Materials sampling and testing methods and documentation procedures prescribed in chapter 8 of the CMM are mobilized into the contract per standard spec 106.3.4.1 and standard spec 106.3.4.3.1.

CMM provisions mobilized by the contract: CMM 8-15.10.2.1, CMM 8-15.10.2.2, CMM 8-15.10.2.3

8-15.1 General

Field densities are taken by nuclear methods in accordance with established procedures as required by the contract. If the contract contains quality management program (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 per standard spec 460.3.3.2. Once a method has been selected for determining mat density; that method should be used throughout the project.

8-15.2 Nuclear Gauges

The State of Wisconsin Department of Health Services (DHS), Radiation Protection Section issues a license to WisDOT specifying that use of radioactive gauges by the department be supervised by the WisDOT Radiation Safety Officer (RSO). The RSO must be kept informed of the location and usage activities of WisDOT nuclear gauges at all times. The WisDOT RSO contact information will be supplied to each user of a WisDOT nuclear density gauge.

The WisDOT RSO may be contacted at the following telephone numbers:

(608) 516-6359, Primary

(715) 421-8002, Wisconsin Rapids Office

Nuclear gauge owners are responsible for compliance with State of Wisconsin DHS Radioactive Materials license or NRC license requirements. In addition, they must comply with WisDOT requirements when engaged in work on WisDOT projects. Personnel who either use nuclear gauges or directly supervise the use of gauges must be trained in radiation safety and transportation of radioactive materials, and must maintain the appropriate Highway Technician Certification Program (HTCP) certifications.

Sampling and testing certification is an FHWA requirement in the CFR 23 part 637. The Nucdensitytec-1 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

http://www.uwplatt.edu/htcp/

In addition to certification of the operator, the department requires that all individual nuclear moisture / density gauges used on WisDOT projects be on the approved list. This policy applies to all WisDOT, consultant, and contractor gauges used for acceptance or QMP density testing. Before each construction season, the gauge must be calibrated by a manufacturer approved calibration service provider, and then the tester must perform calibration adjustments for each gauge using the reference blocks located in the Wisconsin Rapids Sign Shop, 2841 Industrial Street, Wisconsin Rapids, WI. This procedure must be followed if the gauge is sent in for any manufacturer calibration or service during the construction season. Contact the RSO at the numbers listed above for access to the blocks and scheduling.

WisDOT maintains an annual list of consultants and contractors certified gauges approved to perform nuclear testing on WisDOT administered projects. Consultants and contractors must be on this list in order to perform acceptance and nuclear gauge testing on WisDOT projects. This list is established and maintained by the Quality Assurance Unit in central office, and is available at:

http://www.dot.wisconsin.gov/business/engrserv/approvedprod.htm

To verify that the department has the correct information for your company, you must submit the following information yearly:

1. Current copy of your Wisconsin Agreement State License or your Federal Nuclear Regulatory Commission (NRC) license.
2. Copies of current nuclear moisture and density gauge 3 block calibration certificates (5 blocks for other states) conducted by the manufacturer or an approved calibration service.
3. Company contact person, RSO, or safety officer (please update as changes occur).
4. The WisDOT Block Calibration form,(including new constants), WS7011.

Please send this information to:

Wisconsin Department of Transportation

Bureau of Technical Services, Truax Center

ATTN: WisDOT RSO
3502 Kinsman Blvd
Madison WI 53704-2507
michael.bohn@dot.wi.gov
(Note: email is to be used as the primary means of sending this information)

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

8-15.3 Nuclear Density Gauge Safety

8-15.3.1 Lost or Stolen Gauges

If a gauge is lost or stolen, notify the Radiation Safety Officer (RSO) as soon as possible. The RSO will notify the appropriate regulatory agency per DHS 157.

8-15.3.2 Damaged Gauges

The operator will follow these procedures in the event of gauge damage (per DHS 157 Appendix H). All companies must have available an appropriate radiation survey meter in accordance with

http://docs.legis.wisconsin.gov/code/admin_code/dhs/110/157.pdf

- Seal off the area for a distance of 15 feet around the gauge in question to prevent exposure to themselves and others. Protect the gauge from further damage.
- Stop the vehicle or heavy piece of equipment that is involved, it must be detained in order to verify that it is not contaminated.
- Never let the gauge in question be left UNATTENDED.
- Visually inspect the gauge to determine the extent of the damage to the source(s), source housing(s), and shielding. Check the base of the gauge for any splits or punctures. Take Pictures, take notes and statements to document incident.
- Do not handle the gauge if it has been damaged severely enough that source rod or internal shielding is cracked or broken open.
- Notify the Radiation Safety Officer (or notify supervisor who will contact the RSO) as soon as possible. *The RSO will notify the appropriate regulatory agency.*
- Follow the instructions of the RSO

8-15.4 Annual Bureau of Technical Services Gauge Block Calibration Procedures

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

1. Bureau of Technical Services 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, Humbolt 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, Humbolt, or InstroTek, record the required data Wet 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. Recenter 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.

Removed use of ValiDator for calibration of gauges.

Record the Block results on the WisDOT Block Calibration form WS7011 and submit to the RSO.

8-15.5 Nuclear Density Testing HMA

8-15.5.1 General

Take necessary steps to coordinate and schedule the required nuclear test equipment and a trained operator so the required density testing may be performed expeditiously within the specified time requirements. All density testing must be done as soon as practical after the completion of the compaction process and before opening to traffic. On a closed road testing must be completed before the end of the next working day after placement.

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

During tests, the gauge must be kept the following minimum distances from:

- Pavement transverse construction joints.....20 feet
- Bridge deck expansion joints.....20 feet
- Operator.....3 feet
- Bystanders.....15 feet
- Equipment, manholes, etc. .....15 feet
- Other nuclear devices.....30 feet
- Unrestricted edge of pavement.....1.5 feet
- Restricted edge of pavement.....1 foot

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

8-15.6 Project Nuclear Density Testing

The operator will take new standard counts for density and moisture at the project. (Note: it is important to check the standard counts daily to account for changing conditions and to check gauge performance. An incorrect moisture count will cause a gauge to incorrectly determine density. This check should be done daily on all manufacturers' gauges (Troxler, CPN, Humbolt, Seaman and so forth).

