

1813 **STANDARD TEST FOR EFFECT OF MOISTURE ON ASPHALT
CONCRETE PAVING MIXTURES (LOTTMAN TEST)**
ASTM D 4867 (MN/DOT Modified)

1813.1 SCOPE

This test method covers procedures for preparing and testing asphalt concrete specimens for the purpose of measuring the effect of water on the tensile strength of the paving mixture. This test method can be used to evaluate the effect of moisture with or without antistripping additives including liquids and pulverulent solids such as hydrated lime or Portland cement.

This test method can be used to test asphalt concrete mixtures in conjunction with mixture design testing to determine the potential for moisture damage, to determine whether or not an antistripping additive is effective, and to determine what dosage of an additive is needed to maximize the effectiveness. This test method can also be used to test mixtures produced in field plants and to determine the effectiveness of additives on the mixture and under the conditions imposed in the field. The results may be used to predict long term stripping susceptibility of bituminous mixtures.

The values stated in either SI units or inch-pound units in parentheses shall be regarded separately as the standard. The values in each system may not be exact equivalents; therefore, each system must be used independently without combining values in any way.

1813.2 SUMMARY OF TEST METHOD

- A. Potential for Moisture Damage - The degree for susceptibility to moisture damage is determined by preparing a set of laboratory-compacted specimens conforming to the job-mix formula without an additive. The specimens are compacted to a void content corresponding to void levels expected in the field usually in the 6 to 8% range. The set is divided into two subsets of approximately equal void content. One subset is maintained dry ("untreated") and used as a control, while the other subset is partially saturated with water and moisture conditioned ("treated"). The tensile strength of each subset is determined by the tensile splitting test. The potential for moisture damage is indicated by the ratio of the tensile strength of the wet subset to that of the dry subset.

- B. Additive Effect - The effect of an antistripping additive is determined on a set of specimens containing an additive prepared and tested as described above. The effect of an additive dosage may be estimated by repeating the tests on sets with different additive dosages.
- C. Plant-Produced Mixtures - The potential for moisture damage or the effectiveness of an additive in a plant-produced mixture is determined on specimens that are laboratory compacted to $7 \pm 1\%$ void content using the Marshall apparatus and $7 \pm 0.5\%$ void content using the Gyratory compactor, divided into wet and dry subsets, and evaluated as described above.

1813.3 APPARATUS

Equipment for preparing and compacting specimens from either MN/DOT Lab Manual Sections 1805 (Marshall) or 1820 (Gyratory) as appropriate.

- A. Vacuum Pump with Manometer or Vacuum Gage - In accordance with Manual Section 1807. The pump should be capable of evacuating air from the vacuum container to 508mm (20 inches) Hg.

NOTE 1: When using the high vacuum pumps associated with the Rice Test (Section 1807) the vacuum system should include a regulator connected to the pump with a gauge suitable for controlling and measuring the applied vacuum. The size of the residual pressure manometer generally used in the Rice Test may be too small to measure the partial vacuum of 20 inches.
- B. Vacuum Container - In accordance with Section 1807.
- C. Balance - Conforming to the requirements of AASHTO M 231 having a readability & sensitivity of 0.1 grams and an accuracy of 0.1 grams or 0.1% and having a minimum capacity of 5000g. The balance shall be equipped with suitable apparatus for suspending the sample container in water from the center of the weighing platform or pan of the balance.
- D. Water Baths - Temperature controlled.
 - 1. One bath capable of maintaining a temperature of 60 ± 1.0 °C (140 ± 1.8 °F) for 24 hours.
 - 2. One bath capable of maintaining a temperature of 25 ± 1.0 °C (77 ± 1.8 °F).
- E. Loading Jack and Ring Dynamometer - In accordance with AASHTO Test Method T 245 or a Mechanical or Hydraulic Testing Machine capable of maintaining the required strain rate and measuring load with equal or better precision.

- F. Steel Loading Strips - In accordance with AASHTO Test Method T 283. The length of the loading strips must exceed the thickness of the specimens.

