1805 RESISTANCE TO PLASTIC FLOW OF BITUMINOUS MIXTURES MARSHALL METHOD

AASHTO Designation T 245 (MN/DOT Modified)

1805.1 SCOPE

The two primary features of the Marshall Method of mix design are a density, void analysis and a stability/flow test of the compacted specimens. The Marshall Method uses standard test specimens of 64mm (2.5") height by 102mm (4") diameter. To provide sufficient data, triplicate test specimens are prepared for each trial mix.

NOTE 1: This procedure differs from AASHTO in that MN/DOT requires the mechanical hammers to have a bevel on the foot (a.k.a. "hammer face"). The height tolerance of a compacted specimen differs in that Mn/Dot requires a compacted specimen to be 2.5" ± 0.125". Mn/Dot also states that the compaction temperature shall be 275 ± 10 °F unless modified binders are used, then the producers recommended compaction temperature shall be used. Mn/DOT stipulates that a 45 minute short-term cure is applied to lab-mixed material in order to simulate the absorption at the mix plant and during transit time to the paving site.

1805.2 APPARATUS

A. Pans - For heating aggregates.

B. Oven - For heating aggregates, bowls, molds, oil and capable of maintaining a temperature of 110 ± 5 °C (230 ± 9 °F).

C. Hot plate - For heating hammers.

D. Thermometers - For aggregates, asphalt, and asphalt mixtures.

E. Balance - A balance conforming to the requirements of AASHTO M 231 (Class G2) with a minimum capacity of 5000g, a readability and sensitivity of 0.1g and an accuracy of 0.1g or 0.1%.

F. Scoop, Trowels, Spoons, and Spatulas.

G. Mechanical Mixer - Equipped with mixing bowl.

H. Triple Mechanical Marshall Compactor - Calibrated to give results comparable with a hand operated hammer. The compactor shall have a rotating mechanism in the base measured at 18 – 30 rpm.

I. Marshall Compaction Hammers - Having a 4536 ± 9g (10 ± 0.02lb) sliding weight, a free fall of 457.2 ± 1.52mm (18 ± 0.06 in) and a foot with a diameter of 98.4 ± 0.41mm (3.875 ± 0.016") having a beveled face.

NOTE 2: When calibrating mechanical hammers follow the procedure outlined section 2005, but with an additional step of measuring the bevel of the foot. To determine the bevel, measure the height difference between the thickest and thinnest points on the hammer's foot. A 1° bevel correlates to a difference of 1.77mm (0.0698"). The measured difference should fall between 1.1mm – 2.0mm (0.045 - 0.080 in).

J. Marshall Compaction Molds -101.6 ± 0.13mm (4.0 ± 0.005") dia x 76.2mm (3 in.) in height with extension collars and base plates.

K. Specimen Extruder - For removing compacted specimens from molds.

L. Marshall Testing Machine - a compression load frame device capable of providing a constant 50.8mm (2 in.)/min vertical movement.

M. Proving Ring or Load Cell – With a capacity of 22.2kN (5000 lb.).

N. Marshall Breaking Head - With an inside radius of curvature of 50.8mm (2 in.).

O. Flowmeter - A gauge with 0.25mm (0.01 in) division.

P. Waterbath - A thermostatically controlled to 60 ± 1 °C (140 ± 1.8 °F).

1805.3 TEMPERATURES

Virgin aggregates are heated to 143 ± 5.6 °C (290 ± 10 °F). (May be heated overnight.)

R.A.P. materials are heated to 143 ± 5.6 °C (290 ± 10 °F). Minimum heating time - 2 hours; maximum heating time - 4 hours.

A.C. is heated to the upper end of the manufacturers recommended mixing temperature. Do not allow the A.C. to remain at that temperature for more than 4 hours. (A.C. may be heated only one time; i.e., if mixing schedule is disturbed and not done as scheduled, a new sample of A.C. must be used.)

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Mixing bowls should be heated to the same temperature as the aggregates.

Molds are heated to the desired compaction temperature, 135 ± 5.6 °C (275 ± 10 °F).

Temperature for short term curing is 143 ± 5.6 °C (290 ± 10 °F).

1805.4 MIXING

A. Place the pre-heated bowl on the mixer, add the hot aggregates and RAP (if it's a recycled mix), then mix the aggregates thoroughly. If hand mixing refer to AASHTO T 245.

NOTE 3: Prior to mixing an initial or "butter" mix is required to condition the mixing equipment. Remove and discard the butter mix from the bowl and paddle by scraping and leaving a uniform, residual asphalt coating.

B. If using a digital balance that will read negative weights place the container with the hot A.C. on the balance and tare to zero. Pour the A.C. into the bowl while mixing, checking the weight after each pour until the target amount (± 0.5 gram) is achieved.

NOTE 4: For other types of balances, first tare to zero then weigh the can and A.C. subtract the target amount of A.C. from the actual weight of the can and A.C. Record the difference and commence pouring, checking the weight after each pour, until that difference (± 0.5 gram) is achieved.