8-15.7 QMP QC & QV Nuclear Density Gauge Comparison

Gauge is run thru a comparison process verses a correlation process.

Select a representative section of the compacted HMA pavement prior to or on the first day of paving for the comparison process. The section does not have to be the same mix design. Compare the 2 or more gauges used for density measurements (QC, QV). The QC and QV gauge operators will perform the comparison on 5 test sites jointly determined. Record each density measurement of each test site for the QC, QV and other acceptance gauges. Calculate the average of the difference in density between the QC and QV gauges of the 5 test sites. Locate an additional 5 test sites if the average difference exceeds 1.0 lb/ft^3. Measure and record the density on the 5 additional test sites for each gauge if applicable. Calculate the average of the difference in density between the QC and QV gauges of the 10 test sites. If the average difference of the 10 tests exceeds 1.0 lb/ft^3, the regional HMA Coordinator will use their gauge to investigate the situation with the QC and QV personnel, with the consultation of the RSO, to determine necessary actions. If calibration factors need to be adjusted in the field, contact the RSO beforehand for guidance and documentation.

On Soils, Sand & Gravel, Recycled Materials, Stabilized Bases, etc, select a representative section of the compacted material prior to or on the first day of placement for the comparison process. Compare the 2 or more gauges used for QC and QV density measurements in BS or in DT mode. The QC and QV gauge operators will perform the comparison on 5 test sites jointly located. Record each density measurement of each test site for the QC, QV and other acceptance gauges. Calculate the average of the difference in dry density between the QC and QV gauges of the 5 test sites. If the average dry density difference exceeds 1.5 lb/ft^3, locate an additional 5 test sites. Measure and record the density on the 5 additional test sites for each gauge if applicable. Calculate the average of the difference in dry density between the QC and QV gauges of the 10 test sites. If the average difference of the 10 tests exceed 1.5 lb.ft^{3,} replace one or more gauges and repeat the comparison process. Use the last two test sites from the final comparison process and proceed with your moisture basis calculations as explained in CMM 8-15.12.1. If the difference in moisture content between a gauge and the corresponding sample exceeds 1.0 lb/ft^3, 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.

8-15.8 HMA QMP Reference Site Monitoring

After performing the gauge comparison on HMA, establish a project reference site approved by the department. Clearly mark a flat surface of concrete or asphalt or other material that will not be disturbed for the duration of the project. Perform reference site monitoring of the QC, QV, and any additional gauges at the project reference

site. Conduct an initial 10 density tests with each gauge on the project reference site and calculate the average value for each gauge to establish the gauge's reference value. Use the gauge's reference value as a control to monitor the calibration of the gauge for the duration of the project. Check each gauge on the project reference site at least once a day, before performing any density testing. Calculate the difference between the gauge's daily test result and its reference value. Investigate if a daily test result is not within 1.5 lb/ft^3 of its reference value. Conduct 5 additional tests at the reference site once the cause of the deviation is corrected. Calculate and record the average of the 5 additional tests. Remove the gauge from the project if the 5 test average is not within 1.5 lb/ft^3 of its reference value. The regional HMA coordinator will use their gauge to investigate these situations with the QC and QV personnel to determine necessary actions.

8-15.9 Non QMP HMA Nuclear Density Reference Site Monitoring

For non QMP HMA Nuclear Density projects, the regional block can be used as the project reference site. Each gauge needs to be within 1.0 lb/ft^3 of the block's reference value. If the region chooses to use a project located reference site, use the procedure explained in CMM 8-15.8.

8-15.10 Use of Nuclear Moisture/Density Gauges on HMA

During testing, the gauge must always be set on a flat level surface on the material being tested, with the longest dimension of the gauge positioned parallel to the edge of the pavement. Outline the gauge with a lumber crayon or paint stick and show the direction of the source. Record the sub-lot number, percent compaction and density in lbs/ft^3 on the pavement for all acceptance and verification tests.

Check the gauge on the reference site at least once a day if a new density or moisture standard is established, and before performing any moisture or density tests. The designated materials persons (standard spec 106.1.2) will determine how the documentation will be communicated at the preconstruction meeting. A new density and moisture standard must be established daily during paving operations of new HMA pavements that require density testing. 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.

The following data must be recorded daily on field project data sheets. These sheets will be made available to the project engineer upon request:

- Reference site block data
- Standard block data, including the density and moisture standard
- Density count, moisture counts or contact and air gap counts

8-15.10.1 Target Maximum Density

For HMA pavement density determination, the target value in lb/ft^3 is established using the mixture maximum specific gravity (G_{mm}). On the first day of paving an HMA mixture design, the target maximum density will be the G_{mm} value indicated on the mix design multiplied by 62.24 lb/ft^3 . The target maximum density for all other days will be the G_{mm} four-test running average from the end of the previous days' production multiplied by 62.24lb/ft^3. If four tests have not been completed by the end of the first day, the average of the completed G_{mm} test values multiplied by 62.24 lb/ft^3 will be used until a four-point running average is established.

The following data must be recorded for each test on the worksheet for MRS entry

- Density standard and moisture standard
- Density count, moisture counts or contact and air gap counts
- Total wet density or bulk density
- % Compaction
- Manufacturer name and serial number
- Operators name
- Mix design number (WisDOT 250 ID) and daily Target max density target number (G_{mm} x 62.24 lb/ft^3)

8-15.10.2 Determining Test Locations

There are two different systems for determining locations for nuclear density testing. The linear system is to be used on all paving projects, including mainline paving, shoulders and appurtenances. The nominal tonnage system is to be used in areas where continuous lengths of paving are less than 1500 feet, including side roads, crossovers, turn lanes, ramps and roundabouts. The procedure for using each is described below.

8-15.10.2.1 Determining Test Locations Using Linear Sublots

When using the linear sublot testing specification, the sublot locations are to be determined prior to the project start-up for standard, constant width, mainline paving. Segmented, staged work with variable widths may need some adjustment during construction. A sublot is defined as 1,500 lane feet for each layer and target density. The number of required tests within each sublot is dependent on the lane width and is to be determined according to the Table 1 below. A sublot may include more than one day's paving. It is not required to take an

additional non-random test if a sublot spans more than one day's paving. Examples 3 and 4 demonstrate how to calculate incentive and disincentive in these situations. A partial quantity less than 750 lane feet will be included with the previous sublot at the end of the project. A partial quantity greater than 750 lane feet will be considered a standalone sublot.

