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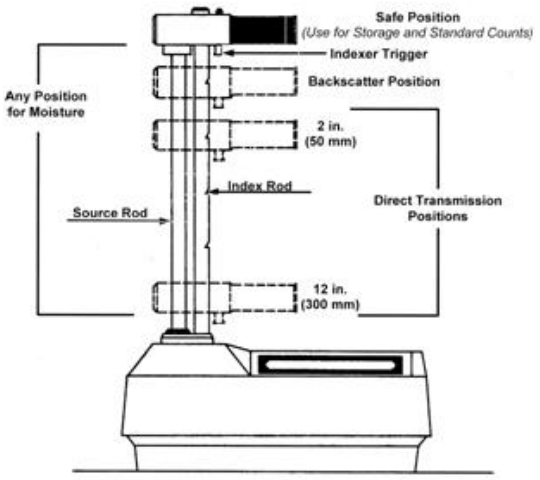

NUCLEAR GAUGE FIELD CERTIFICATION COURSE

VERSION 18.0

Division of Materials and Tests 2018

Nuclear Gauge Field Technician Certification

Why are you here?

- Proper testing practices
  - How to test
  - How to verify gauge is working
  - How to calibrate gauge for asphalt
- Where to test
  - Determine Lots
  - Determine random testing locations

Radiation Safety Course

- Standard Count
- Asphalt Test Strip and Correction Factors
- Testing on Asphalt, Soil, Aggregate

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Instructors

- Matthew Chandler
  Matthew.Chandler@tn.gov
- Ulises Martinez
  Ulises.Martinez@tn.gov
- Jimmy Britt
  Jimmy.Britt@tn.gov
- Rocky Kelley
  Rocky.Kelley@tn.gov

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Class Organization

- Classroom and Demo
- Test:
  - **25** questions
  - Open book/notes
  - To Pass: Must get 70% overall on written exam

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ADA Notice of Requirements

- Can be found at the following website:
  - http://www.tn.gov/tdot/topic/transportation-americans-with-disabilities-notice
- To be in compliance with TDOTs requirements listed on the website above, it is our goal to provide reasonable accommodations to those who identify themselves as having a disability and request such accommodations.
- Please feel free to bring it to any of the course instructors and accommodations will be administered as discretely as possible.

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No Tobacco Related Product Inside Building!!!!!!!!!!!!!!!

No Electronic Cigarette
No Chewing Tobacco Allowed
Spitting into a bottle disturbs others

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Safety Refresher

- Always wear YOUR personal dosimeter while using or transporting the gauge.
- When transporting the gauge off of the job site, only transport with the trigger locked, the case locked and chained to the vehicle and secured and out of view of the public.
- Don't allow un-badged people to stand within 30 feet of a test.
- Don't leave the gauge unattended outside of its case.
- Don't run gauge within 30' of another gauge.
- Don't run the gauge within 10' of a large object.

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Standard Count

- Keep a log of your standard counts!
- Standard counts provide a quick reference check to ensure that the gauge is operating correctly.
- A standard count needs to be taken daily on the reference standard block.
- Max Variation: 1% for density and 2% for moisture.
- Place the reference standard block on the surface you are about to test.

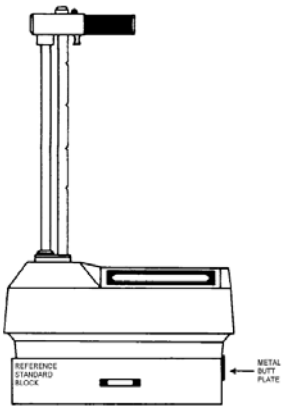

Figure 3-3. Standard Count Position

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Standard Count

Conducting a Standard Count:

1. Ensure source rod is in the SAFE position
2. Make sure to place reference blocks on dry, flat surface
3. Press the <STD> key, then the <YES> key.
4. Press <START> to begin the 4 minute count
5. Record the standard count

Where:

- DS=Density Standard Count
- MS=Moisture Standard Count

Standard Count:
DS=xxxx MS=xxxx

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Standard Count

Example

- Previous Standard Count

Standard Count:
DS= 135.0 MS= 112.0

- New Standard Count

Standard Count:
DS= 137.0 MS= 113.5

Take the difference: For Moisture 113.5-112.0 = 1.5

For Density 136.0-135.0 = 1.0

Divide by your last Standard Count and multiply by 100:

For Moisture (1.5/112.0) x 100 = 1.34%

For Density (1.0/135.0) x 100 = 0.74%

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Standard Count

- If a standard count log has not been kept, do the following:

Step 1: Take two standard counts and make sure they are within the required limits. If this test fails, go to step 2 below.

Step 2: Take five new counts, average the first four, and compared with the 5th reading. Check if the reading is within the required limits. If standard count fails, call your regional RSO for a replacement gauge.

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Standard Count

- Example:
- Count 1: Density – 160.0 Moister – 120.0
- Count 2: Density – 165.0 Moister – 123.0
- Count 3: Density – 162.0 Moister – 120.0
- Count 4: Density – 159.0 Moister – 125.0
- Count 5: Density – 160.0 Moister – 120.0

Average 161.5

Average 122.0

Density = (161.5-160.0)/161.5 x 100 = 0.9 %
Moister = (122.0-120.0)/122.0 x 100 = 1.6 %

TESTING

PROCTOR DENSITY (Soils/Aggregate) or THEORETICAL MAXIMUM DENSITY(Asphalt)

- **Press <MA/PR>** to display Marshall for Asphalt or Proctor for soil/gravel. Make a selection**.** To change value PR or MA press down/up ↓↑arrow**. Press <START/ENTER>** to exit.
  - **PR value can be obtained from the Proctor Density Report.**
  - **The Theoretical maximum Density can be obtained from the JMF for the Asphalt Mix**

MA: ■■■ (↑ ↓)
Change MA value?

PR: ■■ (↑ ↓)
Change PR value?

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Original to:
Headquarters Materials and Tests
Copies to:
Regional Materials and Tests
Project Supervisor

STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION
DIVISION OF MATERIALS AND TESTS
6601 CENTENNIAL BLVD.
NASHVILLE, TENNESSEE 37243-0360

PROCTOR DENSITY REPORT

Project Reference No.	9405699	County	WILLIAMSON
Project No.	94011-3243-04	Contract No.	
Material	BULK SOIL SAMPLE	Project Supervisor	R. JOWERS
Report No.	1	Date Sampled	11-Sep-17
Serial No.	175305	Date Reported	25-Oct-17
Contractor		Sampled By	F. RASHID
Producer		Sampled From	SR-96 ARNO RD

GRADATION - TOTAL PERCENT PASSING

Sample No.	B-1
Station	117+00
Depth, ft.	0-5
Location, ft.	65LT
2"	
1-1/2"	
1"	
3/4"	
3/8"	
No. 4	
No. 10	99
No. 16	
No. 40	99
No. 100	93
No. 200	64
Silt and Clay	
Clay	33

SOIL CONSTANTS

Liquid Limit	32
Plastic Limit	23
Plasticity Index	9
Calculated Fi	9
Type	
Group	

CORRECTED FOR +4 MATERIAL

Proctor Density	103.8
Optimum Moisture	18.6
95 % Density	
Moisture Range	
Zero Subgrade	11.4
Moisture Range Below Subgrade	23.1

Proctor Density & Optimal Moisture

STATE OF TENNESSEE ASPHALT JOB MIX FORMULA

Date	01/01/2018	Roadway Surface	No
Region	1		
Hot-mix Producer	Duracap Asphalt Paving - Knoxville Asphalt Mix		
Type	BPMB-HM	Mix	307-A / PG 64-22
Item	307-01.01		
Serial No.:		Design No.:	1180001

