SECTION 815 Density Testing

815.1 General

Field densities are taken by nuclear methods in accordance with established procedures as required by the contract. If the contract contains QMP density testing provisions, the contractor performs quality control density testing and the department performs quality verification density testing. If the contract doesn't include QMP density testing provisions, the department will perform all density testing conforming to standard spec 460.3.3.2. Once a method has been selected for determining mat density, that method should be used throughout the project.

815.2 Nuclear Gauges

Revise 815.2 to remove portion of subsection relating to nuclear gauge licensing and operator certification information. This information can be found in WTM T355.

Sampling and testing certifications are an FHWA requirement in the CFR 23 part 637. The NUCDENSITYTEC-I class is offered only by the University of Wisconsin Platteville as part of the HTCP.

For certification class schedules contact the director of the HTCP at (608) 342-1545 or at:

https://www.uwplatt.edu/department/highway-technician-certification-program

Testing of some soils, fly ash, and coarse materials requires special testing procedures, for which the operator will need additional training. Contact the WisDOT RSO for further information regarding special testing procedures.

815.3 Vacant

Revise 815.3 to remove Nuclear Gauge Safety subsection that included Lost or Stolen Gauges (815.3.1) and Damaged Gauge (815.3.2) subsections. This information can be found in WTM T355.

815.4 Annual BTS Gauge Block Calibration Procedures

Run the block and procedure for each gauge as described below:

1. BTS block procedure
   - Maintain 30' or greater spacing between gauges.
   - Sweep off yellow and green blocks.
   - Perform manufacturer recommended warm up time if applicable. Gauges should only be used when they stabilize to ambient room temperature.
   - Place the manufactures supplied poly standard block on the yellow concrete block and perform the Standard Count, and record data on department supplied block forms.
   - Remove the poly standard block and align the front of the gauge that it touches the front line on the yellow block, and center the gauge.
   - Take a four minute back-scatter (BS) test for CPN, Troxler, Humboldt and InstroTek gauges, or a two-minute test for both Contact and Air gap for Seaman nuclear gauges.
   - Without moving the handle for CPN, Troxler, Humboldt, or InstroTek, record required data Wet pounds per cubic foot (pcf), # Moisture, Density counts, and Moisture counts and then perform the next test.
   - For Seaman gauges record the required data Wet pcf, # Moisture, Density counts, Moisture counts. Re-center the gauge and perform the next test.
   - Take three tests for each concrete test block and record the data for each test. DO NOT perform a new standard for each block.

Record the Block results on the WisDOT Block Calibration form and submit to the RSO.

815.5 Nuclear Density Testing HMA

Revise 815.5 to remove some information from Nuclear Gauge Density Testing HMA subsection. This information can be found in WTM T355.

Gauges must be in the shielded position and locked when not in use. Gauges should never be left unattended when in use.

Gauges must be warmed up and checked following the manufacturer's guidelines.

815.6 Vacant

Revise 815.6 to remove Project Nuclear Gauge Density Testing subsection. This information can be found in WTM T355.

815.7 QMP QC and QV Nuclear Density Gauge Comparison

Revise 815.7 to remove some QMP QC and QV Nuclear Density Gauge Comparison information. This information can be found in WTM T355 and WTM T310.

If calibration factors need to be adjusted in the field, contact the RSO beforehand for guidance and documentation.

Use the last two test sites from the final comparison process and proceed with your moisture basis calculations as explained in CMM 815.12.1. If the difference in moisture content between a gauge and the corresponding sample exceeds 1.0 pcf, then a moisture bias needs to be calculated for that gauge for the specific soil classification. The bias needs to be checked during placement or if the material classification changes. If testing in DT mode, operators need to be cautious to ensure that the pilot holes do not collapse. Provide one of the QC or QV gauges that passed the comparison process, within allowable tolerances, to perform density testing on the project.

815.8 Vacant

Revise 815.8 to remove HMA QMP Reference Site Monitoring and Non QMP HMA Nuclear Density Reference Site Monitoring subsections (formerly numbered 815.8 and 815.9). This information can be found in WTM T355.

815.9 Vacant

815.10 Use of Nuclear Moisture/Density Gauges on HMA

Revise 815.10 to remove some information from Use of Nuclear Moisture/Density Gauges on HMA subsection. This information can be found in WTM T355.

