State of Nevada
Department of Transportation
Materials Division

METHOD OF TEST FOR RELATIVE COMPACTION OF PLANTMIX BITUMINOUS SURFACE USING A NUCLEAR DENSITY GAUGE

SCOPE

This test method is designed to measure the degree of compaction of plantmix base and surface mat and joint density, using a nuclear density testing device.

APPARATUS

1. Thin Layer Density Gauge, Troxler Model 4640-B or 3450.

2. Magnesium reference block.

3. Air gap spacer.

STANDARDIZATION

1. Warm up period: Turn the thin layer density gauge on and warm up for ten minutes. This allows the regulators and deflectors to stabilize.

2. At the start of each shift, standardize the thin layer density gauge to check equipment operation. This procedure can also be used as an operational check whenever test measurements are suspect.

3. The site chosen for standardization should remain the same throughout the contract. Outline the magnesium reference block with keil (lumber crayon) to ensure the same location is used.

4. Place the magnesium reference block on a solid surface having a density of 1600 kg/m^3 (100 lb/ft^3) or greater, preferably a plantmix or concrete surface approximately 10 cm (4 in.) thick. Ensure that the magnesium reference block is level and does not rock back and forth. This location should be at least 3 m (10 ft) away from any large object such as a vehicle, field lab, wall or any water source and at least 9 m (30 ft) from any other nuclear gauge**.**

5. Place the air gap spacer on the magnesium reference block and then place the thin layer density gauge on top of the air gap spacer. The handle end of the gauge should rest over the two posts on the air gap spacer. Verify that the "Standard Mode" is in multi-standard mode.

6. With the lock attached and the handle in the safe position, press the "STANDARD" key on the keypad. The screen will display "Standard Count XXXX XXXX Take a new standard count?" Press the "YES" key. The screen will then show "Place gauge on spacer and both on block, put the rod in safe position, press enter." Check to make sure the thin layer density gauge does not rock, then

press the "START/ENTER" key. The thin layer density gauge will begin taking a four minute standard count.

7. When counting stops, at the end of the four minutes, screen will display "Standard # 1 XXXX X.XX% Pass Standard # 2 XXXX X.XX% Pass Use new standards?" If it shows a PASS/PASS, record the Standard #1 and Standard #2 in the gauge log book. Press the "YES" key. If you receive a PASS/PASS to the right of the percentages, it indicates that the standard counts are within the 1% maximum allowed variation for System 1 reference standard counts and 1.2% maximum allowed variation for System 2 standard counts.

8. If the standard counts for System 1 or System 2 fail, the screen will display "Do you want to use the new STD?" Press the "YES" key. Check the thin layer density gauge to make sure that the magnesium reference block does not rock, no other gauges are in the area and that the standard mode is in multi-standard mode. Then take another standard count.

9. It may take up to five standard counts before obtaining a PASS/PASS result. In the event that a PASS/PASS result is not obtainable, contact the Independent Assurance Lab for further assistance.

CORRELATION WITH DRILLED CORES

1. Perform correlation tests at seven locations within one test section. Thin layer density gauge correlation shall be performed on each mix design and on each different surface of paving (EX. Milled Surface, Second Lift, Type 1 Class B Base etc.). Take the thin layer density gauge shots first and record on NDOT form 040-017. Outline around the base of the thin layer density gauge with Kiel (lumber crayon). For each 1 minute test rotate the thin layer density gauge 90 degrees about the center of the thin layer density gauge for a total of four times at each location. Refer to Figure 1 for the correct positioning of the thin layer density gauge during correlation. Repeat this process at all seven locations.

2. Take the cores from the pavement after the mat has cooled enough to allow drilling without distortion or cracking of the cores. NOTE: Core area may be cooled with dry ice.

3. Determine the density of the cores as per Test Method Nev. T336 and document the results on NDOT form 040-017B.

4. Subtract the drilled core density from the corresponding nuclear density reading and discard the two cores with the biggest difference between the core density and the nuclear density.