Material	Size or Grade	Producer and Location	Percent Used
#4, Soft Limestone (aka Non-Surface) from Aggregate USA - Knoxville John Sevier Hwy			38.400
#7, Soft Limestone (aka Non-Surface) from Aggregate USA - Knoxville John Sevier Hwy			24.000
#10, Soft Limestone (aka Non-Surface) from Aggregate USA - Knoxville John Sevier Hwy			14.400
RAP Processed -1/2, RAP from RAP - Duracap Asphalt Paving - Knoxville Asphalt Mix			20.211
Asphalt Cement	PG 64-22	MARATHON PETROLEUM CO., KNOXVILLE	2.989

Percent AC in RAP1:		Optimum AC Content:	4.00	Total	100.000
Percent AC in RAP2:	5.0	Anti-Strip Supplier:	Tri-State Sand LLC		
Anti-Strip Additive:		Arr Maz	Dosage:	0.5%	
AC Contribution:	Virgin AC 2.99	RAP AC 1.01	Percent Virgin AC:		74.7
Asphalt Sp. Gravity:	1.03		Dust to Asphalt Ratio:		1.08
% Fracture Face on CA:	n/a		% Glassy Particles on CA:		n/a
Theo.Gravity of RAP1:			Eff. Gravity of Agg:		2.762
Theo.Gravity of RAP2:	2.553				
Theo. Gravity of Mix:	2.588	T.S.R.:		Lbs/Ft³:	161.5
L.O.I.:			Ignition Oven Corr. Factor:		
			Warm Mix?		

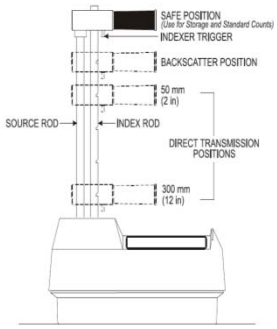
Theoretical Maximum Density

Testing (Asphalt)

- Step 1: Conduct Standard Count
- Step 2: Enter maximum specific gravity (Gmm) value from asphalt mix design.
- Step 3: Enter gauge correction factor from test strip. See Part Two for determining correction factors. (Note: testing may be done prior to obtaining the correction factor, however all tests done during this time must be corrected as soon as possible and prior to finalizing the records for acceptance or assurance tests.)

Testing (Asphalt)

- Step 4: Set gauge setting to Backscatter.



- Step 5: Place gauge in location to be tested.

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Testing (Asphalt)

- Step 6: Activate a test. When collecting a density test, the following approach shall be used:
  - "Four Nineties" Test: Four tests shall be conducted at a single location, rotating around the test location 90 degrees at a time.
  - The four test results will then be averaged to obtain a single test value for that location.
  - Test counts for this approach shall be 15 seconds or longer.

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Testing (Asphalt)

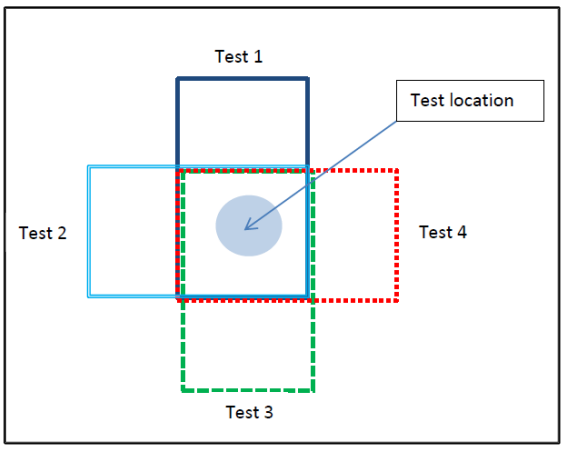

Figure 1. Testing at four 90° locations

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Testing (Asphalt)

- Step 7: Record the test value into the appropriate paperwork.
  - DT-0315, Daily Asphalt Density Report

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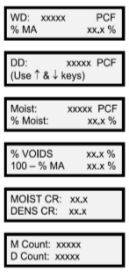
Taking a Measurement - Asphalt

- After the count time has elapsed, the gauge displays the measurement results in a series of six screens, as follows. Use the **down/up ↓↑arrows** to scroll.
- WD: Wet Density is what you record for Asphalt.



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Testing (Soil & Aggregate)

- *Step 1:* Conduct Standard Count
- *Step 2:* Enter maximum dry density and optimum moisture content from Proctor Density report.
- *Step 3:* Select Test location. Create a test hole using the scraper plate and drill rod provided with the gauge.

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Testing (Soil & Aggregate)

- When testing on soils always prepare the ground by using the scraper plate to smooth out any obstacles or fill in any voids.
- This will reduce the chance that open pockets or protruding objects impact the reading.

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Testing (Soil & Aggregate)

- Etch around the base of the scraper plate before picking it up, then place the gauge down inside of this etched area.
- The opening for the source rod will be positioned over the hole that was drilled.

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Testing (Soil & Aggregate)

When using the drill rod to make a hole in the compacted material for testing, always make sure to first place the drill rod removal device –

this is a mistake that will probably be made only once.

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Testing (Soil & Aggregate)

- *Step 4:* Set gauge setting to Direct Transmission at a depth reasonably close to one half the depth of the compacted lift.
- *Step 5:* Place gauge in location to be tested and insert test probe into test hole at a depth reasonably close to one half the depth of the compacted lift. Pull gauge back to ensure probe makes contact with material being tested

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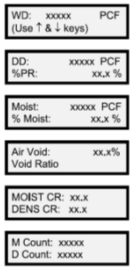
Testing(soil & Aggregate)

- *Step 6:* Activate a test. When collecting a density test, the following approach shall be used:
  - *Single Count Test:* A single test shall be conducted at the test location, given that the test count is minimum 60 seconds.
- *Step 7:* Record the test value into the appropriate paperwork.
  - DT-0298, Daily Report on Soil and Aggregate Stabilization
  - DT-0304, Daily Report on Embankment
  - DT-0307, Daily Report on Mineral Aggregate Base
  - DT-0314, Density Worksheet – Nuclear Method (Aggregate, Soil)

TN TDOT Department of Transportation

Taking a Measurement – Soil and Aggregate Material

- After the count time has elapsed, the gauge displays the measurement results in a series of six screens, as follows. Use the **down/up ↓↑arrows** to scroll.
- DD: Dry Density is what you record for Soil & Aggregate Material



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After the Test

Always pull the trigger and raise the handle to the very top setting prior to moving the gauge even in backscatter mode. This locks in the lead shield around the source making the gauge safe for moving.

Never move the gauge with the source rod exposed.

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Asphalt Test Strips

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Test Strip Calibration (Asphalt)

TDOT Standard specifications 407.15.

- Nuclear Gauge readings are not valid on Asphalt until the gauge is correlated to the mix and project location. A new test strip shall be required for each project and each mix design used on the project (for mix types that require density testing as noted above). Uncorrelated gauges shall not be used for acceptance or assurance testing.

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Test Strip Calibration (Asphalt)

- Required for A, BM, BM2, C, C-W, D, and E mixtures
- Rollers shall meet §407.07
- Each test section shall be 1 paver width/lane width wide and a minimum of 400 SY
  - 9’ wide= 400’ long
  - 10’ wide= 360’ long
  - 11’ wide= 330’ long
  - 12’ wide= 300’ long

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Test Strip Calibration (Asphalt)

- Example: We're setting up a test strip for some BM-2.
- Lane width is 11 feet.
- How long is our test strip?