Table 1 Number of test at each station, as determined by width

Lane Width	No. of Tests	Transverse Location
5 ft or less	1	Random
Greater than 5 ft to 9 ft	2	Random within 2 equal widths
Greater than 9 ft	3	Random within 3 equal widths

Here are some basic steps for determining test locations within sublots:

Step 1: Starting from the beginning station of the project, divide each lane into sublots using the specified sublot length. The only sublot that should have a partial length is the last sublot at the end of the project limits, although bridges or other paving obstacles may cause partial sublot lengths.

Step 2: Using the table in the specification, determine the number of tests required in each sublot, depending on the lane width.

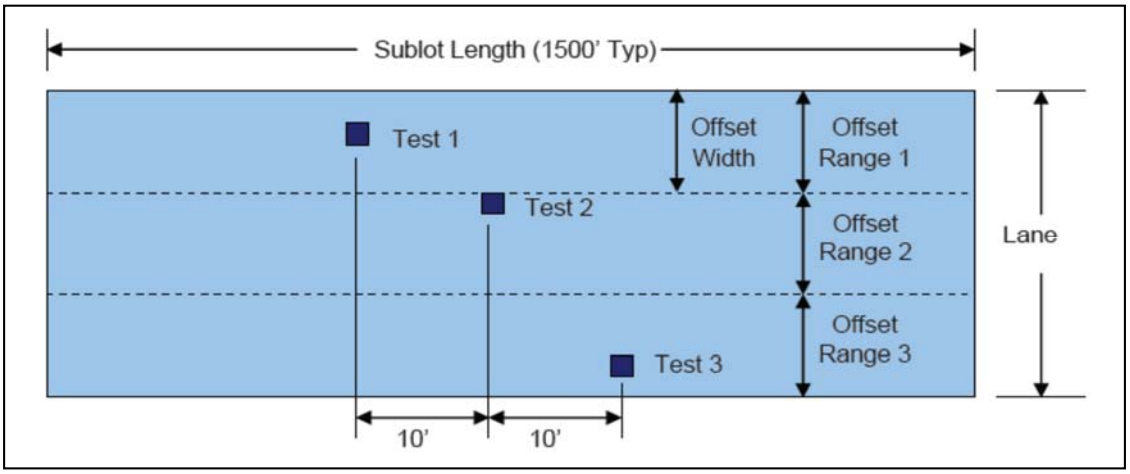
Step 3: Determine one random test station in each sublot. The sublot random test station is computed by multiplying the length of the sublot by a random number, and adding the result to the beginning station of the sublot.

Step 4: Determine the stations for each test site. For a sublot requiring only one test site, the test station will be the random station computed in step 3. For a sublot requiring multiple test sites, the first test will be taken at the station computed in step 3, with each subsequent test being performed 10 feet up station from the previous test.

Step 5: Determine the testing offset width and offset ranges for each lane. The offset width is the lane width divided by the number of required tests in the sublot.

Step 6: Determine the test site offsets. A random transverse location must be computed for each test site by multiplying the offset width by a random number, and adding the result to the beginning of the corresponding offset range.

Figure 1 Linear Sublot Layout



8-15.10.2.2 Side Roads-Intersections-Crossovers-Turn Lanes-Ramps- Roundabouts (<750 Tons per layer)

The number of nuclear density tests required for side roads, intersections, crossovers, turn lanes, ramps, and roundabouts with less than 750 tons per layer prescribed in Table 2 of CMM 8-15.10.2.2 is mobilized into the contract per standard spec 460.3.3.2.

A lot represents a combination of the sublots total combined tonnage per layer, per target Gmm, per day. A sublot represents a side road, intersection, turn lane, crossover, and ramp per layer. Perform the number of tests per lot as specified in Table 2 below:

Table 2 Testing Requirements for Side Roads, Intersections,Turn Lanes, Crossovers, Ramps, and Roundabouts (Less Than 750 Tons per Layer)

Side Roads, Intersections,Turn Lanes, Crossovers, Ramps, Roundabouts SubLot/ Layer Tonnage	Minimum Number of Tests Required
< 25 Tons	0
25 to 100 Tons	1
101 to 250 tons	3
251 to 500 tons	5
501 to 750 tons	7

Figures 2-4 are examples of test layouts for side roads and turn lanes, including calculations for determining tonnage.