EX.	Core Density	Nuclear Density	Difference
1-PM-1	142.3	140.9	1.4
1-PM-2	141.9	142.7	-0.8
1-PM-3	141.1	141.1	-0.0
1-PM-4	144.0	144.4	-0.4
1-PM-5	142.2	142.2	0.0
1-PM-6	140.6	140.4	0.2
1-PM-7	145.1	147.9	-2.8

The biggest difference would be 1-PM-1 and 1-PM-7. Use cores 1-PM-2 through 1-PM-6 for the gauge correlation, to achieve the most consistent correlation.

5. The average of five (5) drilled core densities will be correlated with the average of the five (5) nuclear densities taken at the same location as follows:

   a. If the difference between the two averages is less than ±1% of the average core density, the nuclear gauge readings shall be used without a correction factor.

      EX. Core Density Average x 0.01 = ±1% of Core Density Average
      147.7 x 0.01 = 1.477

      Core Density Average - Nuclear Density Average = Difference
      147.7 - 147.4 = 0.3

      The difference is less than 1.477; therefore there will not be a correction factor for this gauge correlation. (EX. Correction factor = 1.00)

   b. If the difference between the two averages exceeds the ± 1% of the average core density, a correction factor for the thin layer density gauge shall be determined as follows:

      EX. Core Density Average x 0.01 = ±1% of Core Density Average
      153.3 x 0.01 = 1.533

      Core Density Average - Nuclear Density Average = Difference
      153.3 - 149.4 = 3.9

      The difference is greater than the 1.533; therefore there will be a correction factor for this gauge correlation.

      $$\frac{\text{Average of the five (5) core densities}}{\text{Average of the five (5) nuclear densities}} = \text{Correction Factor}$$

      153.3 / 149.4 = 1.03

      The correction factor is then multiplied by the average density on NDOT form 040-017, to obtain the corrected density. Use this correction factor for all future tests until another correlation is performed.

NOTES PERTAINING TO CORRELATION WITH DRILLED CORES

1. Allow core area to cool prior to coring so the cores do not break or become distorted during coring.

2. Take seven (7) core densities and seven (7) nuclear densities in one test section for the gauge correlation procedure. Obtain a core from each location for a total of seven (7) cores. Refer to Test Method Nev. T336 to determine each samples Bulk Specific Gravity

3. Thin layer density gauge correlation shall be documented on NDOT forms 040-017, 040-017A and 040-017B.

4. Correction Factor's shall be reported to the nearest 0.01.

5. Typically the correction factor should be within 0.96 to 1.04. If you are outside this range contact the Independence Assurance Lab for assistance.

6. The only time a gauge correlation should be labeled "informational tests" is if the correlation took place out of the contracts paving limits, then it will be labeled I1-PM-1 to I1-Pm-7 (EX. Paving a frontage dirt road, correlated on another contract etc.) document where the paving took place under remarks on NDOT form 040-017.

7. The gauge correlation section will be the only test section that has seven (7) tests for the test section, 1-PM-1to 1-PM-7, each test section that follows will have five (5) tests for the test section, 2-PM-1 to 2-PM-5, unless the gauge has to re-correlated then there will be another test section with seven (7) tests for the test section.

7. Re-correlate the gauge if the mix design changes, percent compaction decreases or increases drastically with no changes to the rolling pattern, when paving on different surfaces or lifts.

8. Refer to the PROCEDURE section to obtain the random numbers used for the thin layer density gauge correlation with the cores. In two of the subsections two additional shots shall be taken with two additional cores to obtain the seven drilled cores for the thin layer density gauge correlation.

PROCEDURE (3450 or 4640-B SERIES GAUGES)

1. Determine the target density per Test Method Nev. T324 or T750 and program it into the thin layer density gauge. After completion of the desired roller coverage, while the mix is still hot, a series of density tests are taken at locations according to the following:

2. Test Sections

   a. Divide the test section into five subsections of equal length. Four one minute mat density tests are to be taken for each subsection. If a joint or joints are present, two or four one minute joint density tests are to be taken. Refer to the Standard Specifications for the required size of the test sections.

      The exact station at which the mat densities will be taken, is determined from the table of random numbers by multiplying a random number (column A) times the length of each subsection, rounded to the nearest 10 m (25 ft).