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Test Strip Calibration (Asphalt)

- Step 1: Compact test strip area

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Test Strip Calibration (Asphalt)

- The compaction of the test strip shall continue until there is NO appreciable increase in density, 1 lb/ft3 (should also document the temperature of the mat)
- The roller pattern to obtain the greatest density shall be used the remainder of the project

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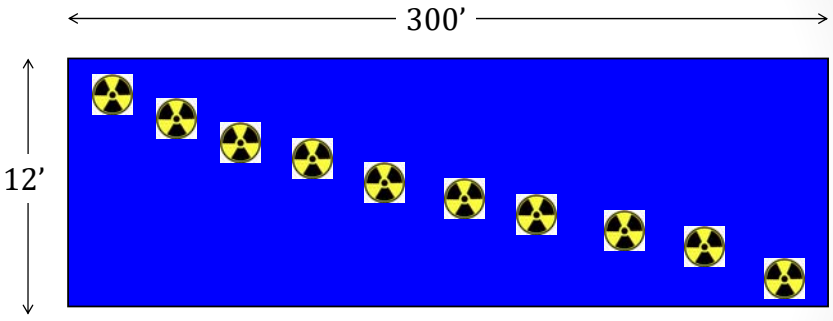
Test Strip Calibration (Asphalt)



Step 2: Layout ten test strip test locations such that the full length and width of the test strip is covered. Mark test location and test number on pavement with spray paint. Write down the density (lb/ft^3) at every location and mark the location so we can cut cores.

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Test Strip Calibration (Asphalt)

- Step 3: Conduct and record (at least) ten sets of uncorrected density (4 90s test method) tests on the compacted test strip area and record test information

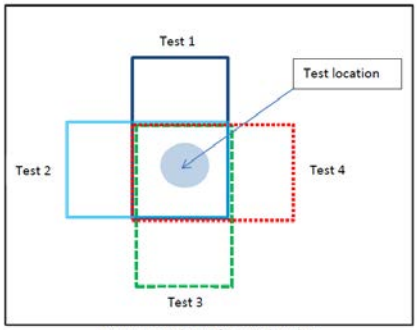

Figure 1. Testing at four 90° locations

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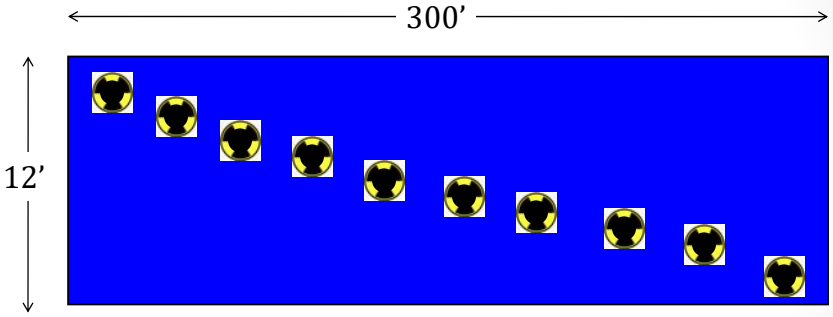
Test Strip Calibration (Asphalt)



Step 4: Cores shall be cut at same locations as nuclear density tests and tested by TDOT Plant Technician for laboratory density in accordance with AASHTO T166. (NOTE: The contractor's technician shall not conduct this testing)

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Test Strip Calibration

- Now we can run the density of the cores in the lab to find the TRUE density of what we tested.

Test Strip Calibration (Asphalt)

- Step 5: The nuclear gauge correction factor shall be the difference between the average of ten nuclear gauge readings and the average of ten core density values.

Test Strip Calibration

Nuclear Gauge Results:	Core Density:
• 140.5 lb/ft^3	• 142.1
• 139.7	• 142.7
• 139.3	• 142.3
• 134.3	• 139.1
• 137.8	• 141.1
• 143.1	• 141.6
• 135.4	• 140.4
• 138.1	• 141.2
• 134.1	• 137.8
• 137.6	• 140.2

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Test Strip Calibration

- The difference between these two averages,

  is our nuclear gauge correction factor.

- What this means is that any time we use THIS nuclear gauge on THIS mix on THIS project, we should add __ ____to our reading.
- This correction factor ONLY applies to THIS PROJECT and THIS MIX DESIGN.

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Offset/Correction Factor (Asphalt)

Density Offset

To access the *Special* functions, press ⟨**SPECIAL**⟩.

Press the down arrow key once to access the *Offset* function.
Press ⟨**START/ENTER**⟩ to display:

```
Offset: Density
(↑ ↓ or ENTER)
```

Press ⟨**START/ENTER**⟩.

```
Dens. Offset OFF
Want to Enable?
```

To enable the *Density Offset* function, press ⟨**ON/YES**⟩.

```
D off= 0.0   PCF
(↑ ↓ or ENTER)
```

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Test Strip Calibration (Asphalt)

- **A new test strip will be required when:**
  - There is a change in job mix formulas
  - A change in the source of materials occurs
  - A change in the material from the same source is observed
  - There is reason to believe that the test strip density is not representative of the mixture being placed. For example, test results are consistently above 100% density or test results have been consistent for a steady number of days and had suddenly changed significantly.
  - A change in paving or compaction equipment occurs.

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Acceptance Testing

- Let's take a moment to discuss the difference between the testing that occurs during *test strips* and *Acceptance Testing*

Quality Acceptance Testing

- Generally, a quality-acceptance plan consists of breaking the total job down into lots
- A lot is accepted or rejected depending on the test results obtained through random sampling that represent the lot
- By handling the acceptance procedure in this way, the project engineer is able to determine the quality of the job on a lot-by-lot basis
- This benefits the construction unit and project engineer by identifying the lots that will be accepted and the lots that will be rejected
- As this type of information is accumulated from lot to lot, a better picture of the quality of the entire project is obtained

Quality Acceptance Testing: Procedure (Soil/Aggregate)

- Identify Density/Moisture Requirements
  - Based on type of material being placed
  - Target values for soils and aggregate are determined by Materials and Tests and submitted to Project Supervisor. For asphalt are determined per spec.
- Determine Required Lot Size/Number of Tests
- Determine Test Locations
- Perform Test(s)
- Report Results

Identify Density/Moisture Requirements

- Acceptance criteria are different for Embankment, Aggregate Base, Asphalt Pavements, Etc.
- This information can be found in the corresponding section in the TDOT specs.
- The target values (soils/aggregate)are determined by TDOT Materials and Tests personnel and will be made available by the TDOT Project Supervisor. *These values may change during the course of the project, so be sure to make sure you have the most current numbers.

Determine Required: Lot Size/Number of Tests/Test Locations

- S.O.P. 1-1: Sampling and Testing Guide
  - Describes the testing frequency for all materials
  - Lists the person responsible for either obtaining the sample of performing the test.
  - Available in PDF format at:

http://www.tdot.state.tn.us/materials/fieldops/sop/default.htm

(see example in Part Five of S.O.P. 1-1)

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Acceptance for Density Section 407.15 (Asphalt)

- The pavement will be divided into LOTs for Acceptance, and there are 5 tests per LOT, 1 per sub-lot
  - Mixtures C, C-W, D, E
    - Lot Size= 10,000 SY
  - Mixtures A, B, B-M, B-M2
    - Lot Size= 5,000 SY

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Lots sizes for Density (Asphalt)

- As of mid-2015, the lot sizes for density changed from being based on square yards to being based on mix tons.
- The new lot size for density testing is **1,000 tons**

TDOT Sampling Procedure (Asphalt)

- SOP 1-1
  - Asphalt: "Each lot shall be divided into 5 equal-sized sublots, and one test should be performed per each sublot. Longitudinal test locations should be determined randomly. No single transverse test location shall be duplicated within any single lot."