Figure 2 Sublot Layout Example – Side Road

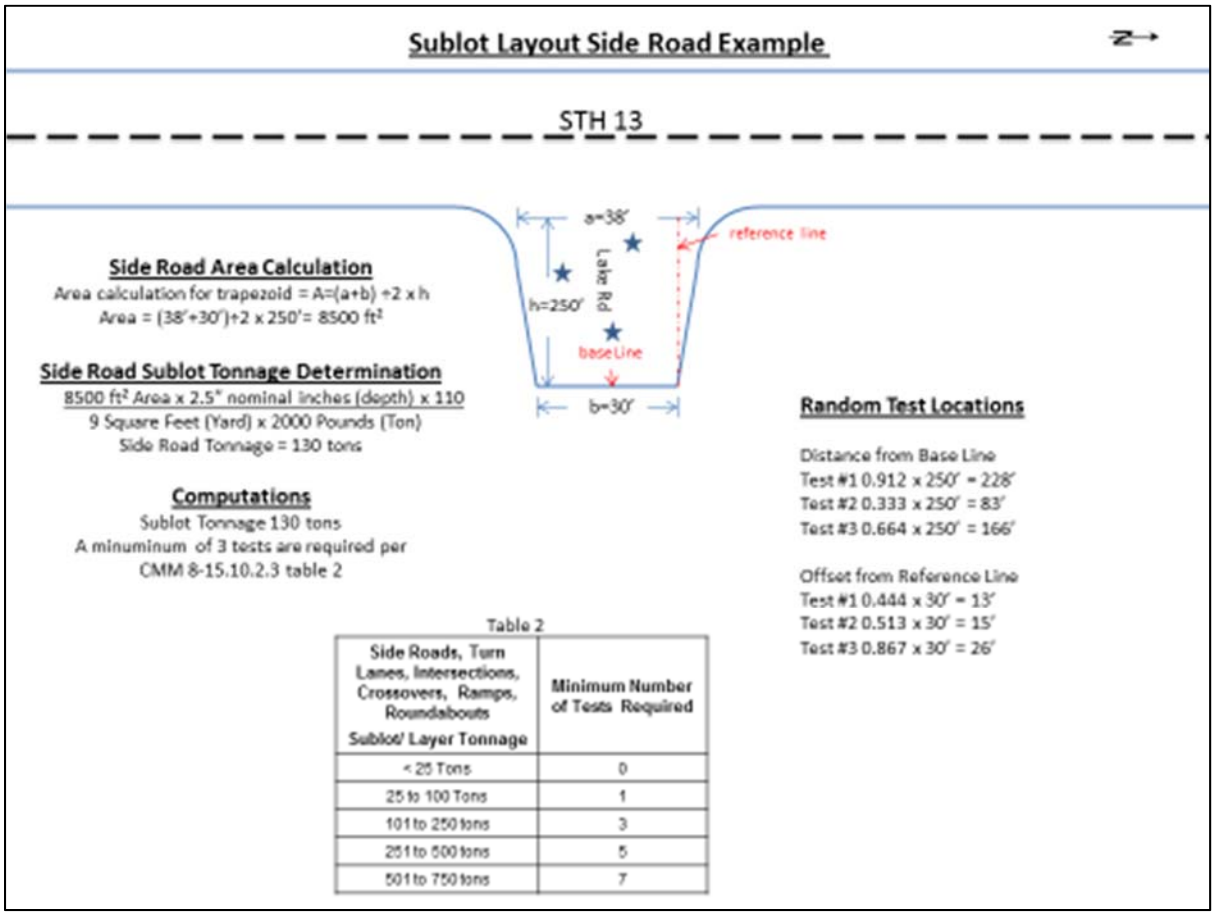


Figure 3 Sublot Layout Example - Turn Lane

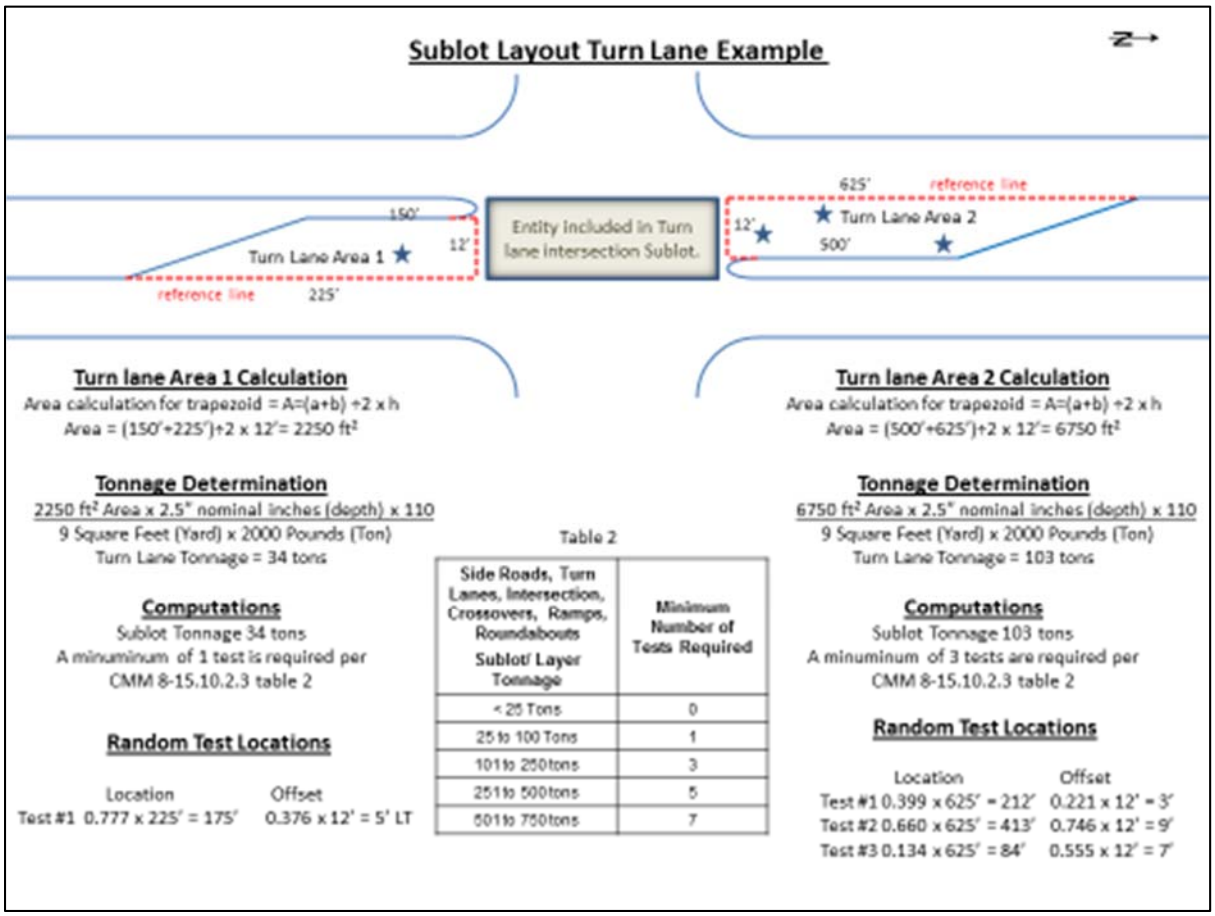
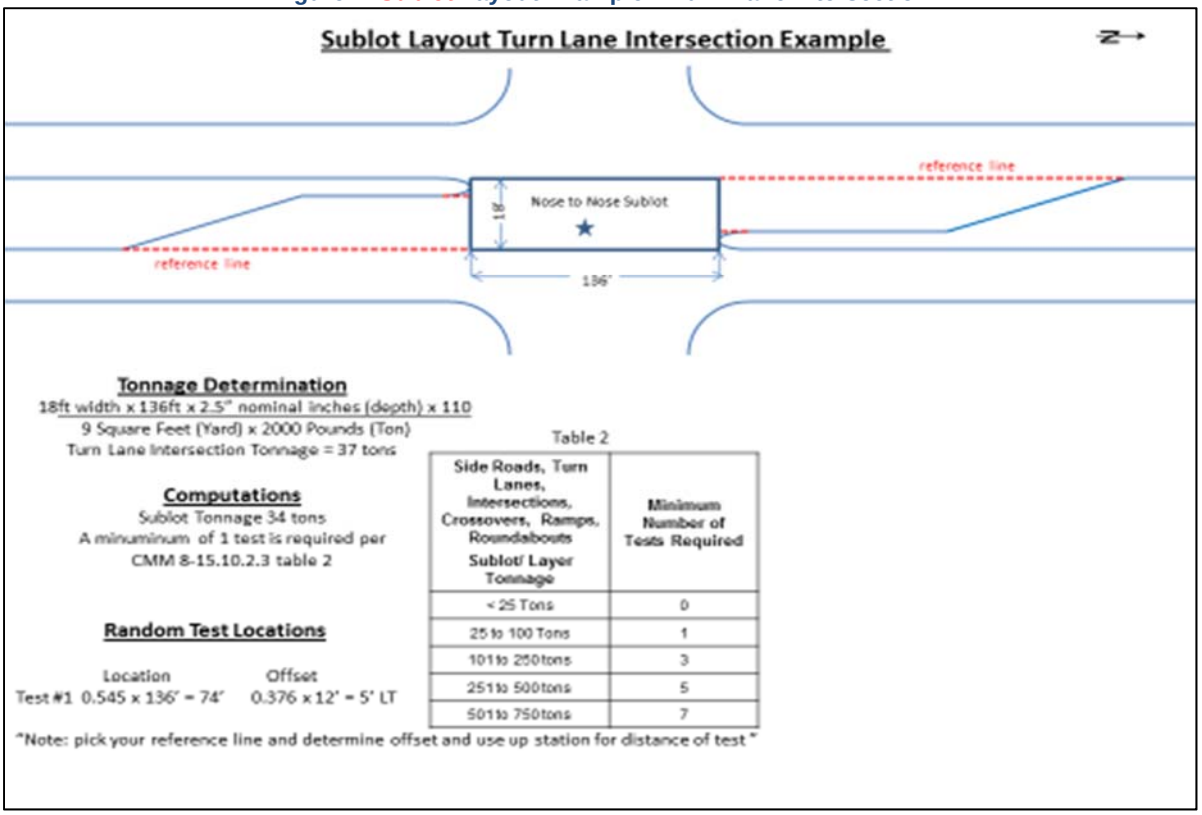