The designated materials persons (standard spec 106.1.2) will determine how the documentation will be communicated at the preconstruction meeting. A new standard is also required if testing different materials on the same day (e.g., testing aggregate base and then switching to HMA testing). Changing the HMA mix type, or base course material sources does not require a new standard.

815.10.1 Vacant

Remove 815.10.1 Target Maximum Density subsection. This information can be found in WTM T355.

815.10.2 Vacant

Remove 815.10.2 Lots and Sublots subsection along with the following subsections; Layout Based on a Single Paved Lane, Single Paved Lane Greater than or equal to 1,500 feet, Single Paved Lane Less than 1,500 feet, Layout Based on Multiple Paved Lanes Within a Contiguous Pavement Area, and Location of Random Test Sites (former subsection numbers 815.10.2.1, 815.10.2.1.1, 815.10.2.1.2, 815.10.2.2, and 815.10.3) This information can be found in WTP H-002.

815.10.2.1 Vacant

815.10.2.2 Vacant

815.10.3 Vacant

815.10.4 Duration of Test and Gauge Placement

Remove some information from 815.10.4 Duration of Test and Gauge Placement subsection. This information can be found in WTM T355 and WTM T310.

All moisture/density gauges have different shapes, so the operator must outline the gauge. For CPN, Troxler, Humboldt and InstroTek gauges, mark an arrow in the direction the source rod is facing. For a Seaman C-75 gauge, the arrow should be marked forward if facing the display, and to the left facing the display for C-200 & C-300 gauges. Always align the gauges to the front of the footprint marked out on the pavement.

815.11 Procedure for Determining Limits of Unacceptable Material

Standard spec 460.3.3.1 requires the engineer to investigate a single nuclear density test result, greater than 3.0% below specified minimums. The engineer needs to access acceptability of that material by performing the following:

1. Test at 50-foot increments both ahead and behind the unacceptable site, using the same offsets as the original test.
2. Continue 50-foot incremental testing until the test value indicates conforming material (i.e., within 3.0% less than minimum required density).
3. Materials within the incremental testing indicating more than 3.0% below minimum required density are defined as unacceptable, and will be handled as follows:
   - 3.1. Remove and replace unacceptable materials with the same mix type, unless otherwise approved by the project engineer, and meeting the required specified density. This will be done to the full

lane width as defined by the density requirements. The shoulder may be considered separately from the mainline. Unacceptable materials replaced are at contractor cost.

3.2. If unacceptable materials are allowed by the project engineer to remain in place, tonnages will be paid at 50%.

Note: If the 50' testing extends into a previously accepted lot, removal of the unacceptable material may be required or allowed to stay in place at a 50% payment deduct; however, the results of these tests must not be used to recalculate the previous accepted lot density.

815.12 Vacant

Remove 815.12 Soils Reference Site Monitoring subsection. This information can be found in WTM T310.

815.12.1 Use of Nuclear Moisture / Density Gauges on Soils, Base Course, etc.

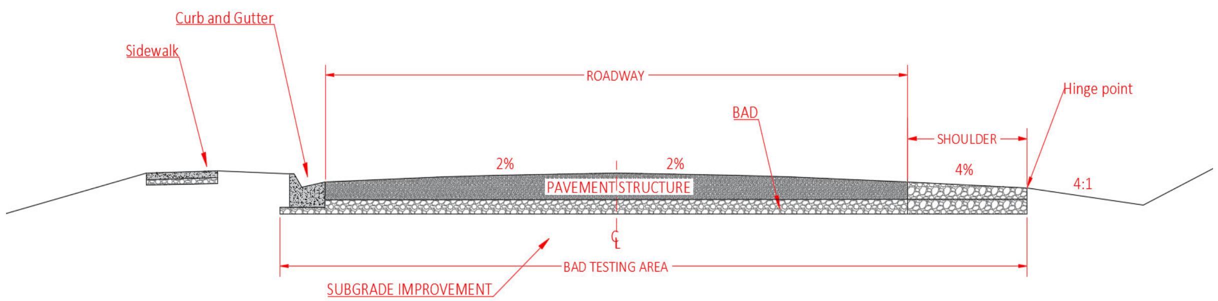
Remove some information from 815.12.1 Use of Nuclear Moisture/Density Gauges on Soils, Base Course, etc. This information can be found in WTM T310.

During testing, the gauge must be set on a flat surface with no more than 1/16" void between the gauge's surface and the material being tested. If any small air voids need to be filled, use only native material as filler.