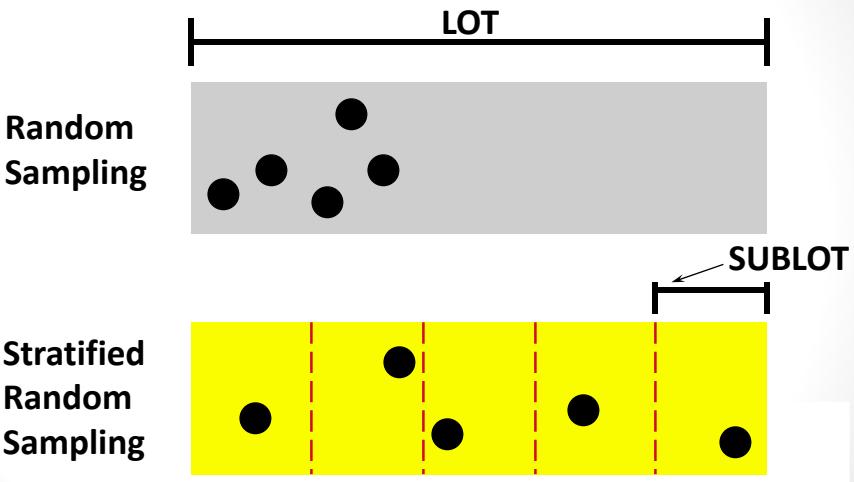
TDOT Sampling Procedure (soil/aggregate)

- SOP 1-1
  - 5 moisture/density tests are required for every 10,000-square-yard (SY) lot of material installed.
  - Tests are to be performed immediately after compaction
  - Specific test/sample locations are to be determined RANDOMLY

Random Sampling

- Any portion of the population has equal chance of being selected
- Bias is introduced when judgment is used
- Use random number tables or other means.

Lots and Sublots



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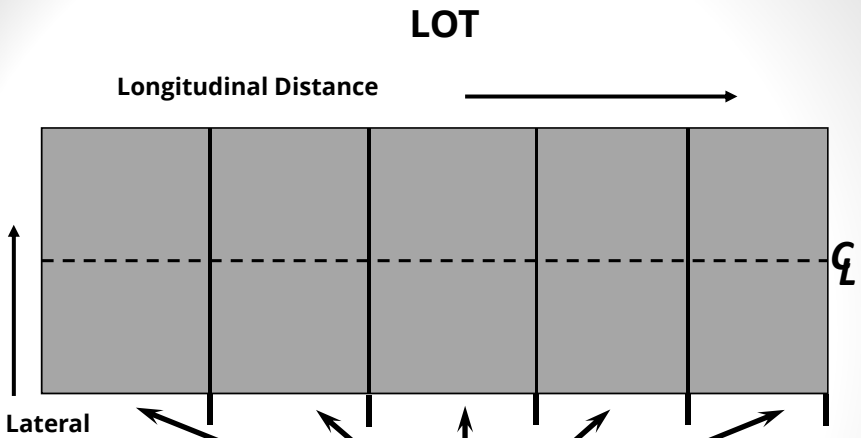

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Random Number Table

.20	.68	.98	.30	.27	.84	.54	.31	.05	.88
.61	.17	.38	.62	.55	.59	.67	.73	.43	.23
.27	.38	.84	.99	.72	.51	.48	.81	.77	.76
.24	.38	.40	.34	.76	.87	.60	.75	.49	.56
.88	.52	.25	.51	.79	.41	.33	.08	.32	.47
.62	.36	.97	.61	.28	.50	.81	.29	.75	.82
.94	.83	.35	.66	.42	.70	.44	.30	.54	.45

**For additional random # tables, see SOP 1-1*

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Random Number Table

	A		B		C		D		E		
1	0.818	0.696	0.758	0.117	0.827	0.567	0.974	0.487	0.074	0.665	1
	0.565	0.826	0.141	0.229	0.996	0.003	0.783	0.079	0.145	0.827	
	0.926	0.785	0.743	0.669	0.411	0.702	0.949	0.460	0.434	0.201	
	0.776	0.529	0.397	0.450	0.851	0.569	0.157	0.571	0.097	0.556	
	0.333	0.996	0.810	0.562	0.053	0.975	0.122	0.055	0.702	0.609	
2	0.626	0.783	0.145	0.210	0.591	0.003	0.493	0.136	0.036	0.223	2
	0.291	0.607	0.048	0.788	0.764	0.020	0.991	0.719	0.948	0.727	
	0.950	0.570	0.324	0.232	0.978	0.033	0.803	0.534	0.367	0.897	
	0.521	0.642	0.912	0.464	0.129	0.047	0.359	0.497	0.382	0.993	
	0.235	0.611	0.262	0.783	0.189	0.047	0.241	0.252	0.706	0.886	
3	0.537	0.505	0.557	0.919	0.939	0.579	0.351	0.525	0.304	0.092	3
	0.286	0.447	0.366	0.025	0.454	0.643	0.647	0.958	0.887	0.702	
	0.492	0.633	0.937	0.229	0.556	0.078	0.468	0.850	0.233	0.009	
	0.428	0.126	0.767	0.250	0.740	0.976	0.835	0.280	0.808	0.401	
	0.443	0.465	0.666	0.947	0.372	0.412	0.408	0.589	0.170	0.211	
4	0.970	0.183	0.800	0.534	0.702	0.508	0.295	0.397	0.391	0.421	4
	0.198	0.464	0.847	0.596	0.228	0.450	0.671	0.787	0.169	0.648	
	0.727	0.087	0.544	0.354	0.630	0.454	0.687	0.320	0.852	0.593	
	0.272	0.647	0.553	0.886	0.761	0.396	0.059	0.207	0.014	0.331	
	0.284	0.210	0.344	0.355	0.060	0.150	0.536	0.940	0.365	0.546	
5	0.027	0.134	0.910	0.121	0.186	0.452	0.081	0.231	0.400	0.598	5
	0.818	0.052	0.867	0.848	0.497	0.386	0.485	0.976	0.283	0.388	
	0.010	0.387	0.919	0.694	0.693	0.272	0.859	0.959	0.613	0.065	
	0.112	0.245	0.158	0.294	0.690	0.704	0.273	0.389	0.075	0.676	
	0.949	0.172	0.810	0.381	0.307	0.129	0.552	0.162	0.016	0.047	
	A		B		C		D		E		

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Testing Locations

STATIONS

- A "station" is a unit used in roadway construction to indicate a longitudinal location along the roadway.
- One station = 100 feet
- i.e. Station 1+00 equals 100 feet

  Station 4+50 equals 450 feet

  Station 105+60 equals 10,560 feet

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Testing Locations

STATIONS

See a trend forming?

Station 85+20 = 85 20

= 8520 feet

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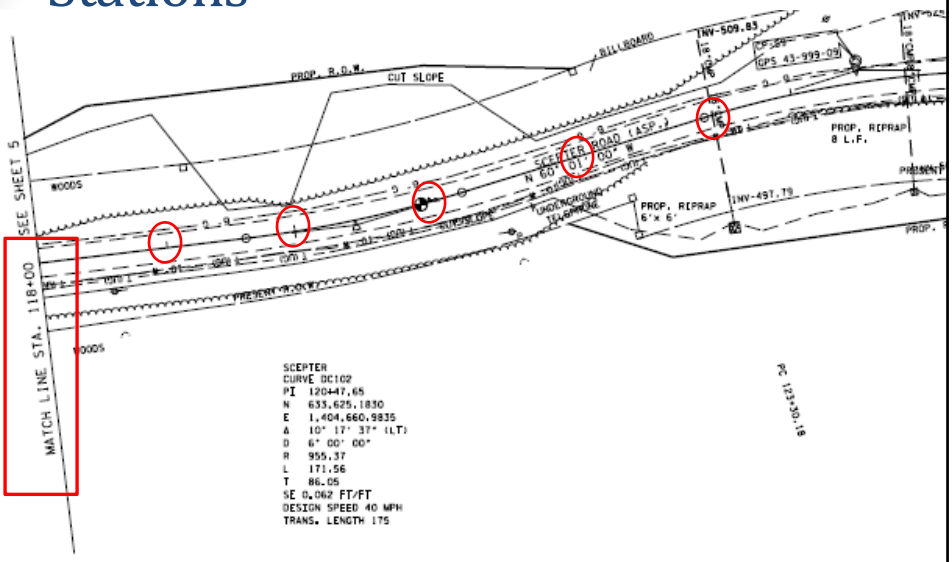
Stations