C. Record any difference outside of the tolerance and correct the report to show the actual amount and percentage of A.C. added.

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D. Continue mixing until particles are thoroughly coated, usually about two minutes with the mechanical mixer; however, some mixes with RAP may take longer.

E. Place the loose mixture in a large, shallow, flat pan. Scrape the sides and bottom of the bowl as well as the paddles to remove any material clinging to them. This material will have a high asphalt content and must be carefully and thoroughly blended by hand into the rest of the mixture. A light coating of silicone lubricant may be sprayed on the pan to retard mixture adherence.

F. Prior to running any tests or compacting any specimens all the mixture must be short-term cured in the oven at 143 ± 5.6 °C (290 ± 10 °F) for 45 ± 15 minutes.

NOTE 5: This is for lab-mixed material only. Do not cure bituminous mixture samples that have been produced in a hot-mix plant. For these "Voids Update" samples see Section 1809.

1805.5 PREPARATION of SPECIMENS

A After the short-term aging process remove the mix from the oven.

B. Quarter the mixture in the pan and, using a flat-bottom scoop, from one quarter take 2000 grams (minimum) of material and reserve this in a small pan. This material is for the "Rice Test". (See Section 1807).

C. From each of the three remaining quarters take enough material for a 63.5 ± 3.175mm (2.5 ± 0.125") Marshall specimen (Approximately 1200 grams will provide this intended specimen height although the amount will vary depending upon the aggregates.)

D. Place each batch in one of the three preheated Marshall molds. Remember to place a paper disk in the bottom of the mold before introducing the mix.

E. If the mixture is at the desired compaction temperature proceed immediately with the compaction as outlined in Section1205.6 If not insert a thermometer into the mix and return the molds to the oven and heat to the desired compaction temperature.

F. The remaining material may be used for other tests or retained for re-checks.

NOTE 6: The order in which individual specimens and tests are taken from a single, larger sample is not important. The goal is to be as representative as possible for all tests.

1805.6 MARSHALL COMPACTION

A. Check temperature of sample. Compaction temperature shall be 135 ± 5.6 °C (275 ± 10 °F). If material is not within temperature specifications continue reheating until temperature is obtained. Note on the worksheet any additional reheating time over 45 minutes.

B. Hammer faces should be clean and heated to 93.3 - 148.9 °C (200 - 300 °F).

C. Place the molds on the machine, align the mold's bottom plate to its proper position then place mold collars over the molds. Turn on the machine. As each mold rotates vigorously spade the mixture with a spatula or trowel 15 times around the perimeter and 10 times over the interior. Smooth the top of the mixture by pulling the mix away from the mold's sides with the spatula/trowel to form a slightly coned shape. Turn off the machine and place a paper disk on top of the mixture.

D. Install the hammers into the machine and place the "plumb pins" in tops of the shafts and gently lower the counter weights. Reset the counter to the required number of blows, turn machine on and apply the required number of blows using a free fall of 457.2 mm (18 inches).

NOTE 7 Hammer shafts should be clean and lightly lubricated using a spray silicone lubricant (or equal). Never touch the shafts with anything except a clean rag.

NOTE 8: Determine at which position on the machine that the hammers supply the most uniform results and use the hammers in those positions. When/if results become non-uniform, re-evaluate and re-position.

NOTE 9: Prepare and use a plan to rotate each hammer at its specific position on the machine so that wear is equalized. A suggested plan is to rotate the hammers after each set of blows by turning the shaft either 90° or 180°.

E. Turn the switch off when compaction is completed. Carefully disengage the hammers from the molds and machine.

F. Remove the molds, take apart their extension collars and base plates, turn over each mold (reverse) and reassemble the molds onto the machine.

G. Replace the hammers and reset the counter and apply the same number of blows to the reversed specimen(s).

H. Since the mixture in the molds cool rapidly the entire compaction process should be completed within ten minutes. (From removal from the oven to the last blow.)

I. After compaction, turn the machine off, remove the hammers and the molds from the machine and clean the hammer faces.

J. Note position of the last side compacted and remove the extension collars and papers from both sides of the specimen(s).

K. Using a china marker or crayon identify, on the last face compacted, each specimen by mix number and Marshall specimen number.

L. Set the mold with the specimen askew on the mold's collar and allow to cool to room temperature. (A fan may be used to facilitate the cooling process.)

1805.7 EXTRUSION and MEASUREMENTS

A. When the specimen(s) have cooled to room temperature place the mold (with the extension collar if needed) into the extractor device.

B. Remove the Marshall specimens from the molds by forcing the specimen out (into the extension collar) by means of an extrusion jack. To aid in extruding the specimen, apply the force to the un-marked side of the specimen.

C. After extruding scrape any excess mix from the edge of the specimens and measure the specimens heights to the nearest 0.1mm or 0.001".

