:

$V_v$  = volume of air voids as percent of the bulk volume of specimen,

$G_{cm}$  = (Rice) maximum mixture specific gravity, and

$G_{mb}$  = measured bulk specific gravity of compacted mixture

**Note 6** - *The measured stability of a specimen multiplied by the Correlation Ratio, corresponding to the volume of the specimen and found in table I, equals the corrected stability for a standard  $63.5 \pm 1.27$  mm ( $2.5 \pm .05$  inch) specimen. The volume of the specimen used to find the Correlation ratio is equal to (B-C) as in paragraph 9.3*

**Note 7** - *Volume-thickness relationship is based on a specific diameter of 4 inches.*

**Table 1 Stability Correlation Ratios**

Volume of Specimen, cm <sup>3</sup>	Approximate Thickness of Specimen, in.	mm	Correlation Ratio
200 to 213	1	25.4	5.56
214 to 225	1 1/16	27.0	5.00
226 to 237	1 1/8	28.6	4.55
238 to 250	1 3/16	30.2	4.17
251 to 264	1 1/4	31.8	3.85
265 to 276	1 5/16	33.3	3.57
277 to 289	1 3/8	34.9	3.33
290 to 310	1 7/16	36.5	3.03
302 to 316	1 1/2	38.1	2.78
317 to 328	1 9/16	39.7	2.50
329 to 340	1 5/8	41.3	2.27
341 to 353	1 11/16	42.9	2.08
354 to 367	1 3/4	44.4	1.92
368 to 379	1 13/16	46.0	1.79
380 to 392	1 7/8	47.6	1.67
393 to 405	1 15/16	49.2	1.56
406 to 420	2	50.8	1.47
421 to 431	2 1/16	52.4	1.39
432 to 443	2 1/8	54.0	1.32
444 to 456	2 3/16	55.6	1.25
457 to 470	2 1/4	57.2	1.19
471 to 482	2.5/16	58.7	1.14
483 to 495	2 3/8	60.3	1.09
496 to 508	2 7/16	61.9	1.04
509 to 522	2 1/1	63.5	1.00
523 to 535	2 9/16	65.1	0.96
536 to 546	2 5/8	66.7	0.93
547 to 559	2 11/16	68.3	0.89
560 to 573	2 3/4	69.9	0.86
574 to 585	2 13/16	71.4	0.8s
586 to 598	2 7/8	73.0	0.81
599 to 610	2 15/16	74.6	0.78
611 to 625	3	76.2	0.76