If the gauge needs to have a moisture bias for a specific soil, the gauge operator needs to conduct tests at 2 random locations with that soil type. After each moisture / density gauge test is completed, the material directly below the gauge will be retained and a 1-point Proctor test must be run at its natural moisture level. Then use part of the sample and perform a natural dry-back. Compare the average moisture content of the natural soil to the average moisture reading of the gauge. If the difference between the two averages exceeds 1.0 pcf, then a moisture bias is needed for that gauge for that specific material.

For density testing of 1-1/4" base aggregate, the defined area for testing should be between shoulder hinge points or the edge of subgrade improvement. A hinge point is defined as the location where the shoulder steepens in the clear zone. The edge of subgrade improvement is defined as the horizontal extent of where the subgrade has been compacted. Hinge points are typically found in rural settings, and the edge of subgrade improvement areas are typically located near curb and gutter installations in urban settings. An example of a typical roadway section is shown in Figure 815-1 to provide guidance in locating the base aggregate dense (BAD) testing area.

FIGURE 815-1 Base Aggregate Dense (BAD) Testing Area



815.12.2 Establishing a Moisture Density Gauge Bias for Soils

Remove some information from 815.12.2 Establishing a Moisture Density Gauge Bias for Soils subsection. This information can be found in WTM T310.

All Proctor tests must have a minimum of 5 points, 2 ascending and 2 descending, with 1 point at or near the optimum moisture.

815.13 Test Strip Requirements for Stone Matrix Asphalt (SMA) and Coarse (Gap-graded) mixes

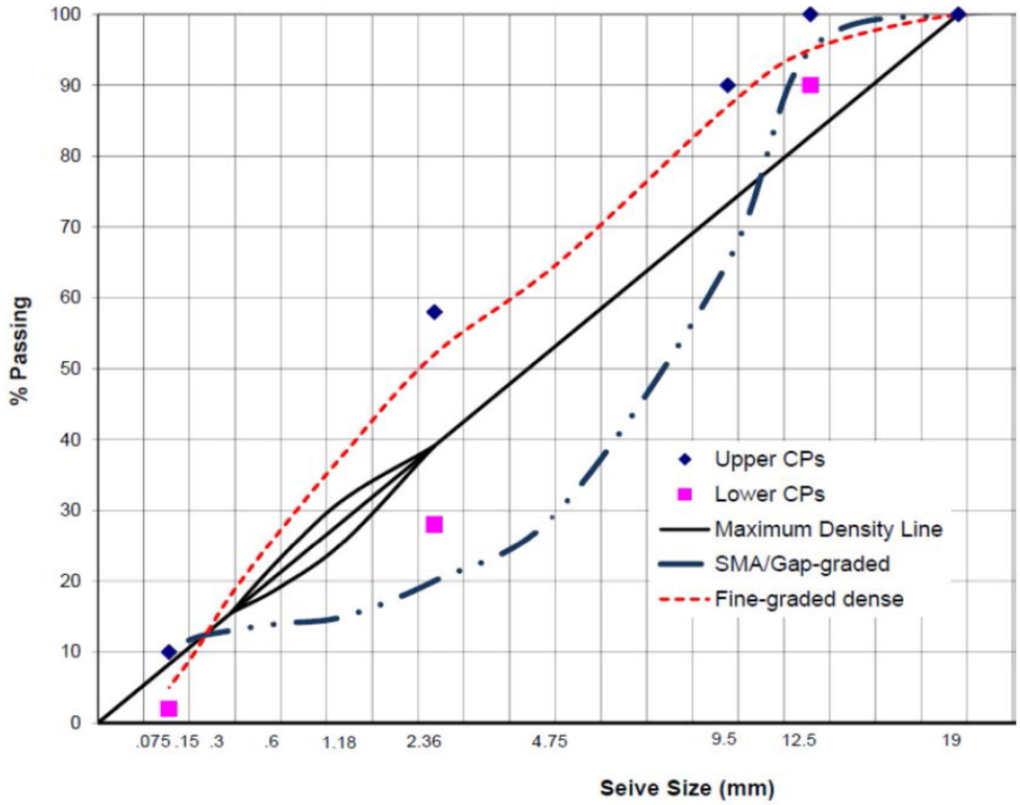
The procedure for correlating gauges to pavement cores using as test strip for SMA and gap graded mixes prescribed in 815.13.1 is mobilized into the contract in standard spec 460.3.3.2.