Figure 4 Sublot Layout Example – Turn Lane Intersection



8-15.10.3 Location of Random Test Sites

The specifications provide that each lot will be sampled at random locations. The random location determined for testing will be used for the lane and adjacent shoulder within that sublot. A lot will be one day's production of each sublot type or one production shift if running 24 hours per day.

The centerline is to be used as the reference line to determine offset (identify either right or left of centerline).

Locations of test sites must be determined randomly using ASTM D3665, department approved spreadsheet, a calculator equipped to provide random numbers, or other approved method.

The operator must check the test location for being level below the gauge. To ensure that the surface is flat, check opposite corners of the gauge for rocking. When the test site does not meet the above conditions, the site may be moved within 5 feet ahead or back and 2 feet right or left of the selected site. If this adjustment in the site location will still not meet the above criteria for finding a level test location, randomly select a new test site. Record your reason in the remarks area on the work form.

8-15.10.4 Duration of Test and Gauge Placement

The duration of tests must be conducted for four minutes when using CPN, Troxler, and Humbold and InstroTek gauges. Tests with Seaman gauges will be conducted for two minutes in contact mode and two minutes in air gap mode. During testing of pavements, the gauge must always be set on a flat surface with the longest dimension of the gauge positioned parallel to the edge of the pavement, and at least 30 feet from other nuclear devices and 15 feet from equipment, vehicles etc.

To ensure that the surface is flat, check opposite corners of the gauge for rocking. Mark out the outline of the moisture density gauge with a lumber crayon or paint stick and an arrow indicating source location. Once the test location has been set the gauge reading at that location must be counted as a legitimate test. Mark the density lbs/ft^3 and the percent compaction on the pavement. Re-rolling of the test location is prohibited under all circumstances.

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.

When testing soils or aggregate; prepare an area sufficient in size to accommodate the gauge. Remove all loose and/or disturbed material and plane the area to a smooth, flat, and level condition to obtain maximum contact between the gauge and the material being tested. When a void exceeds 1/16" in depth, the operator must use native fines or fine sand to fill these voids and then smooth the surface with a rigid plate or other suitable tool. The area filled beneath the gauge should not exceed 10 percent of the total area.

It is critical that the gauge is placed on a flat and level surface of the material to be tested in order to accurately determine the moisture/density of the material.

8-15.11 Procedure for Determining Limits of Unacceptable Material

For single nuclear density test results greater than 3.0% below specified minimums per standard spec 460.3.3.1, perform the following:

a. Test at 50 foot increments both ahead and behind the unacceptable site, using the same offsets as the original test.
b. Continue 50 foot incremental testing until the test value indicates a minimum payment factor of 70%.
c. Materials within the incremental testing indicating less than a 70% payment factor are defined as unacceptable, and will be handled as follows:
    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.
    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.

8-15.12 Soils Reference Site Monitoring

After performing the gauge comparison on soils, establish a project reference site approved by the department. Clearly mark a flat surface of concrete or asphalt or other material that will not be disturbed for the duration of the project. Perform 10 density tests in BS mode with each gauge at the project reference site and calculate the average density value for each gauge to establish each gauge's reference value. Use the gauge's reference value as a control to monitor the calibration of the gauge for the duration of the project. Check each gauge on the project reference site a minimum of once per day during placement of materials on the project. Calculate the

difference between the gauge's daily test result and its reference value. Investigate if a daily test result is not within 1.5 lb/ft^3 of its reference value. Conduct 5 additional tests at the reference site once the cause of the deviation is corrected. Calculate and record the average of the 5 additional tests, if applicable. Remove the gauge from the project if the 5-test average is not within 1.5 lb/ft^3 of its reference value.