Testing Locations

- STEP 1-
  - Determine LOT size, and with known lane width, determine LOT and sublot lengths
- STEP 2-
  - With known beginning station, determine beginning sublot stations

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Testing Locations

- STEP 3-
  - Using random number table, or calculator, select 5 numbers.
- STEP 4-
  - Multiply a random number by the sublot Length.
- STEP 5-
  - Add to beginning sublot stations to determine longitudinal testing locations. *A second random number is used to find transverse location for S&A*

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Determining Lot Length (Asphalt)

- Since lots are now always 1,000 tons, determining lot lengths has changed:

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Lots and Sublots

Mix Type	Thickness (inches)	Spread (lb/SY)	Lot/ Sublot	Mat Width (Feet)									
				4	6	8	9	10	11	12	14	15	16
D, CW	1.25	132.5	Lot	34000	22600	17000	15100	13600	12300	11300	9700	9100	8500
			Sublot	6800	4520	3400	3020	2720	2460	2260	1940	1820	1700
E	1.5	154.5	Lot	29100	19400	14600	12900	11700	10600	9700	8300	7800	7300
			Sublot	5820	3880	2920	2580	2340	2120	1940	1660	1560	1460
B, BM, BM2	2	226	Lot	19900	13300	10000	8800	8000	7200	6600	5700	5300	5000
			Sublot	3980	2660	2000	1760	1600	1440	1320	1140	1060	1000
B, BM, BM2	2.25	254.25	Lot	17700	11800	8800	7900	7100	6400	5900	5100	4700	4400
			Sublot	3540	2360	1760	1580	1420	1280	1180	1020	940	880
B, BM, BM2	2.5	282.5	Lot	15900	10600	8000	7100	6400	5800	5300	4600	4200	4000
			Sublot	3180	2120	1600	1420	1280	1160	1060	920	840	800
B, BM, BM2	2.75	310.75	Lot	14500	9700	7200	6400	5800	5300	4800	4100	3900	3600
			Sublot	2900	1940	1440	1280	1160	1060	960	820	780	720
A	3	345	Lot	13000	8700	6500	5800	5200	4700	4300	3700	3500	3300
			Sublot	2600	1740	1300	1160	1040	940	860	740	700	660
A	4	460	Lot	9800	6500	4900	4300	3900	3600	3300	2800	2600	2400
			Sublot	1960	1300	980	860	780	720	660	560	520	480

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Example Problem

- Situation
  - Placing D-mix, lane is 12 feet wide
  - Road has 18,000 ADT
  - Spread Rate is 132.5 lb/yd^2
  - Beginning Station 100+00

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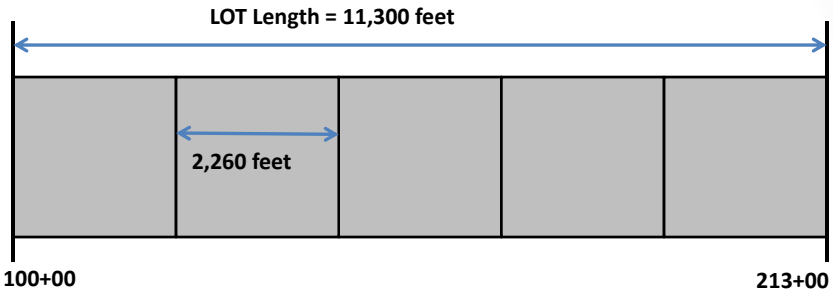
Example Problem (cont.)

- STEP 1- Determine Lot Length
  - 1,000 Ton lot
  - 132.5 lb/yd2
  - 12-feet wide
  - Begin Station = 100+00

Example Problem (cont.)



Example Problem (cont.)

- **STEP 1-**

  LOT= 11,300’ SUB-LOT=2,260’

- **STEP 2- (Beginning Station 100+00)**
  - [100+00]+2,260 = 10,000+2,260 = 12,260 = 122+60
  - [122+60]+2,260 = 12,260+2,260 = 14,520 = 145+20
  - [145+20]+2,260 = 14,520+2,260 = 167+80
  - [167+80]+2,260 = 190+40
  - [190+40]+2,260 = 213+00
  - [100+00]+11,300 = 213+00

End of Lot

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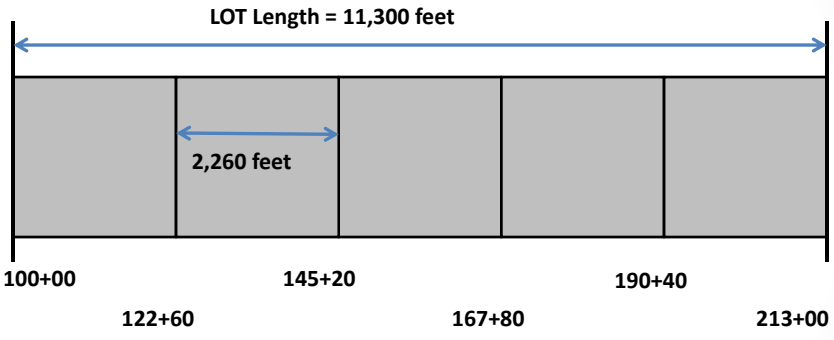
Example Problem (cont.)



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Example Problem (cont.)

- **STEP 3-** Using a random number table, select 5 numbers

.20	.68	.98	.30	.27	.84	.54	.31	.05	.88
.61	.17	.38	.62	.55	.59	.67	.73	.43	.23
.27	.38	.84	.99	.72	.51	.48	.81	.77	.76
.24	.38	.40	.34	.76	.87	.60	.75	.49	.56
.88	.52	.25	.51	.79	.41	.33	.08	.32	.47
.62	.36	.97	.61	.28	.50	.81	.29	.75	.82
.94	.83	.35	.66	.42	.70	.44	.30	.54	.45

Random Number Table

Example Problem (cont.)

- **STEP 4-** Determine the distance within each sublot that each test will be located using both the sublot length and a random number.
  - Round to the nearest whole number.

  - Sublot #1 = (2,260' x 0.38) = **859 feet**
  - Sublot #2 = (2,260' x 0.50) = **1,130 feet**
  - Sublot #3 = (2,260' x 0.61) = **1,379 feet**
  - Sublot #4 = (2,260' x 0.76) = **1,718 feet**
  - Sublot #5 = (2,260' x 0.20) = **452 feet**

Example Problem (cont.)

- **STEP 5-** Determine where the gauge reading will be taken by adding each length to the start of each sublot.
  - Sublot #1 = (10,000') + 859' = 10,859' = **108+59**
  - Sublot #2 = (12,260') + 1,130' = 13,390' = **133+90**
  - Sublot #3 = (14,520') + 1,379' = 15,899' = **158+99**
  - Sublot #4 = (16,780') + 1,718' = 18,498' = **184+98**
  - Sublot #5 = (19,040') + 452' = 19,492' = **194+92**

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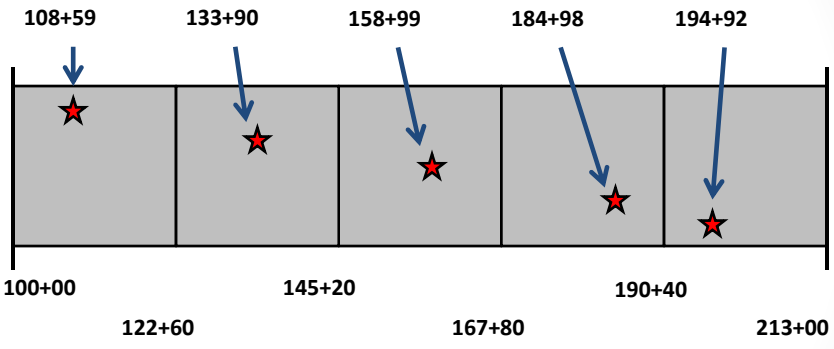
Example Problem (cont.)