815.13.1 Test Strip Description

Revise 815.13.1 figure number and add reference to WTM T355.

Density determination procedures and requirements must be used to correlate nuclear gauges to pavement cores for SMA and gap graded mixes. Since SMA is a type of gap-graded mixture, only the term SMA will be used to describe both SMA and gap-graded mixtures.

FIGURE 815-2 SMA(Gap Graded) Gradations



Correlate nuclear gauges to pavement cores for SMA pavement using a WisDOT test strip according to WTM T355 Appendix X1. Construct one approved test strip for each mix design of SMA for each contract. Ensure the test strip is acceptably compacted and meets all requirements specified in the contract special provisions for SMA pavements. The test strip is to remain in place and becomes part of the completed pavement. The following describes the SMA density and volumetric testing tolerances required for an SMA test strip.

Notify the department at least 48 hours in advance of construction of the test strip. At the beginning of the first shift of production requiring a test strip, produce approximately 500 ton of SMA and cease production until the required testing is completed. Test strips must be located in a section of the roadway to allow a representative (i.e. not a ramp or shoulder, etc.) rolling pattern.

815.13.1.1 Sampling and Testing Intervals

Remove some information from 815.13.1.1 Sampling and Testing Intervals subsection. This information can be found in WTM T355.

Laboratory testing will be conducted from three split samples, with portions designated for QC, QV, and retained. Required field tests include contractor quality control (QC) and department quality verification (QV) nuclear density gauge tests and pavement coring.

During production for the test strip, HMA mixture samples are obtained from trucks before departure from the plant. Two split samples are collected during the production of test strip material. Sampling and splitting are in accordance with section CMM 815.13.1.3 and as further detailed in CMM 836. These two samples will be randomly selected from each half of the test strip tonnage (T), excluding the first 50 tons, and will be identified by the project engineer:

TABLE 815-1: Interval Windows for Test Strip Volumetric Samples

Sample Number	Production Interval (tons)
1	50 to T/2
2	T/2 to T

All test reports are submitted to the department upon completion and approved before paving resumes.

815.13.1.2 Field Tests

Remove some information from 815.13.1.2 Field Tests subsection and add references to WTM procedures.

Daily standardization of gauges on reference blocks and a reference site is performed in accordance with WTM T355. A gauge comparison according to WTM T355 must be completed before the day of test strip construction. Nuclear gauge readings and pavement cores are used to determine nuclear gauge correlation in accordance with WTM T355 Appendix X1. The target maximum density used to determine core density is the average of the two QC volumetric/mix Gmm values from the test strip multiplied by 62.24 pcf. Each team must have at least two gauges correlated at the time of the test strip. Any data collected by a team without an acceptable gauge (i.e., correlated during test strip) will not be accepted. Two gauges per team are not required to be onsite daily after completion of the test strip.

Each core, 150 mm (6 inches) in diameter must be taken at locations identified in WTM T355 Appendix X1. Each random core must be full thickness of the layer being placed. This may require cutting/separation of core from underlying layers at the pavement layer interface to ensure that subsequent testing is performed only on the most recently placed layer/mix.

Coring and filling of core holes must be approved by the project engineer and performed according to WTM R67.

815.13.1.3 Laboratory Tests

Remove some information from 815.12.1.3 Laboratory Tests subsection and add references to various WTM procedurs.

QC and QV samples are tested for Gmm, Gmb, and AC. Air voids and VMA are then calculated using these test results. QC samples are also tested for aggregate gradation. Material is collected from trucks at the plant according to the frequency described in CMM 815.13.1.1 above. Sample sizes must be consistent with the minimums for a three-part split as described in WTM R47.

Bulk specific gravities for cores and gyratory compacted specimens are determined according to WTM T166. Two QC volumetric tests are conducted during the test strip, and the department representative randomly selects one of the two splits for QV testing. The Gmm is determined according to AASHTO T209 as modified in WTM 209.

The bulk specific gravity values determined from field cores are used to calculate a correction factor (i.e., offset) for the QC and QV nuclear density gauges to be used throughout the remainder of the project for that mix and layer. QC and QV teams may wish to scan with additional gauges at the locations detailed in WTM T355 Appendix X1, as only gauges used during the test strip correlation phase will be allowed on the remainder of the project.

For additional information on sample size, splitting, and laboratory testing, refer to WTM R97 and WTM R47.