If the department supplies a ValiDator II for the established project reference site, conduct an initial 5 density tests in back scatter (BS) mode and 5 tests in DT mode at all depths that will be tested in the field. Use the gauge reference value as a control to monitor the calibration of the gauge for the duration of the project. Check each gauge on the project ValiDator II a minimum of once per day at each testing location during placement of materials on the project. Calculate the difference between the gauge's daily test result and its reference value. Investigate if a daily test result is not within 1.0 lb/ft^3 of its reference value. Conduct 5 additional tests at the reference site once the cause of the deviation is corrected. Calculate and record the average of the 5 additional tests. Remove the gauge from the project if the 5-test average is not within 1.0 lb/ft^3 of its reference value.

8-15.12.1 Use of Nuclear Moisture / Density Gauges on Soils, Base Course, etc.

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.

Prepare the test site and check the gauge for rocking. Position the gauge handle and perform testing in either BS mode or in DT mode at 4-inch, 6-inch, or 8-inch depths. If there is a possibility that the pilot hole will collapse during testing, then use the backscatter test mode. After each test, the operator must remove the material below the gauge and check for any visible voids, cobbles, or organics that could have affected the test results.

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 lb/ft^3, then a moisture bias is needed for that gauge for that specific material.

8-15.12.2 Establishing a Moisture Density Gauge Bias for Soils

A density gauge measures the moisture content simultaneously with the density of a material. A moisture bias represents the average difference in moisture content between in-situ nuclear gauge measurements and the oven-dried samples for a particular nuclear gauge and a particular type of material.

Determine a gauge moisture bias for every soil or aggregate base at startup of testing or during gauge comparison. Use the procedure below, corresponding with the gauge type, to establish the correct gauge bias for any particular type of soil or base.

CPN & Seaman Gauges

1. On a compacted soil having a uniform moisture content, measure the density and moisture at two different locations using the density gauge in backscatter (BS) mode.
2. Obtain a soil sample from each test location (150 to 200 g) from directly beneath the center of the gauge footprint.
3. Weigh each wet sample. Oven-dry wet sample at 100° C, until the sample weight remains constant. Calculate the moisture content (M_{sample}) of each soil sample as follows:

   $$M_{sample}\ (\%) = \frac{(\text{Wet Weight} - \text{Dry Weight})}{\text{Dry Weight}} \text{ x } 100$$

4. Determine the oven-dry moisture of each test site (M_{site}), in pounds per cubic foot, as follows:

   $$M_{site} = \frac{M_{sample} \text{ x } D_{gauge}}{(M_{sample} + 100)},$$

   Where:

   M_{site}= site moisture, PCF

   M_{sample} = moisture content, % of dry weight (step 3)

   D_{gauge} = gauge measured wet density, PCF (from step 1)

5. Determine the correction factor (gauge moisture bias) to be applied to the gauge moisture readings.

   M_{Bias} (PCF) = M_{site} - M_{gauge}

   The average of the two bias values is the gauge moisture bias. This value can be used for all field testing of that project with that gauge for that same soil type.

Troxler 3411

1. Take two gauge readings at the site. Record the readings M_{gauge}) and calculate the average of the two readings (%). The average should be used for the offset factor calculation.
2. Remove a soil sample from each measurement site, then use the oven-dry laboratory method to determine the moisture content (%) of the samples (M_{sample}). Calculate the average moisture of the two soil samples (%). This average value should be used for the offset factor calculation.

3. Calculate the offset factor (*k*).

$$k = \frac{M_{sample(\%)} \text{ x } M_{gauge(\%)}}{(M_{gauge(\%)} + 100)} \text{ x } 1000$$

Troxler 3440

1. On a compacted soil having a uniform moisture content, determine the total density and moisture of two locations using the density gauge in the BS mode.
2. Obtain soil samples (150 to 200 g) from each site directly under the middle of the gauge test site footprints.
3. Weigh each sample, oven dry to a constant weight at 110° C, and weigh each dry sample. Compute the average moisture content as follows:

$$M_{sample}\ (\%) = \frac{(\text{Wet Weight} - \text{Dry Weight})}{\text{Dry Weight}} \text{ x } 100$$

4. Average the two M_{sample} (%) moisture results. Enter in the moisture offset – gauge derived, enter the average moisture of the samples (M_{sample}, dry-back %) and enter the average of the two gauge moisture readings (%).
5. Average the two M_{sample} (%) moisture results. Enter in the moisture offset – gauge derived, enter the average moisture of the samples (M_{sample}, dry-back %) and enter the average of the two gauge moisture readings (%).

Check the gauge on the project reference site a minimum of once per day during placement of all material placed within the 1:1 slopes on the project and compare it to the gauge's reference value. Maintain the reference site test data for the gauge at an agreed location.

All Proctor tests must have a minimum of 5 points, 2 ascending and 2 descending, with 1 point at or near the optimum moisture. The following data must be recorded on all project data sheets:

- Reference site block data
- Standard block data, including the density standard and moisture standard
- Density count, moisture counts or contact and air gap counts
- Total wet density or bulk density
- Dry density or bulk density dry
- Moisture # and moisture %
- Proctor number and target number
- Pit number, grading area, soils classifications, elevation
- % compaction
- Manufacturer name and serial number
- Station, elevation, and offset
- Upper or lower zone
- Operators name
- Moisture bias noted in test remarks