1813.4 PREPARATION OF LABORATORY TEST SPECIMENS

- A. Make at least six specimens for each test, compacted to $7 \pm 1\%$ air voids when using the Marshall apparatus. Three specimens are to be tested dry (considered as a control subset) and three are to be tested after partial saturation and moisture conditioning.
- B. For gyratory mixes make at least four specimens compacted to $7 \pm 0.5\%$ air voids where two specimens are tested dry and two tested after partial saturation and conditioning.
- C. Use specimens 101.6 mm (4") in diameter and 63.6 mm (2.5") high for Marshall mixes.

NOTE 2: When using aggregate larger than 1 in. (25.4 mm), use specimens at least 152.4 mm (6") in diameter.

- D. Use specimens 152.4mm (6") in diameter and 95.0mm (3.7") high for Gyratory mixes.
- E. Prepare lab design mixtures in batches large enough to make at least three specimens or, as an alternative, prepare three batches each large enough for 1 specimen.

NOTE 3: If theoretical maximum specific gravity is to be determined, use a batch large enough or prepare a separate batch to provide a specimen for this purpose.

For laboratory produced the theoretical maximum specific gravity should be based on the average of at least two tests within 0.011 at the optimum asphalt content.

- F. When a liquid antistripping additive is used heat a sufficient quantity of asphalt cement for one batch to 148.9 ± 5.6 °C (300 ± 10 °F), or to the manufacturer's recommended mixing temperature for modified asphalt in a one-quart can in an oven.
1. Add the required quantity of additive and immediately mix, for approximately 2 minutes or until completely coated.
 2. Maintain the treated asphalt cement at mixing temperature in the can until it is used.
 - a. Discard the treated asphalt cement within 4 hours after reaching mixing temperature.

- G. When using a pulverulent solid antistripping additive use the addition procedure simulating the procedure expected in the field. Follow the appropriate procedure below.

1. When dry powder is added to dry aggregate, dry batch and heat the mineral aggregate to 148.9 ± 5.6 °C (300 ± 10 °F). Add the required quantity of additive to the aggregate, and thoroughly mix the entire mass until a uniform distribution of additive is achieved. Take care to minimize the loss of additive to the atmosphere in the form of dust. After mixing, maintain the treated aggregate at the required mixing temperature until it is used.
2. When dry powder is added to damp aggregate batch the damp mineral aggregate and adjust the moisture content of the combined aggregate to the expected field moisture level. Add the required quantity of additive to the damp aggregate, and thoroughly mix the entire mass until a uniform distribution of additive is achieved. Take care to minimize the loss of additive to the atmosphere in the form of dust. After mixing, dry the treated aggregate, heat to the required mixing temperature and maintain at that temperature until it is used.
3. When powder slurry is used add the required quantity of additive to water using the powder to water ratio expected in the field. Take care to minimize the loss of additive to the atmosphere in the form of dust. To prevent settling, continuously mix the resulting slurry until it is used. Batch the damp mineral aggregate, adjust the moisture content as required in 2, above. Add the required quantity of slurry, and thoroughly mix the entire mass until a uniform distribution of slurry is achieved. After mixing dry the treated aggregate, heat to the required mixing temperature and maintain at that temperature until used.

1813.5 COMPACTION OF SPECIMENS

- A. Proportion, mix and compact specimens in accordance with one of the following: Manual Sections 1805 or 1820 as appropriate. If Section 1805 is used either a manual or mechanical hammer may be used.
- B. After mixing, cure the mixture in an oven at a temperature of 143.3 ± 5.6 °C (290 ± 10 °F) for 2 hours ± 15 minutes.
- C. Determine the desired number of blows or revolutions needed to obtain test specimens with approximately 7 percent air voids. To estimate this number compact trial test specimens at varying number of blows for Marshall compaction or number of revolutions in a gyratory mix, plot the results and extrapolate an estimate of blows or revolutions needed from the plotted points.

NOTE 4: Generally speaking it has been found that in Marshall mixes with low crushing, 11 to 13 blows per side should yield and air void close to 7%. High crush mixes usually require 15 to 17 blows per side. In gyratory mixes the formula: $.91(Gmm)(1679)$ can be used to determine the amount of mixture required to produce approximately 7% air voids in a specimen 95mm in height. Coarse mixes may require an adjustment in the formula such as; $.89(Gmm)(1679)$ to achieve 7% air voids. Determine the exact procedure by trial and error for each mixture.