      The exact distance in from the edge of the mat where the mat densities will be taken is determined from the table of random numbers (column B) times the width of the mat, rounded to the nearest 0.3 m (1 ft) for the distance in from the edge. NOTE: Do not take the mat density test any closer than 0.3 m (1 ft) from the edge of the mat.

The first four (4) one minute tests (rotated 90 degrees about the center of the thin layer density gauge) are to be taken in each subsection. If the mat was inlayed, perform two (2) one minute joint tests on each joint within 0.15 m (6 in.) of the joint (rotated 180 degrees) at the same station as determined in column A.

b. Random numbers are always used in a series of ten, five from column A and five from column B. Any random number block may be used as long as a different block is selected for each new test section.

EX. Random Number Block = 15 Width of the entire mat = 13.8 ft
Beginning Station "X" 413 + 12 Ending Station "X" 350 + 95

Note: One station equals 100 ft

("X" 413 + 12) – ("X" 350 + 95) = 6217 ft

6217 ft (length of test section) / 5 (total subsections) = 1243.4 ft (length of each subsection)

Station – Length of Subsection = Station to Station for each Subsection

("X"413 + 12) – 1243.4 = "X"400 + 68.6
("X" 400 + 68.6) – 1243.4 = "X" 388 + 25.2
("X" 388 + 25.2) – 1243.4 = "X" 375 + 81.8
("X" 375 + 81.8) – 1243.4 = "X" 363 + 38.4
("X" 363 + 38.4) – 1243.4 = "X" 350 + 95

Column A	x	Subsection Length	=	Distance for each Subsection Test Station
.698		1243.4		867.9
.796		1243.4		989.7
.348		1243.4		432.7
.358		1243.4		445.1
.698		1243.4		867.9

("X"413+12) – 867.9 = "X"404+44.1 rounded to nearest 10 m (25 ft) = "X"404+50
("X"400+68.6) – 989.7 = "X"390+78.9 rounded to nearest 10 m (25 ft) = "X"390+75
("X"388+25.2) – 432.7 = "X"383+92.5 rounded to nearest 10 m (25 ft) = "X"384+00
("X"375+81.8) – 445.1 = "X"371+36.7 rounded to nearest 10 m (25 ft) = "X"371+25
("X"363+38.4) – 867.9 = "X"354+70.5 rounded to nearest 10 m (25 ft) = "X"354+75

Column B	x	Mat Width	=	Distance in from edge of Mat	=	Rounded to nearest .5 m (1 ft)
.683		13.8		9.4		9.0
.996		13.8		13.7		13.0 (mat is only 13.8)
.743		13.8		10.3		10.0
.595		13.8		8.2		8.0
.539		13.8		7.4		7.0

1st density test is at "X" 404 + 50, 9.0 ft in from edge of mat
2nd density test is at "X" 390 + 75, 13.0 ft in from edge of mat
3rd density test is at "X" 384 + 00, 10.0 ft in from edge of mat
4th density test is at "X" 371 + 25, 8.0 ft in from edge of mat
5th density test is at "X" 354 + 75, 7.0 ft in from edge of mat

3. Density Testing

a. Program the target density from Test Method Nev. T324 or T750 into the thin layer density gauge. Input the target density for the Marshall and Voidless parameters into the thin layer density gauge. Select the "MA/VOIDLESS" key. The screen will display "MA: XXX.X pcf VD: XXX.X Do you want to change?" Press the "YES" key. Screen will display "Marshall XXX.X pcf " Input the target density and press the "START/ENTER" key. Screen will display "Voidless Density XXX.X pcf." Input the same target density and press the "START/ENTER" key. Thin layer density gauge will then go back to the main screen.

b. Select the proper depth by pressing the "THICK" key. The screen will display "Layer Thickness: X.XX in. Input and Press Enter." NOTE: Set the depth for the thin layer density gauge at 6 mm (0.25 in.) less than what is being placed. (EX. Paving 3 in. set the thin layer density gauge thickness at 2.75 in.) Thin layer density gauge will then go back to the main screen.

c. Set the count time for 1 minute by pressing the "TIME" key. The screen will show "Count Time XX min. Do you want to change?" Press the "YES" key. The screen will show "Sel: 1 – 0.5 min. 2 – 1 min. 3 – 2 min. 4 – 4 min." Press 2 for the 1 minute count time. Thin layer density gauge will then go back to the main screen. The 1 minute test is the only "TIME" allowed for density testing.