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Soils/Aggregate Example Problem

Situation

- Placing Type A Base Material
- Typical base stone cross-section is 30 Feet
- Beginning Station 100+00

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Example Problem (Continued)

- STEP 1- (Per SOP 1-1)
  - 10,000 SY LOT
  - LOT Length: 10,000 yd^2 x 9 = 90,000 ft^2

    90,000 ft^2 / 30 ft = ~~3000 ft length~~
  - SUB-LOT Length: 3000 ft / 5 = ~~600 ft~~

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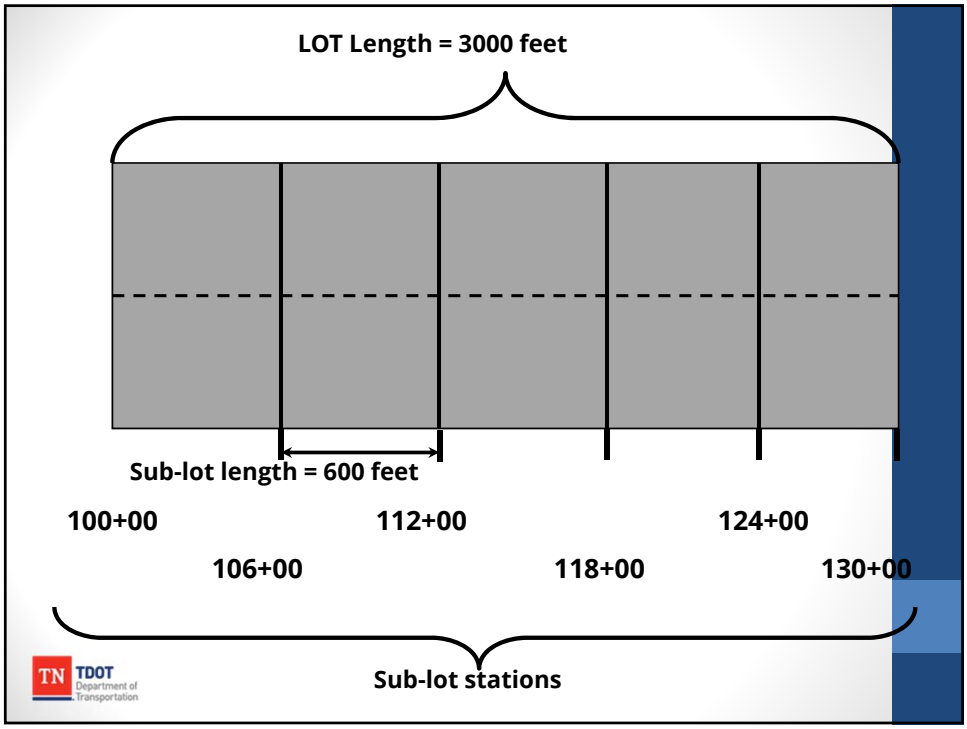
Example Problem (Continued)

- STEP 2- (Beginning Station 100+00)

• 100+00	+600= 106+00
• 106+00	+600=112+00
• 112+00	+600=118+00
• 118+00	+600=124+00
• 124+00	+600=130+00



Example Problem (Continued)

- STEP 3-
  - Using a random number table, select 5 numbers

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Random Number Table

.20	.68	.98	.30	.27	.84	.54	.31	.05	.88
.61	.17	.38	.62		.59	.67	.73		.23
.27	.38	.84	.99	.72	.51	.48	.81	.77	.76
	.38	.40	.34	.76	.87	.60	.75	.49	.56
.88	.52	.25	.51	.79		.33	.08	.32	.47
.62	.36	.97	.61	.28	.50	.81	.29	.75	.82
.94	.83	.35	.66	.42	.70	.44		.54	.45

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Example Problem (Continued)

- Step 4 -
- Use
  - Sub-lot Length from Step 1
  - Sub-lot Stations from Step 2
  - Random Numbers from Step 3

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Example Problem (Continued)

- STEP 4 -
  - 0.41 x 600′ = 246′
    - 2+46 + 100+00 = 102+46
  - 0.30 x 600′ = 180′
    - 1+80 + 106+00 = 107+80
  - 0.43 x 600′ = 258′
    - 2+58 + 112+00 = 114+58
  - 0.55 x 600′ = 330′
    - 3+30 + 118+00 = 121+30
  - 0.24 x 600′ = 144′
    - 1+44 + 124+00 = 125+44

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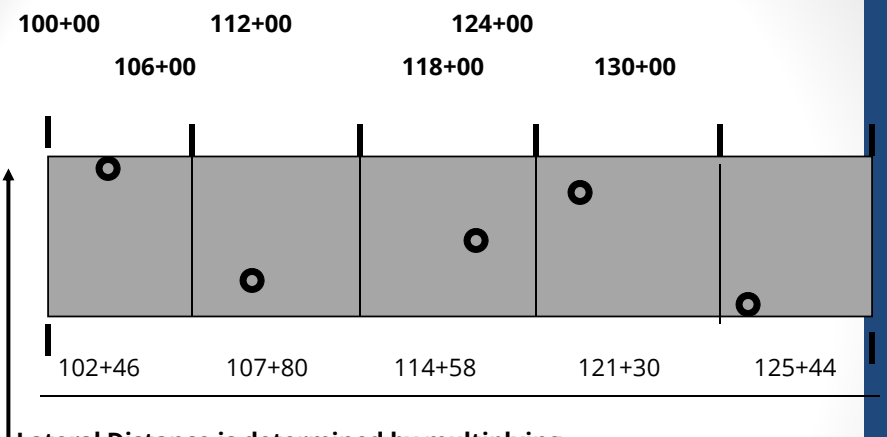
Example Problem (Continued)

- STEP 5-
  - Randomly select the transverse location for testing



Lateral Distance is determined by multiplying random numbers by road width.

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APPENDIX

TDOT Standard Operating Procedures, Specifications, Supplemental Specifications, Special Provisions, & Circular Letters

Standard Operating Procedures

- SOP 1-1: Sampling and Testing Guide
- SOP 7-1: Nuclear Gauge Operation
- SOP 7-2: Nuclear Gauge Safety Plan

TDOT Specifications

- 407.15 Test Strip

Supplemental Specifications

- Section 400

TDOT Forms

- Density Worksheet – Nuclear Method (Aggregate, Soil) DT-0314
- Daily Asphalt Density Report DT-0315
- Daily Report on Soil and Aggregate Stabilization DT-0298
- Daily Report on Embankments DT-0304
- Daily Report on Mineral Aggregate DT-0307

Tennessee Department of Transportation
Division of Materials and Tests

Part Five: Using Random Numbers for Sampling and Testing
(With Examples and Random Number Tables)

Significance

The selection of test locations is critical in ensuring control of materials and construction work. If the results from the test locations conform to specified tests, the rest of the work is assumed to conform as well.

Test sites, then, are samples of construction work under your inspection. Their locations should be random and representative of the entire lot of material.

The procedures outlined below will help you to choose random and representative test locations using random number tables. Random numbers may also be generated by the use of a random number function on a calculator, a spreadsheet program, etc.

Random Number Tables

Randomness in transportation construction inspection indicates unpredictability in the time or location of sampling and testing of a material or procedure in a construction phase.

Random numbers occur in no pattern or sequence. When you review a series of random numbers, you do not know what number may come next; there is no particular order in which random numbers occur.