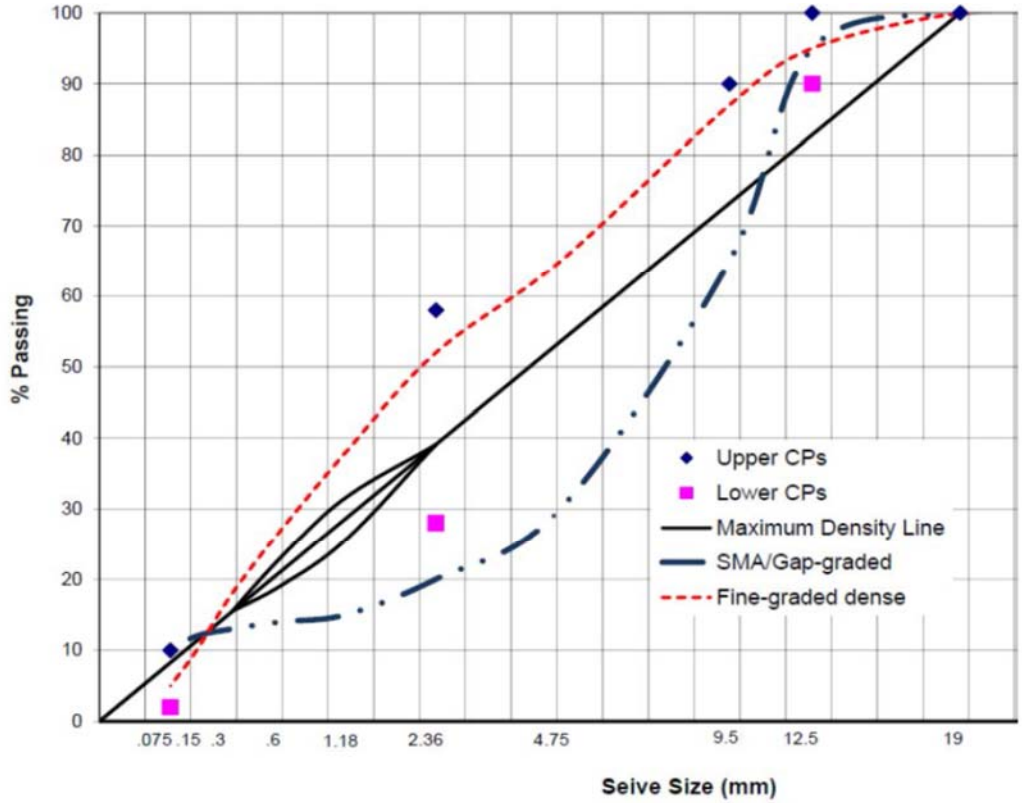
8-15.13 Density Testing Requirements for Stone Matrix Asphalt (SMA) and Coarse (Gap-graded) mixes

The procedure for determing compactive effort to stablize the SMA and gap graded mixes prescribed in CMM 8-15.13.1 is mobilized into the contract per standard spec 460.3.3.2.

8-15.13.1 Density Testing SMA & Gap Graded Mixes

Density determination procedures and requirements for Stone Matrix Asphalt (SMA) pavements and coarse, gap graded mixes are different from other HMA pavements. The following procedure must be used to determine the compactive effort needed to stabilize the SMA and gap graded mixes. Gap-graded mixtures have gradations when plotted on a 0.45 power graph cross the maximum density line from the fine side to the coarse at or before the No. 8 sieve and are predominately on the low side (at or below the minimum allowable in Table 460-1) of the allowable passing for the sieve sizes that plot on the coarse side of the maximum density curve. Since SMA is a type of gap-graded mixture, only the term SMA will be used in the following to describe both SMA and gap-graded mixtures. See Figure 5- SMA (Gap-Graded) Gradations.

Figure 5 SMA(Gap Graded) Gradations



Determine compactive effort for SMA pavement using the control strip method. Construct a control strip at the beginning of work for each layer of SMA to be compacted. Ensure that the control strip, when acceptably compacted and meeting finish and smoothness requirements, remains in place and becomes part of the completed pavement. Ensure that the SMA mixture is composed of the same material with the same mixture design as the rest of the layer.

The initial placement of the first 1500 feet of SMA will be accepted by ordinary compaction 450.3.2.6.2. After the placement of the initial 1500 feet of SMA pavement, density will be determined by the control strip method as follows. The control strip shall consist of 1,000 feet of the SMA mixture that contains a minimum of one mixture QC test and twelve sites for nuclear density testing. Within the control strip, the Department, using random numbers for stationing, will determine twelve locations for density testing. Upon completion of the desired compaction for the control strip, the contractor will perform nuclear density tests at the twelve locations. Do not use additional materials to aid in seating the gauge.

Determine the control strip target density by calculating the median value of the random twelve nuclear density locations. Within 24 hours, provide the department with test results for the mixture QC sample and control strip target density. Use the control strip target density as the target compactive effort for remaining layer acceptance if the air voids from the mixture QC sample taken during control strip construction falls between 3.5% and 5.0%. If the test results do not meet these minimum requirements, an investigation will result and a new control test strip may be required. Acceptance of the remaining layer will be determined by standard department procedures using the control strip median density, recorded as a percentage of the target density. Stop mixture production and initiate an investigation if any of the following conditions occur:

1. There is a change in mix design (i.e. new 250 number);
2. The previous day's maximum specific gravity average from QC testing, varies by ≥0.020 from the value from the initial QC test;
3. The overall blend changes have deviated from the original mix design by ≥ 10%;
4. There is a change in the average lot density in two sequential lots either below or above control strip target density by 2.0% (in PCF) inclusive
5. Any other condition occurs which in the judgment of the project engineer would warrant the establishment of a new control strip density.

Note: for shoulders paved integrally with mainline pavement, but over different base/subgrade materials, determine and test at another twelve randomly located test spots in the shoulder area. Determine the shoulder

control strip target density by calculating the median value of the random twelve nuclear density locations.

Example of determining median target density:

Sort the 12 measured densities into numerical order. For this example the densities are sorted from the lowest to highest value.

1. 150.2
2. 152.2
3. 152.6
4. 153.0
5. 154.7
6. **154.8**
7. **155.2**
8. 156.9
9. 157.0
10. 157.4
11. 157.5
12. 157.5

Since there is an even number of tests, the median value is the average of the middle two values in the sorted list. Thus, in this example, 154.8 and 155.2 pcf are the 6th and 7th values measured, the middle two values. The median value is the average of these two values:

Median Value = (154.8 + 155.2)/2 = 155.0 pcf.

Target Density = 155.0 pcf.

ACCEPTABLE RANGE 151.9 to 158.1 pcf (98-102%)

Submit the results to the project engineer. QMP Nuclear Density testing applies for SMA as it would normally apply for mainline paving greater than 10,000 Tons. The Materials Reporting system is not designed to accept nuclear density test results for SMA. SMA 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 to be done as described in CMM 8-15.7 and will be completed before density testing in the control strip.