The 12 density tests required for determining the control strip density and rolling pattern for asphalt base, prescribed in 815.13.2 is mobilized into the contract in standard spec 460.3.3.2.

815.13.2 Density Testing Asphaltic Base Mixtures

The control strip consists of 1000 feet of the asphaltic base mixture that contains a minimum of one QC mixture test and twelve sites for nuclear density testing. Within the control strip, the department, using random numbers for sample determination, will identify twelve locations for density testing. Upon completion of the desired compaction for the control strip, nuclear density tests will be performed by the contractor at the twelve locations. Do not use additional materials to aid in seating the gauge.

The Control Strip accepted density will be determined by calculating the median value of the random twelve nuclear density locations. Within (4) hours, the contractor will provide the department with test results for the QC sample and Control Strip acceptance density. The QC sample is taken randomly within the first 300 tons of production not to include the first 50 tons. The Control Strip will validate the rolling pattern to be used for the remainder of the contract if the air voids from the initial QC sample taken during the control strip construction falls between 2.5% to 4.0%. If the test results do not meet these minimum requirements during the first control strip, an investigation will result, and a new control test strip and new QC sample will be required. Once the contractor has proven in the control strip that he can maintain a minimum density of 91.0% density, the rolling pattern will be accepted and used for the remainder of the project. The department maintains the right to verify that the rolling pattern is maintaining a minimum density of 91.0% at any time. If the department's test is less than 91.0%, a new control strip may be required, at the department's discretion. QMP nuclear density testing does not apply to asphaltic base. Mixture production will be stopped, and an investigation initiated if any of the following conditions occur:

1. The previous day's maximum specific gravity average from QC testing varies by ≥ 0.020 from the value of the initial QC test;
2. If a new mix design is required (i.e, 250 number), a new test strip will be required.

3. Any other condition occurs which in the judgment of the project engineer would warrant the establishment of a new control strip density.

Submit the results to the project engineer. The Materials Reporting System is not designed to accept nuclear density test results for Asphaltic Base. Asphaltic Base is not subject to density incentive/disincentive bid items. Also note that the control strip is not to be used for gauge comparison. That procedure is done as described in WTM T355 and will be completed before density testing in the control strip.

815.14 Reports Forms

A Daily Nuclear Reference Check Record form must be completed each day that a gauge is used. All data fields must be recorded.

The operator must choose the form relevant to the gauge manufacturer and fill in all columns. This form may also be used for recording data when determining the value for a field reference location.

A copy of the appropriate form will be left with the project engineer, unless mutually agreed upon.

Nuclear density forms are on the AASHTOWare Project Knowledge Base (AWPKB) website at:

https://awpkb.dot.wi.gov/Content/constr/Pantry/StatewideForms.htm

815.15 Acceptance and Incentive/Disincentive

For nuclear density testing data that indicate densities of less than the specified minimums, appropriate steps should be taken to identify and resolve the problem. Review all test procedures and derived data to ensure the test data is correct. Problems relating to the nuclear test equipment should be referred immediately to the RSO.

Additional tests taken for information purposes must not be averaged with the initial test or used to reduce payment when the tests are non-complying.

815.15.1 Disincentive for HMA Pavement Density

The determination is based on five factors:

1. Type of HMA Pavement, location, and layer.
2. Amount of deficiency in attained density in terms of percent below minimum required density. See standard spec 460.5.2.2 for percent of contract unit price allowed.
3. Contract unit price per ton of HMA pavement.
4. Number of tons of asphaltic mixture in the deficient lot. This may be determined by any available means, such as by plant or load records, delivery tickets, theoretical yield quantity, etc.
5. A non-compared gauge was used to conduct testing.

815.15.2 Incentive for HMA Pavement Density

Note: This section and the contained examples do not apply to stone matrix asphalt (SMA) pavements

If the lot density is greater than the minimum specified in standard spec 460.3.3.1, table 460-3 and all air void test results for that mixture placed during the same day are within 2.5% to 4.0%, the pay should be adjusted for the lot as specified in standard spec 460.5.2.3 or the special provisions.