A sample random-number table is shown below.

	A		B		C		D		E		
	0.814	0.759	0.651	0.947	0.965	0.994	0.581	0.877	0.500	0.208	
	0.105	0.015	0.323	0.630	0.223	0.616	0.070	0.469	0.672	0.931	
1	0.035	0.841	0.590	0.184	0.488	0.794	0.909	0.940	0.062	0.031	1
	0.741	0.336	0.346	0.926	0.237	0.967	0.385	0.657	0.521	0.921	
	0.278	0.697	0.423	0.365	0.010	0.210	0.264	0.745	0.378	0.337	
	0.834	0.355	0.952	0.924	0.591	0.003	0.280	0.363	0.175	0.254	
	0.204	0.159	0.006	0.006	0.764	0.020	0.768	0.209	0.959	0.147	
2	0.426	0.860	0.160	0.009	0.978	0.033	0.394	0.445	0.682	0.600	2
	0.990	0.330	0.581	0.946	0.129	0.047	0.384	0.363	0.038	0.275	
	0.837	0.658	0.140	0.344	0.189	0.047	0.675	0.923	0.101	0.122	
	0.537	0.505	0.909	0.794	0.249	0.339	0.850	0.326	0.510	0.961	
	0.286	0.447	0.286	0.975	0.458	0.484	0.992	0.078	0.947	0.756	
3	0.492	0.633	0.262	0.660	0.451	0.511	0.255	0.439	0.185	0.712	3
	0.428	0.126	0.884	0.203	0.199	0.222	0.638	0.492	0.062	0.967	
	0.443	0.927	0.626	0.542	0.746	0.683	0.822	0.242	0.481	0.077	
	0.343	0.529	0.955	0.122	0.692	0.721	0.393	0.774	0.986	0.485	
	0.070	0.948	0.408	0.338	0.921	0.355	0.252	0.916	0.255	0.456	
4	0.832	0.666	0.385	0.337	0.918	0.098	0.209	0.163	0.921	0.241	4
	0.858	0.470	0.756	0.923	0.799	0.250	0.101	0.615	0.891	0.120	
	0.153	0.773	0.722	0.819	0.626	0.393	0.340	0.202	0.120	0.793	
	0.142	0.636	0.217	0.005	0.597	0.628	0.994	0.150	0.375	0.969	
	0.882	0.905	0.272	0.637	0.201	0.768	0.002	0.568	0.176	0.702	
5	0.369	0.985	0.930	0.070	0.891	0.835	0.340	0.283	0.863	0.566	5
	0.423	0.658	0.311	0.795	0.174	0.419	0.909	0.600	0.885	0.145	
	0.461	0.878	0.363	0.644	0.890	0.278	0.219	0.312	0.585	0.923	
	A		B		C		D		E		

Lot sizes vary depending on the type of construction and the material. For example, a lot for earthwork construction is defined by the width and length of roadway, while concrete tests for bridge decks (slump, temperature, and air content) are determined by the volume of concrete delivered to the site.

Determine the lot size and the number of samples and tests required per lot from the Sampling and Testing (S&T) Guide and Schedule (SOP 1-1).

Knowing the type of construction and the material to be tested, use the S&T Schedule to determine the type of test and frequency of testing.

This SOP changes as construction materials, equipment, and practices change, so you must consult the current Part 2: Acceptance Sampling &Test Schedule.

Below are three examples using random numbers.

Example 1: Moisture and density must be measured on a lift of aggregate for subgrade preparation of a roadbed. The proposed roadway is 48-feet wide.

According to the Sampling and Testing Schedule (SOP 1-1, Part 2, shown below), five tests for moisture and density are required for every 10,000-square-yard lot of aggregate placed.

Subgrade Preparation	Soil	Proctor Density & Optimum Moisture	Materials & Tests	As required by material changes.	May be sampled before grading construction or after grading prior to sub-grade preparation.	
		Density, Moisture	Project Inspector	5 tests per10, 000 yd^2 lot for top 6 inches.	Immediately before placing pavement structure.	Average of 5 tests in lot used to determine pass-fail, with no individual test below 95% of Proctor. Average lot to be no less than 100%.

Since the project is 48 feet wide, the lot length will be, *at most,*

$$\frac{10000\ \text{yd}^2\ \text{area of aggregate} \times 9\frac{\text{ft}^2}{\text{yd}^2}}{48\ \text{feet wide}} = 1875\ \text{feet per lot}$$

We decide to use 1000 linear feet of roadway as our designated lot since this is shorter than the allowable lot length of 1875 feet.

Using the table of random numbers shown below, we randomly choose a block of numbers, say, block C2.

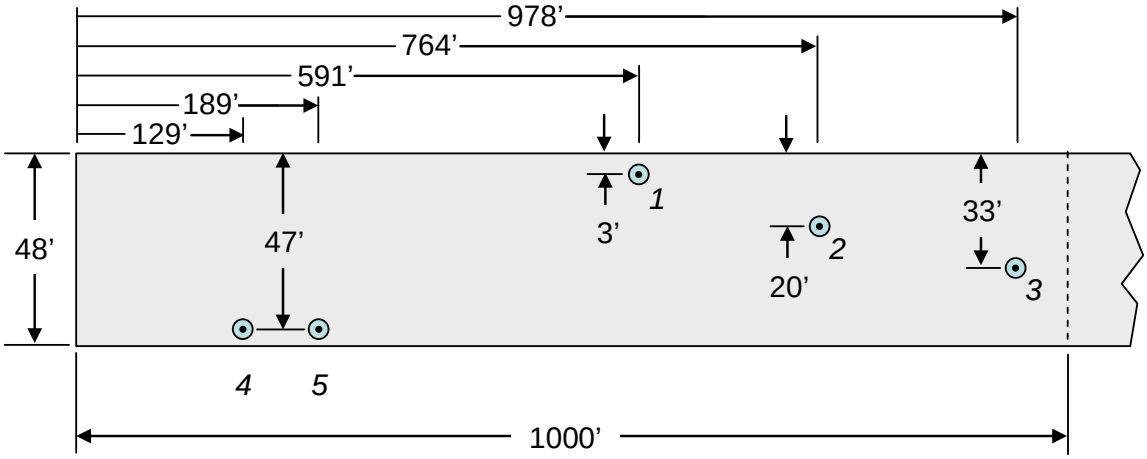
	A		B		C		D		E		
	0.271	0.584	0.674	0.883	0.379	0.976	0.555	0.083	0.967	0.812	
	0.185	0.905	0.686	0.491	0.424	0.566	0.724	0.582	0.393	0.176	
1	0.283	0.202	0.692	0.475	0.436	0.304	0.375	0.660	0.731	0.384	1
	0.567	0.800	0.642	0.205	0.827	0.129	0.598	0.216	0.124	0.787	
	0.703	0.621	0.893	0.063	0.755	0.194	0.133	0.110	0.795	0.824	
	0.103	0.338	0.620	0.594	0.591	0.069	0.639	0.203	0.313	0.733	
	0.536	0.826	0.362	0.321	0.764	0.408	0.487	0.515	0.591	0.676	
2	0.017	0.218	0.365	0.209	0.978	0.688	0.546	0.490	0.795	0.241	2
	0.840	0.594	0.341	0.006	0.129	0.986	0.350	0.437	0.927	0.782	
	0.161	0.720	0.366	0.219	0.189	0.985	0.899	0.501	0.793	0.889	
	0.251	0.496	0.741	0.314	0.014	0.839	0.124	0.209	0.292	0.099	
	0.380	0.901	0.262	0.180	0.459	0.843	0.640	0.720	0.131	0.132	
3	0.637	0.274	0.959	0.050	0.924	0.773	0.314	0.390	0.819	0.410	3
	0.310	0.324	0.111	0.760	0.706	0.165	0.930	0.515	0.639	0.116	
	0.568	0.379	0.600	0.362	0.697	0.006	0.080	0.680	0.028	0.206	
	0.378	0.392	0.910	0.202	0.512	0.156	0.336	0.465	0.813	0.471	
	0.805	0.641	0.118	0.878	0.932	0.196	0.018	0.094	0.419	0.211	
4	0.830	0.106	0.643	0.706	0.720	0.299	0.252	0.598	0.955	0.021	4
	0.367	0.538	0.050	0.448	0.896	0.669	0.968	0.984	0.890	0.117	
	0.274	0.509	0.848	0.645	0.890	0.998	0.389	0.611	0.586	0.137	
	0.566	0.802	0.283	0.151	0.399	0.316	0.559	0.684	0.318	0.516	
	0.078	0.505	0.541	0.962	0.868	0.007	0.192	0.610	0.255	0.081	
5	0.458	0.811	0.454	0.476	0.156	0.385	0.198	0.102	0.762	0.372	5
	0.486	0.345	0.786	0.759	0.465	0.222	0.487	0.355	0.935	0.223	
	0.783	0.432	0.275	0.218	0.942	0.054	0.641	0.278	0.957	0.778	
	A		B		C		D		E		