d. Do not utilize the "Average" function, verify that the average function is set at 1. The average of the 4 tests shall be hand calculated.

e. At each predetermined test site, place the thin layer density gauge on the mat. Check for rocking by placing a hand on opposite corners of the base. Outline the base of the thin layer density gauge with a piece of keil (lumber crayon). Place the source rod in the "Measure" position and press the "START/ENTER" key. At the end of the 1 minute count time the thin layer density gauge will display"Dens: X.X PCF %MA: X.XX% 100 - %MA: XX.XX% %VOID: X.XX". Write the density down on NDOT form 040-017, rotate the thin layer density gauge 90 degrees about the center of the thin layer density gauge and take another one minute density test at this location, refer to Figure 1 for thin layer density gauge positioning. Repeat this procedure for four (4), one minute density tests at this one test location.

f. Record each one minute density test and hand calculate the average of the four (4) tests on NDOT form 040-017. NOTE: Do NOT use the average mode in the thin layer density gauge.

g. The average of the four (4) density tests will constitute one test site density.

h. Repeat the above process at each of the 5 predetermined test site locations within the test section.

4. Joint Density Testing

a. Place the thin layer density gauge on the mat directly adjacent (within 6 in.) and parallel to the joint line at the same station that the four (4) one minute density tests were taken. Align one edge of the thin layer density gauge along the mat seam. The thin layer density gauge should be firmly seated on the new HOT mat and located as close to the joint as possible without extending any part of

the gauge beyond the seam. Put the probe in the "Measure" position and press the "START/ENTER" key. At the end of the 1 minute count time the thin layer density gauge will display "Dens: X.X PCF %MA: X.XX% 100 - %MA: XX.XX% %VOID: X.XX." Write the joint density down on NDOT form 040-017. Take two (2) one minute density readings on the joint, rotating the gauge 180 degrees about its center after each reading, refer to Figure 1 for thin layer density gauge positioning. If the mat has been inlayed, it will require joint measurements on each HOT side of the mat.

b. Record each one minute joint density test and hand calculate the average of the two (2) tests on NDOT form 040-017.

c. The average of the readings for each individual joint (two one minute tests), will constitute one test site joint density.

d. Joint density tests will not be required on unconfined edges. Joint density tests are completed on the hot side of the mat.

PERCENT COMPACTION

1. Percent relative compaction of an individual test site or small test section:

   a. % Relative Compaction = $\frac{\text{((Average Density) or (Corrected Density) x (Correction Factor))}}{\text{Target Density}}$

   b. Record the percent relative compaction to the nearest whole percent.

2. Take the average of the five (5) corrected densities (Mean Test Section Density) and compute the Mean Percent Relative Compaction as follows:

   a. Mean Percent Relative Compaction = $\frac{\text{Mean Test Section Density}}{\text{Target Density}}$

   b. Record the percent compaction to the nearest whole percent.

3. Refer to Standard Specifications for the minimum and maximum density requirements.
   Note: Do not incorporate joint densities when calculating the Mean Test Section Density

ADDITIONAL ROLLING PROCEDURES

1. If an individual test either on the mat or on a joint does not meet the required minimum specifications for compaction, additional rolling may be required. After additional rolling, take another test by testing at a single location chosen at random within the same subsection. (This is not considered a re-test, since there are no re-tests on plantmix. The second test will be the one documented for the complete test section.) Note: Any changes from the original compaction must be documented under remarks.

2. If the mean test section compaction for the mat does not meet the required minimum specifications for compaction, additional rolling may be required on the entire test section. After additional rolling, take a series of five (5) tests using a new random block number, see Figure 2. (This is not considered a re-test, since there are no re-tests on plantmix). Note: Any changes from the original compaction must be documented under remarks.

3. No additional rolling will be performed if the surface temperature of the lift is below 68ºC (155ºF).

4. If additional compactive effort still results in a failing test, joint test or test section, the Resident Engineer must indicate under the remarks on NDOT form 040-017 what necessary steps are to take place if any pertaining to the failure in question.