- D. After determining the blows or revolutions needed compact six new test specimens to $7 \pm 1.0\%$ air voids when using the Marshall apparatus.
- E. For gyratory mixtures compact at least 4 new specimens to $7 \pm 0.5\%$ air voids.

NOTE 5: Additional specimens should be prepared at this time. These extra specimens will allow for a better grouping into equal subsets and to serve as replacements in the event of damaged or discarded specimens due to over saturation, not meeting the air void parameters or any mishandling during testing. Refer to NOTES 12 and 13 in Section 1813.7

- F. Cool specimens in the mold to room temperature as rapidly as possible by placing them in front of a fan
- G. Extract from molds then determine the bulk specific gravity and grouping procedure outlined in Section 1813.7 within 24 hrs.
- H. For gyratory specimens (as a guideline) cool for approximately 20-30 minutes then extract carefully from warm mold. If the specimens cool too long, then the paper disc may be difficult to remove. However if the specimen is extracted too soon then the compacted gyratory sample may be quite tender and will tend to mushroom out. Carefully place the specimen in front of a fan and bring to room temperature.

1813.6 PREPARATION OF FIELD SPECIMENS

- A. Sample in accordance with Mn/Dot specification 2350.5, C3, 2360.4e7 or approved method on file in the Bituminous Office.

NOTE 6: After sample has been obtained it shall be split in the field with 50% for agency testing and 50% for contractor testing.

- B. Transport hot mix specimen to laboratory for testing. No additional cure time is required.
- C. Stabilize the mixture temperature to approximately the temperature found in the field when rolling begins.
- D. Compact the specimens in accordance with Section 1813.5 and cool to extract from the molds.

- E. If specimens are not to be compacted in the field laboratory place the samples in a sealed container, transport to the laboratory and reheat to the temperature required.
- F. Proceed with the steps in the compaction procedure. See Section 1813.5.

1813.7 EVALUATION OF TEST SPECIMENS AND GROUPING INTO SUBSETS

- A. Determine the theoretical maximum specific gravity in accordance with Manual Section 1807. See Section 1813.13, line "H" of the worksheet.

NOTE 7: For laboratory produced mixtures the average of two Maximum Specific Gravity tests within 0.011 at the optimum asphalt content should be used.

NOTE 8: For verification of new mix designs use the submitted maximum specific gravity if the verification sample is within the 0.019 tolerance. (See Sections 1807 and 1812.)

NOTE 9: For production Lottmans, use the individual maximum specific gravity of the job-mix at the time the sample was taken.

- B. Determine the specimen height and diameter with calipers in three locations and record the average to the nearest 0.1mm (0.01"). See Section 1813.13, lines "A" and "B" of the worksheet.
- C. Determine the bulk specific gravity (refer to Manual Section 1806) and express the volume of the specimen in cubic centimeters.

NOTE 10: The term (SSD weight minus weight in water) is the volume of the specimen in cubic centimeters. (Refer to 1806 in Mn/Dot lab manual). See Section 1813.13, lines "C" thru "G" of the worksheet.

- D. After measuring the height of the specimens weigh each of them in air to the nearest 0.1g and record the dry weight. See Section 1813.13; line "C" of the worksheet.
- E. Immerse the specimens in water at 25 ± 1 °C (77 ± 1.8 °F) for 3 to 5 minutes.
- F. Placing one specimen at a time on the weighing platform and tipping the specimen to release any air bubbles without lifting any part of the specimen from the water, weigh the specimen to the nearest 0.1g. See Section 1813.13, line "E" of the worksheet.
- G. Immediately after obtaining the the immersed weight remove the specimen from the water, surface-dry the specimen by rolling it in and blotting it on a damp towel.

- H. Weigh the specimen in air and record the saturated surface-dry (SSD) weight to the nearest 0.1g. See Section 1813.13; line "C" of the worksheet.
- I. Calculate the percent air voids in accordance with Manual Section 1808 and express the volume of air in cubic centimeters. See Section 1813.13, line "I" of the worksheet.