Examples of Computing Incentive/Disincentive for QMP Nuclear Density

Project Information for Examples 2 and 3:

A project begins at station 56+78 and ends at station 234+25. It is a 2-lane roadway with a shoulder on each side. The traffic lanes are 12 feet wide and the shoulders are 3 feet wide. Shown in figure 815-11 is the eastbound traffic lane and shoulder for the length of the project. The contractor will be paving the shoulder integrally with the traffic lane. The pavement is a 2-inch overlay and the same HMA mix type is used on the entire project. The bid price for the HMA pavement item is $41.75 per ton. The specified target density for the traffic lane is 93.0%. The target density for the shoulder is 92.0%.

Day One:

The contractor begins paving at station 56+78 and ends the day at station 102+97, a total length of 4,619 feet. A quantity of 677 tons was placed on the eastbound traffic lane, and 169 tons was placed on the integral shoulder.

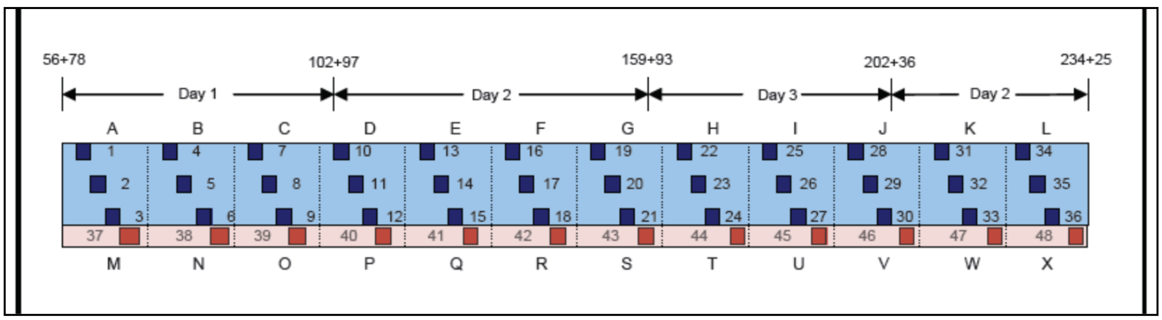
Day Two:

The contractor begins paving at station 102+97. Due to traffic staging requirements, the contractor stops paving at station 159+93, 5,696 feet, and begins paving again at station 202+36. They end the day at the end of the project, station 234+25, 3,189 additional feet. A quantity of 1303 tons was paved on the eastbound traffic lane, and 326 tons was placed on the integral shoulder.

Day Three:

The contractor begins paving at station 159+93 and ends the day at station 202+36, 4,243 feet. A total of 622 tons was placed on the eastbound traffic lane, and 156 tons was placed on the integral shoulder.

FIGURE 815-11 Linear Sublot Example Project



Example 2:

Use the example project information and the following test results from Day One. All of the day's air voids tests were acceptable (Density Calculated off the pcf value, sublot is the average of the density %)

Sublot ID	Test ID	% Density	Sublot Avg % Density
A 56+78 to 71+78	1	93.8	94.1
	2	94.2	
	3	94.4	
B 71+78 to 86+78	4	94.1	94.5
	5	94.7	
	6	94.6	
C 86+78 to 101+78	7	93.6	94.1
	8	94.5	
	9	94.3	

Sublot ID	Test ID	% Density	Sublot Avg % Density
M	37	93.2	93.2
N	38	94.2	94.2
O	39	93.0	93.0

1. Compute the average density for each traffic lane sublot and each shoulder sublot.
   SOLUTION: See the results in the table above.
2. Compute the density incentive or disincentive for the day's paving.
   SOLUTION:
   -Traffic Lane:
   The specified target density for the traffic lane is 93.0%. All of the sublot averages were no more than one percent below the target density, so all of the day's traffic lane test results are used to compute the daily lot density and the lot incentive pay.
   - Lot density = (93.8 + 94.2 + 94.4 + 94.1 + 94.7 + 94.6 + 93.6 + 94.5 + 94.3) / 9 tests = 94.2%

   According to standard spec 460.5.2.3, this lot density is eligible for incentive pay of $0.40 per ton. 677 tons of HMA was placed on the traffic lane on day 1, therefore the contractor receives $270.80 density incentive for the day 1 traffic lane lot. This is for all of sublot A, B & C and the 119' in sublot D that did not reach the random number.
   - Shoulder:

   The minimum required density is 92.0%. All of the sublot averages were acceptable, so all of the day's shoulder tests are used to compute the shoulder lot density. The average of all the shoulder tests is 93.5%. According to the specification, this lot density is eligible for incentive pay of $0.40 per ton. 169 tons of HMA was placed on the shoulder on day 1, therefore the contractor receives $67.60 density incentive for the day 1 shoulder lot.