GENERAL:

1. Under no circumstance is the thin layer density gauge (Troxler Model 4640-B) to be used for testing the compaction of concrete or dirt.

2. Do not leave the gauge on the hot plantmix surface any longer than absolutely necessary when taking the four, one minute counts. Long term exposure to high temperatures will reduce the service life of the components and temporarily effect the accuracy of the gauge.

3. If there is more than 1000 m^2 (1000 yd^2) (small section or miscellaneous test) of the mat to be tested it shall be made into a full test section even if it's less than the 5500 m^2 (6600 yd^2). There shall not be multiple small sections tested in a row. If paving approaches note that it is an approach under remarks.

4. The small sized area of 90% compaction per the Standard Specifications is not meant for mainline paving.

5. The mean percent relative compaction from NDOT form 040-017 is NOT applicable to partial test sections or joint densities.

6. For all coarses of 25 mm (1 in.) or less, use "Method A" from the Standard Specifications. No compactions per "Method B" shall be required since the thin layer density gauge detects underlying material for lifts of 25 mm (1 in.) or less.

Thin layer density gauge positioning for one density test location.

Thin layer density gauge positioning for one joint density test location.

FIGURE 1

TABLE OF
RANDOM NUMBERS

A	B	A	B	A	B	A	B	A	B
1		2		3		4		5	
.576	.730	.430	.754	.271	.870	.732	.721	.998	.239
.892	.948	.858	.025	.935	.114	.153	.508	.749	.291
.669	.726	.501	.402	.231	.305	.009	.420	.517	.858
.609	.482	.809	.140	.396	.025	.937	.310	.253	.761
.971	.824	.902	.470	.997	.392	.892	.957	.640	.463
6		7		8		9		10	
.053	.899	.554	.627	.427	.760	.470	.040	.904	.993
.810	.159	.225	.163	.549	.405	.285	.542	.231	.919
.081	.277	.035	.039	.860	.507	.081	.538	.986	.501
.982	.468	.334	.921	.690	.806	.879	.414	.106	.031
.095	.801	.576	.417	.251	.884	.522	.235	.398	.222
11		12		13		14		15	
.509	.025	.794	.850	.917	.887	.751	.608	.698	.683
.371	.059	.164	.838	.289	.169	.569	.977	.796	.996
.165	.996	.356	.375	.654	.939	.815	.592	.348	.743
.477	.535	.337	.155	.767	.187	.579	.787	.358	.595
.788	.101	.434	.638	.021	.894	.324	.871	.698	.539
16		17		18		19		20	
.566	.815	.622	.548	.947	.169	.317	.472	.864	.466
.901	.342	.873	.964	.942	.985	.123	.086	.335	.212
.470	.682	.412	.064	.150	.962	.925	.355	.909	.019
.068	.242	.667	.356	.195	.313	.396	.460	.740	.247
.874	.420	.127	.284	.448	.215	.833	.652	.601	.326
21		22		23		24		25	
.897	.877	.209	.862	.428	.117	.100	.259	.425	.284
.875	.969	.109	.843	.759	.239	.890	.317	.428	.802
.190	.696	.757	.283	.666	.491	.523	.665	.919	.146
.341	.688	.587	.908	.865	.333	.928	.404	.892	.696
.846	.355	.831	.218	.945	.364	.673	.305	.195	.887
26		27		28		29		30	
.882	.227	.552	.077	.454	.731	.716	.265	.058	.075
.464	.658	.629	.269	.069	.998	.917	.217	.220	.659
.123	.791	.503	.447	.659	.463	.994	.307	.631	.422
.116	.120	.721	.137	.263	.176	.798	.879	.432	.391
.836	.206	.914	.574	.870	.390	.104	.755	.082	.939
31		32		33		34		35	
.636	.195	.614	.486	.629	.663	.619	.007	.296	.456
.630	.673	.665	.666	.399	.592	.441	.649	.270	.612
.804	.112	.331	.606	.551	.928	.830	.841	.602	.183
.360	.193	.181	.399	.564	.772	.890	.062	.919	.875
.183	.651	.157	.150	.800	.875	.205	.446	.648	.685

FIGURE 2