NOTE 11 The volume of air is the volume of the specimen multiplied by the percent air voids. See section 1813.13; line "J" of the worksheet

NOTE 12 Individual Marshall specimens are required to have air voids between 6.0-8.0%. Gyratory specimens must be between 6.5-7.5%. If any single specimen from a subset falls outside this range, then eliminate it from the test. Replacement with another specimen is allowed only if you had compacted additional specimens at that time (see section 5). A specimen from a new batch set would have a different cure time and physical properties. If more than one puck from a subset is outside the specified range, and there are no replacements, all the specimens shall be discarded from further testing. Compaction of a new set of six specimens is required. For Gyratory mixes a minimum of 2 specimens per subset is required.

NOTE 13 In the case of split field mixtures, where there may not be enough material submitted, and a single specimen from a subset falls outside the specified range, use the average of the remaining two and make a notation. If more than one puck from a subset is outside the specified range, and there are no replacements, all the specimens shall be discarded from further testing. A new sample must be obtained and compaction of a new set of six specimens is required.

- J. Sort the specimens into two subsets so that the average air voids of the two subsets are approximately equal.

NOTE 14: In deciding which subset is to be treated (moisture-conditioned) or non-treated (dry) first attempt to arrange the groupings as close to a 7.0% void average as possible. Pick the subset with the higher average voids and treat this set.

1813.8 PRECONDITIONING OF TEST SPECIMENS

- A. Store the control subset (untreated) to be tested dry at room temperature for 24 hours.
- B. Partially saturate the subset to be moisture conditioned ("treated") with distilled or deionized (mineral free) water at room temperature using a vacuum chamber.
- C. Place the specimen(s) into the vacuum container.
- D. Separate the specimen(s) from the bottom of the container and/or from each other by a spacer (a large paperclip works well).

- E. Fill the container with distilled water to a level of approximately one inch above the specimen's surface.
- F. Partially saturate each specimen to within a range of 60.0 to 80.0%, but to a target of 65-70%.
- G. Apply a partial vacuum such as 508mm (20 inches) of mercury (Hg) as measured by a vacuum gauge or 254mm (10 inches) of mercury (Hg) of absolute pressure measured with a residual manometer/gauge for a short time such as 5 minutes.

NOTE 15: Experiments with partial vacuum at room temperature indicate that the degree of saturation is very sensitive to the magnitude of the vacuum and practically independent of the duration. The degree is determined by the capacity of the vacuum pump. Without regulating the vacuum the results will be highly variable. Refer to Section 1813.3, Apparatus, under vacuum pump when using the vacuum system for the "Rice Test". The level of vacuum needed appears to be different for different mixtures.

- H. Remove the specimens from the vacuum container and immediately immerse them into the 25 ± 1.0 °C (77 ± 1.8 °F) water bath.
- I. Determine the immersed mass of each specimen.
- J. Roll and blot surface-dry using a damp towel to determine the saturated surface-dry mass in accordance with Manual Section 1806. See Section 1813.13, lines "L" and "M" of the worksheet.
- K. Determine the new volume of the partially saturated specimen by subtracting the immersed weight from the saturated surface-dry mass. See Section 1813.13, line "N" of the worksheet.
- L. Determine the volume of the absorbed water by subtracting the initial air-dry mass of the specimen from the saturated surface-dry mass of the partially saturated specimen. See Section 1813.13, line "O" of the worksheet.
- M. Determine the degree of saturation for individual specimens by dividing the volume of the absorbed water by the volume of air voids calculated in Section 1813.7 and express the result as a percentage. See Section 1813.13, line "% Saturation" of the worksheet.
- N. If the volume of water is between 60.0 and 80.0% (suggested target is 65-70%) of the volume of air, proceed to the next step of conditioning.
- O. If the volume of water is less than 60.0% repeat the partial saturation procedure using a slightly higher partial vacuum. If it is difficult to reach the minimum degree of saturation the water used to saturate may be heated up to 60 °C (140 °F).

- P. If the volume of water is more than 80.0% the specimen has been damaged and must be discarded.

NOTE 16: If the average air voids of the saturated subset is less than 6.5% a degree of saturation of at least 65% is mandatory.

- Q. After saturation is achieved immediately “treat” the saturated specimens by soaking them in distilled or deionized (minerals free) water at 60 ± 1.0 °C (140 ± 1.8 °F) for 24 hrs.