Example 3:

Use the example project information and the following test results from day three. All of the day's air voids tests were acceptable.

Sublot ID	Test ID	% Density	Sublot Avg % Density
H 161+78 to 176+78	22	91.8	91.8
	23	91.9	
	24	91.7	
I 176+78 to 191+78	25	95.1	94.9
	26	94.8	
	27	94.9	
J 191+78 to 202+36	28	92.0	91.9
	29	91.8	
	30	91.9	
T	44	91.9	91.9
U	45	94.4	94.4
V	46	92.1	92.1

Compute the density incentive or disincentive for the day's paving.

SOLUTION:

1. Traffic Lane:

   According to the specification, a minimum density of 93% is required for the traffic lane. When verifying whether or not the sublot densities meet the requirements, it is found that sublot H and sublot J have average densities that are more than one percent below the required minimum. According to the specification, the quantities of HMA pavement and asphaltic material items placed this day in each of these sublots is subject to disincentive, and the day's test results within these sublots are not included when computing the incentive for the remainder of the lot.

2. Sublot H:

   Day 3 began inside the limits of sublot G, at station 159+93, but beyond its random test location. The tests for sublot G represent material placed on day 2. The tests in sublot H represent the day 3 material from station 159+93 to 176+78, total length of 1685 feet long (185' from sublot G, paved on day 3, and 1500' in sublot H) by 12 feet wide.

   Quantity represented by tests in sublot H =

   $$\frac{1685\,ft\ \times 12\,ft}{9\,ft^2/yd} \times \frac{2\,in\ \times 112\,lb/yd^2/in}{2000\,lb/ton} = 252\,tons$$

   According to the disincentive pay table in the specification, the quantities are subject to a pay factor equal to 95 percent of the contract price. This is equivalent to a 5 percent pay reduction.

   Disincentive Density HMA Pavement = 252 tons x ($41.75/ton x 0.05) = -$526.05

3. Sublot I:

   Quantity represented by tests in sublot I =

   $$\frac{1500\,ft\ \times 12\,ft}{9\,ft^2/yd} \times \frac{2\,in\ \times 112\,lb/yd^2/in}{2000\,lb/ton} = 224\,tons$$

   According to the incentive pay table, 224 tons of the HMA pavement item are eligible for an incentive of $0.80 per ton, or a total of $179.20.

4. Sublot J:

   Day 3 ended within the limits of sublot J, beyond its random test location. The day 3 quantity placed within sublot J, from station 191+78 to 202+36, at length of 1,058 feet, is represented by its tests. The day 2 quantity placed toward the end of sublot J is represented by the tests taken on day 2 within sublot K.

   Quantity represented by tests in sublot J =

   $$\frac{1058\,ft\ \times 12\,ft}{9\,ft^2/yd} \times \frac{2\,in\ \times 112\,lb/yd^2/in}{2000\,lb/ton} = 158\,tons$$

   According to the disincentive pay table in the specification, the quantities are subject to a pay factor equal to 95 percent of the contract price. This is equivalent to a 5 percent pay reduction.

   Disincentive Density HMA Pavement = 158 tons x ($41.75/ton x 0.05) = -$329.83

5. Shoulder:

   All of the day 3 shoulder sublots have acceptable density values, so we use all of the results to compute the day's shoulder lot density.

   Day 3 shoulder lot density = (91.9 + 94.4 + 92.1) / 3 tests = 92.8%

   The lot density of 92.8% is not more than 1.0% above the required minimum of 92.0%, therefore the day 3 shoulder pavement does not receive any density incentive.

Note: For shoulders paved integrally with the traffic lane see standard spec 460.5.2.3(3).

Day 3 Incentive/Disincentive Summary:

Incentive Density HMA Pavement (Lot I) = $179.20

Disincentive Density HMA Pavement (Lot H) = -$526.05

Disincentive Density HMA Pavement (Lot J) = -$329.83

815.16 Density Data Submittal

After verifying the contractor's data, the department calculates pay adjustments using the department's MRS software. The contractor must submit the required density test information electronically using the MRS software. The contractor should contact Atwood Systems to have the necessary software installed. Call toll free phone: (877) 518-1920 or email at: support@atwoodsystems.com

Note: Asphaltic Base test results are recorded and submitted on DOT forms, and not submitted to the MRS system.