D. Measure the specimens using one of the two methods below. The specimens shall measure 63.5 ± 3.175mm (2.5 ± 0.125")

1. Method A - Using jig for measurements, obtain heights (thickness). Record on work sheet. (See Example Worksheet in Section 1808.4

2. Method B - Using calipers, take three readings around specimens, average and record average height

1805.8 It is important to determine the bulk specific gravity (Refer to Section 1806) before running the stability and flow.

A. Specimens should be cooled to room temperature at 25 ± 5 °C (77 ± 9 °F).

B. After measuring the height of the specimens, weigh each of the specimens in air to the nearest 0.1g and record the dry weight as (**A**).

C. Immerse the specimens in water at 25 ± 1°C (77 ± 1.8 °F) for 3 to 5 minutes. Placing one specimen at a time on the weighing platform below the scale and tipping the specimen to release any air bubbles without lifting the specimen from the water, weigh to the nearest 0.1g and record the immersed weight (**C**) as soon as the balance readout stabilizes.

D. Immediately after obtaining the immersed weight remove the specimen from the water and then immediately surface-dry by rolling and blotting the specimen on a damp towel. Weigh the specimen to the nearest 0.1g and record the Saturated Surface-Dry weight (SSD) as (**B**). This entire step of obtaining an SSD and weighing shall be completed within 15 seconds of removal from the water bath. After the specimen has been surface-dried any water that seeps from the specimen during the weighing operation is considered part of the SSD weight.

1805.9 MARSHALL STABILITY and FLOW

The stability of the mixture is defined as the maximum load resistance that the standard test specimens will develop at 60 °C (140 °F). The flow value is the strain (deformation) or total movement occurring in the specimens between no load and maximum load during the stability test.

A. After determining the bulk gravities of the test specimens, place them in a water bath at 60 ± 1 °C (140 ± 1.8 °F) for 30-40 minutes.

B. Remove a specimen from the bath, surface dry with a damp towel and center it in the lower segment of the breaking head.

C. Check the guide rods to see if they are clean and lubricated.

D. Fit the upper segment of the breaking head on the guide rods and specimen.

E. Center the complete assembly onto the load-measuring device.

F. If using a proving ring zero the dial indicator.

G. The flow meter is calibrated or set to zero while a 101.6mm (4") diameter metal cylinder is in the breaking head.

H. Position the flow meter on the guide rod. Hold the flow meter sleeve firmly against the upper segment of the testing head while the load is being applied.

I. Apply a load at a constant rate of deformation of 50.8mm (2 in.) per minute until failure occurs. The point of failure is defined by the maximum load reading obtained.

J. Note the dial reading on the proving ring at the instant when the load, as indicated by the dial, decreases and lift off the flow meter.

K. Record this as the maximum stability dial reading and record the reading of the flow meter at this time.

L. The Marshall flow is the total sample deformation from a no load to a point where the peak load starts to decrease.

NOTE 10: The maximum time allowed between removal of specimen from the water bath and the maximum load point is 30 seconds.

M. Use the stress-strain chart/table for the proving ring or load cell to convert the (load) dial reading to actual Newtons (pounds). The stability value is expressed as total Newtons or pounds to produce failure.

The flow value is expressed in units of 0.25mm (1/100 inch). For example, if the specimen deformed 3mm (0.12 inch), the flow value would commonly be referred to as a 12. However, report each flow value to the nearest $1/100^{th}$ of an inch. In the example above the appropriate notation would be 0.12. (See the Example Worksheet in Section 1808.4)

N. Correct the stability for each Marshall specimen whose heights deviate from 63.5mm (2.5").

O. Specimens shall satisfy the thickness requirement of 63.5 ± 3.175mm (2.50 ± 0.125”). Specimens that are not 63.5mm thick, but fall within the tolerances shall be converted to an equivalent 63.5mm value by a conversion factor.

1. To convert multiply the load in Newtons (pounds) by the appropriate height correlation factor from the table in Section 1805.9 below.

2. Average the corrected stability of the three specimens and record. (See line “P” on the Example Worksheet in Section 1808.4).

3. Do not include in the average, any specimen whose bulk specific gravity was determined to be out of tolerance in Section 1806.2.

1805.9 TABLE 1

STABILITY CORRELATION RATIO TABLE

HEIGHT OF SPECIMEN (mm)	HEIGHT OF SPECIMEN (in.)	CORRELATION RATIO
59.6 – 61.1	2.346 – 2.408	1.09
61.2 – 62.7	2.409 – 2.471	1.04
62.8 – 64.4	2.472 – 2.538	1.00
64.5 – 66.0	2.539 – 2.601	0.96
66.1 – 67.4	2.601 – 2.655	0.93

NOTE 11: The above table is provided for calculating the Marshall Stability on all Bituminous cores and those Marshall specimens that are within the height requirement. Marshall specimens whether from mixture or recompacted material from cores must conform to the requirement of 63.5 ± 3.175mm (2.5 ± 0.125”) as stated in Section 1805.5.