NOTE 17: If a freeze-thaw conditioning cycle is desired, the following procedure is suggested instead of the above step of “treating” for 24 hrs. Wrap each of the partially saturated specimens tightly with two layers of plastic film using masking tape to hold the wrapping if necessary. Place each wrapped specimen into a leak-proof plastic bag containing approximately 3 ml of distilled water and seal the bag with a tie or tape. Place the wrapped and bagged specimens into an air bath freezer at -18 ± 2.0 °C (-0.4 ± 3.6 °F). After at least 15 hours in the freezer, remove the specimens and immerse them in a water bath at 60 ± 1.0 °C (140 ± 1.8 °F) for 24 hours. (After 3 minutes of immersion and after specimen surface thaw occurs remove the bag and wrapping from the specimens.)

1813.9 TESTING - “TREATED” SUBSET

- A. After the 24 hour moisture-conditioning period, adjust the temperature of the “treated” subset by soaking them in a water bath for 1 hour at 25 ± 1.0 °C (77 ± 1.8 °F).
- B. Carefully transfer the specimens from the 60 °C (140 °F) bath as they may be tender.
- C. At the conclusion of the 1 hour soak period record the immersed weight of each conditioned specimen in the 25 ± 1.0 °C (77 ± 1.8 °F) bath.
- D. Remove the specimens and quickly surface-dry each with a damp towel. Record the new saturated surface-dry weight.
- E. Measure the new height (thickness) and the new diameter of the “treated” subset by use of a caliper.
- F. Take the average of three readings and record to the nearest .01 inch. See Section 1813.13, lines “P” thru “S” of the worksheet.
- G. To determine the final water absorption and the degree of saturation:
1. Calculate the volume of the moisture-conditioned specimens by subtracting the immersed weight from the saturated surface-dry weight. See Section 1813.13, line “T” of the worksheet.

2. Determine the volume of the absorbed water by subtracting the initial air-dry mass of the specimen from the saturated surface-dry weight of the moisture-conditioned specimen. See Section 1813.13, line "U" of the worksheet.
 3. Determine the final degree of saturation by dividing the above-calculated volume of the absorbed water by the initial volume of air voids calculated in Section 1813.7 and express the result as a percentage.
 4. A degree of saturation exceeding 80% at this time is acceptable. See Section 1813.13, line "% Saturation" of the worksheet.
- H. To determine the indirect tensile strength of the "treated" subset at 25 ± 1.0 °C (77 ± 1.8 °F):
1. Place a specimen into the loading apparatus and position the loading strips so that they are parallel and centered on the vertical diametrical plane. The length of the loading strips must exceed the specimen's thickness.
 2. Apply a diametrical load at 50.8mm/min (2 in/min) until the maximum load is reached. Record the maximum load in pounds (N). See Section 1813.13, line "V" of the worksheet.
 3. Continue loading until the specimen fractures. A vertical crack will appear in the specimen.
 - a. Remove the specimen from the machine and pull the two halves apart, visually estimate the approximate degrees of stripping and broken aggregate and record on the worksheet.

1813.10 TESTING - "UNTREATED" SUBSET

- A. After 24 hours adjust the temperature of the dry "untreated" subset by soaking them in a water bath for 20 minutes at 25 ± 1.0 °C (77 ± 1.8 °F). Determine the indirect tensile strength of the "untreated" subset at 25 ± 1.0 °C (77 ± 1.8 °F)
- B. After the 20 minute soak period remove each specimen and quickly surface dry them with a damp towel. There is no need to weigh or measure the untreated specimens.
- C. Place a specimen into the loading apparatus and position the loading strips so that they are parallel and centered on the vertical diametral plane. The length of the loading strips must exceed the specimen's thickness. Apply a diametral load at 50.8mm/min (2 in/min) until the maximum load is reached.

- D. Record the maximum load in pounds (N). See Section 1813.13. Line "K" of the worksheet.
- E. Continue loading until a vertical crack appears in the specimen. Pull the specimen apart and visually estimate and record the approximate degrees of stripping and broken aggregate. Record on the worksheet.

1813.11 CALCULATION

- A. Calculate the dry tensile strengths as follows: (See Section 1813.13, line "W" of the worksheet)

$$S_{td} = \frac{2K}{\pi BA}$$

Where:

- S_{td} = Tensile Strength, psi (kPa)
K = Maximum Load, lbs (Newtons)
B = Specimen Height Immediately Before Tensile Test, inches (mm).
A = Specimen Diameter, inches (mm).