The 12 density tests required for determining the control strip density and rolling pattern for asphalt base, prescribed in CMM 8-15.13.2 is mobilized into the contract per standard spec 460.3.3.2.

8-15.13.2 Density Testing Asphaltic Base Mixtures

The control strip shall consist 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 shall be 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 to be done as described in CMM 8-15.7 and will be completed before density testing in the control strip.

8-15.14 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.

- WS4603 is for use with Seaman gauges.
- WS4604 is for use with Troxler/Humboldt gauges.
- WS4605 is to be used by CPN gauges.

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.

- WS4601 Nuclear Soils Density Testing Records (for lot testing) is used for its specific application.
- WS4602 Nuclear HMA Lot Density Testing Record is used for nuclear density testing observations and computation (department acceptance).

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

- WS4607 Nuclear HMA Density QC/QV Test Record is to be used for all QMP density projects for acceptance and verification. Also use the following to determine and document sublot information:
- WS4611 Density Sublot Random Test Locations
- WS4613 Nuclear HMA Density QC/QV Sublot Testing Record

8-15.15 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.

8-15.15.1 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 correlated gauge was used to conduct testing.

8-15.15.2 Incentive for HMA Pavement Density

If the lot density is greater than the minimum specified in Table 460-3 in standard spec 460.3.3.1 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.

8-15.15.2.1 Examples of Computing Incentive/Disincentive for Density

Example 1 (nominal tonnage lots):

HMA Pavement, Type HT 58-34 S Lot 2R
Total HMA Tonnage for Project: 20,000 Tons
% Density of Target Maximum (G_{mm}) = 90.4%
Required % Density of the G_{mm} = 93.0%
Lot Tonnage = 750
Contract Price per Ton = $26.50
From Table 460-3 in 460.3.3.1and 460.5.2.2:

- Amount below Specified Minimum (Table 460-3) = 93.0 - 90.4 = 2.6
- Payment Factor (standard spec 460.5.2.2) = 70% (30% Credit to the Department)
- Credit to the Department (HMA Mix) = 30% x $26.50/Ton x 750 Tons = $5962.50

If this were the only failing lot on the project, the final quantities on the estimate would be as shown in Table 3.

Example 2 (nominal tonnage lots):

HMA Pavement, Type HT 58-34 S Lot 3R
% Density of Target Maximum (G_{mm}) = 94.6%

Required % Density of the G_{mm} = 93.0%
Lot Tonnage = 750
Air Voids for day = 2.9-3.2%
Payment Factor = 94.6 – 93.0 (Table 460-3)= 1.6
Adjusted Unit Price = $0.40/Ton x 750 Tons (standard spec 460.5.2.3)= $300

If this is the only lot with a higher density than required on the project, the final quantities on the estimate would be as shown in Table 3 below:

Table 3 Estimate for Pay Adjustment for Incentive/Disincentive Density

Bid Item	Description	Unit	Cost/Unit	Total Quantity	Total
460.7244	HMA Type 4 HT 58-34 S	TON	$26.50	20000.00	$530,000.00
460.2000	Incentive Density HMA Pavement	DOL	$1.00	300.00	$300.00
804.2005	Disincentive Density HMA Pavement	DOL	$1.00	-(962.5)	-($5962.50)

Project Information for Examples 3 and 4 (daily tonnage lots & linear sublots):

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 the figure below 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 HMA mixture includes 5.5% asphaltic material. 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.

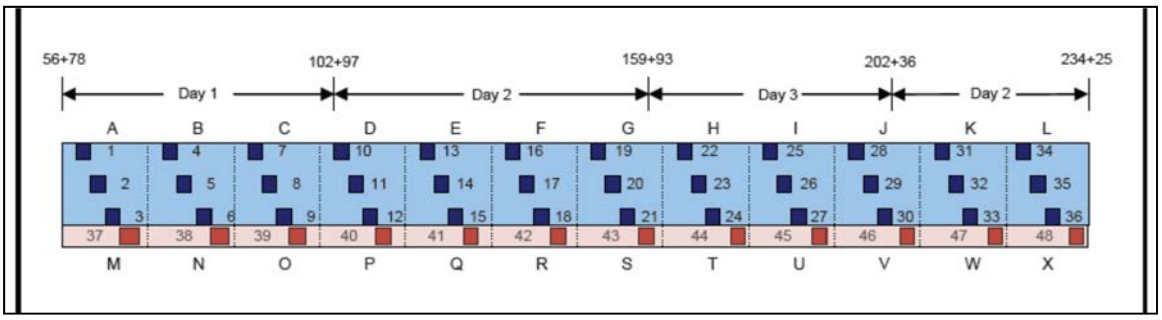
Day Two:

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 6 Linear Sublot Example Project



Example 3 (daily tonnage lot & linear sublots):

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	
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 4 (daily tonnage lot & linear sublots):

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, a 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 =

$$\frac{(1685' \times 12')}{(9\ sf/sy)} \times \frac{(2\ in. \times 110\ lb/sy/in)}{(2000\ lb/ton)} = 247\ tons$$

   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 = 247 tons x ($41.75/ton x 0.05) = -$515.61

3. Sublot I:

   Quantity represented by tests in sublot I =

$$\frac{(1500' \times 12')}{(9\ sf/sy)} \times \frac{(2\ in. \times 110\ lb/sy/in)}{(2000\ lb/ton)} = 220\ tons$$

   According to the incentive pay table, 220 tons of the HMA pavement item are eligible for an incentive of $0.80 per ton, or a total of $176.00.

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=

$$\frac{(1058' \times 12')}{(9\ sf/sy)} \times \frac{(2\ in. \times 110\ lb/sy/in)}{(2000\ lb/ton)} = 155\ tons$$

   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 = 155 tons x ($41.75/ton x 0.05) = -$323.56

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.

Day 3 Incentive/Disincentive Summary:

Incentive Density HMA Pavement (Lot I) = $176.00

Disincentive Density HMA Pavement (Lot H)= -$515.61

Disincentive Density HMA Pavement (Lot J) = -$323.56

8-15.16 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: SMA and Asphaltic Base test results are recorded and submitted on DOT forms, and not submitted to the MRS system.