- B. Calculate the wet tensile strengths as follows: (See Section 1813.13, line "X" of the worksheet)

$$S_{tm} = \frac{2V}{\pi QP}$$

Where:

- S_{tm} = Tensile Strength, psi (kPa)
V = Maximum Load, lbs (Newtons)
Q = Specimen Height (after conditioning and immediately before tensile test), inches (mm)
P = New Specimen Diameter After Conditioning, inches (mm).

- C. Calculate the tensile strength ratio as follows: (See Section 1813.13, line "TSR" of the worksheet)

$$\text{TSR} = \frac{S_{tm}}{S_{td}} \times 100$$

Where:

- TSR = Tensile Strength Ratio, %
 S_{tm} = Wet Strength or Average Tensile Strength of the Moisture-Conditioned Subset, psi (kPa)
 S_{td} = Dry Strength or Average Tensile Strength of the Dry Subset, psi (kPa)

1813.12 REPORT

Report the following information:

- Number of specimens in each subset.
- The individual and average air voids of each specimen and subset.
- Time and amount of vacuum for saturation.
- The individual and average degree of saturation after partial saturation and after moisture conditioning.
- Tensile strength of each specimen in each subset
- The tensile strength ratio (TSR).
- The results of visually estimating the stripping and broken aggregate.

NOTE 18: If the conditioning procedure described in NOTE 17 is used, that fact should be included in the report.

1813.13 WORKSHEET

LOTTMAN WORKSHEET

Project No. _____ T. M. No. _____ Date _____
 Spec _____ Type _____ %AC in mix _____ Blows _____ or Target ht _____
 Remarks _____

TREATED SPECIMENS

UNTREATED

SPECIMENS

| | | | | | | | | | | |
|----------------------------|---|--|--|--|---------|--|--|--|--|---------|
| Sample I.D | | | | | Average | | | | | Average |
| Diameter in, (mm) | A | | | | | | | | | |
| Thickness in, (mm) | B | | | | | | | | | |
| Dry wt in air | C | | | | | | | | | |
| SSD wt | D | | | | | | | | | |
| Weight in water | E | | | | | | | | | |
| Volume, D-E | F | | | | | | | | | |
| Bulk Spg, C/F | G | | | | | | | | | |
| Max Spg | H | | | | | | | | | |
| % Air voids, 100*[(H-G)/H] | I | | | | | | | | | |
| Vol. Air Voids, I*(F/100) | J | | | | | | | | | |
| Load lbs., (Newtons) | K | | | | | | | | | |

Saturated for _____ minutes at _____ mm. Hg

| | | | | | | | | | | |
|-------------------------|---|--|--|--|---------|--|--|--|--|--|
| SSD Weight | L | | | | Average | | | | | |
| Weight in water | M | | | | | | | | | |
| Volume, L-M | N | | | | | | | | | |
| Volume Abs. Water, L-C | O | | | | | | | | | |
| % Saturation, 100*(O/J) | | | | | | | | | | |
| % Swell, 100*[(N-F)/F] | | | | | | | | | | |

Conditioned 24 hours in 140°F Water Bath

| | | | | | | | | | | |
|------------------------------|---|--|--|--|---------|--|--|--|--|---------|
| New Diameter in, (mm) | P | | | | Average | | | | | Average |
| New Thickness in, (mm) | Q | | | | | | | | | |
| SSD Weight | R | | | | | | | | | |
| Weight in Water | S | | | | | | | | | |
| Volume, R-S | T | | | | | | | | | |
| Vol. Abs. Water, R-C | U | | | | | | | | | |
| % Saturation, 100*(U/J) | | | | | | | | | | |
| % Swell, 100*[(T-F)/F] | | | | | | | | | | |
| Load lbs., (Newtons) | V | | | | | | | | | |
| Dry Strength, 2K/BAπ | W | | | | | | | | | |
| Wet Strength, 2V/QPπ | X | | | | | | | | | |
| TSR, 100*(X/W ¹) | | | | | | | | | | |
| % Visual Stripping | | | | | | | | | | |
| % Broken Aggregate | | | | | | | | | | |

¹ Use the average value in the calculations.

Tested by: _____

COMMENTS:

This page intentionally left blank