Using block C2, we have 10 random numbers that range between 0 and 1 carried to the thousandth decimal place. We will use these as multiplication factors to determine our test locations in the following table. The left-hand column of numbers in block C2 will be used to determine the longitudinal coordinates (length of the proposed roadway) by multiplying the lot length by the random number, then rounding to the nearest whole number. The right-hand column of numbers in block C2 will be used to determine the lateral coordinates (perpendicular to the proposed roadway) by multiplying the lot width by the random number, then rounding to the nearest whole number.

SAMPLE NO.	LENGTH	RANDOM NO.	LONGITUDINAL COORDINATE
1	1000	0.591	591
2	1000	0.764	764
3	1000	0.978	978
4	1000	0.129	129
5	1000	0.189	189

SAMPLE NO.	WIDTH	RANDOM NO.	LATERAL COORDINATE
1	48	0.069	3
2	48	0.408	20
3	48	0.688	33
4	48	0.986	47
5	48	0.985	47

Now, we simply match the first longitudinal coordinate with the first lateral coordinate to locate the first test location. Then, we match the remainder of the longitudinal and lateral coordinates to determine the remaining 4 test locations. The figure below shows the locations of the tests on the roadbed.



PLAN VIEW OF TEST AREA
(NOT TO SCALE)

Example 2: Nuclear gauge tests of density on 3.5 inches of Grading 307-A asphalt pavement that is 12 feet wide. The spread rate for 3.5 inches is 402.5 lbs/yd^2.

According to the Sampling and Testing Schedule (SOP 1-1, Part 2, shown below), five tests for density are required for every 1,000 ton lot of asphalt placed.

Bituminous Plant Mix Pavements	Plant Mix Asphalt Gradings A, B, BM, BM2, C, CW, D, E, and E Shoulder	Density	Project Inspector	1,000 tons	As soon as practical after compaction, when nuclear method is used. When used, cores will be obtained in accordance with SP407DEN.	Each lot shall be divided into 5 equal-sized sublots, and one test should be performed per each sublot. Longitudinal test locations should be determined randomly. No single transverse test location shall be duplicated within any single lot.

Since the lot size is 1,000 tons, the maximum lot size will be,

$$\frac{1{,}000 \text{ tons} \times 2{,}000 \dfrac{\text{lb}}{\text{ton}}}{402.5 \dfrac{\text{lb}}{\text{yd}^2}} = 4{,}969 \text{ square yards}$$

Converting this into square feet,

$$4{,}969 \text{ yd}^2 \times 9 \frac{\text{ft}^2}{\text{yd}^2} = 44{,}721 \text{ft}^2$$

Since the project is 12 feet wide, the maximum lot will be,

$$44{,}721 \text{ft}^2 \div 12 \text{ ft wide} = 3{,}726.8 \text{ ft}$$

Dividing this lot into five equal sub-lots, $3727 \text{ ft} \div 5 = 745 \text{ feet per sub - lot}$

LOT SIZE (yd^2)		LANE WIDTH (ft)			
		10	11	12	13
5,000	LOT LENGTH	4500	4091	3750	3462
	SUB-LOT LENGTH	900	818	750	692
10,000	LOT LENGTH	9000	8182	7500	6923
	SUB-LOT LENGTH	1800	1636	1500	1385

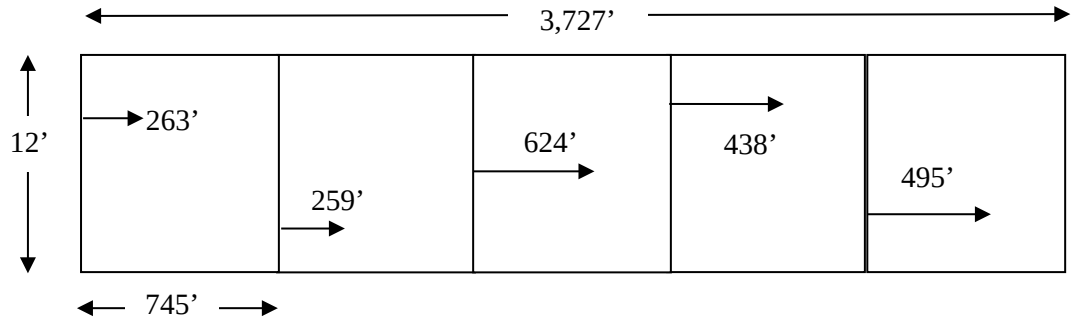
Using the table of random numbers shown below, we randomly choose a block of numbers, say, block D5.

	A		B		C		D		E		
	0.781	0.437	0.811	0.662	0.105	0.135	0.509	0.792	0.137	0.779	
	0.311	0.114	0.878	0.378	0.984	0.741	0.177	0.558	0.725	0.807	
1	0.746	0.926	0.294	0.674	0.952	0.597	0.559	0.685	0.891	0.909	1
	0.381	0.729	0.057	0.378	0.166	0.332	0.807	0.034	0.628	0.090	
	0.954	0.130	0.447	0.548	0.199	0.658	0.897	0.349	0.396	0.742	
	0.265	0.732	0.808	0.566	0.484	0.163	0.114	0.631	0.992	0.934	
	0.769	0.313	0.280	0.451	0.035	0.787	0.223	0.994	0.111	0.777	
2	0.729	0.963	0.946	0.178	0.198	0.252	0.085	0.630	0.677	0.055	2
	0.140	0.111	0.712	0.641	0.576	0.558	0.407	0.384	0.653	0.181	
	0.923	0.316	0.508	0.284	0.406	0.228	0.920	0.875	0.403	0.503	
	0.602	0.516	0.251	0.954	0.268	0.197	0.809	0.004	0.769	0.678	
	0.138	0.246	0.819	0.198	0.418	0.126	0.835	0.187	0.680	0.855	
3	0.178	0.399	0.550	0.565	0.071	0.916	0.560	0.219	0.537	0.856	3
	0.613	0.157	0.218	0.001	0.535	0.576	0.146	0.010	0.215	0.190	
	0.097	0.155	0.388	0.403	0.252	0.987	0.775	0.596	0.365	0.231	
	0.373	0.974	0.929	0.104	0.447	0.449	0.447	0.147	0.424	0.195	
	0.880	0.803	0.036	0.846	0.058	0.834	0.010	0.314	0.011	0.621	
4	0.749	0.231	0.217	0.206	0.869	0.810	0.804	0.426	0.157	0.881	4
	0.020	0.048	0.404	0.368	0.917	0.374	0.444	0.214	0.432	0.827	
	0.052	0.601	0.318	0.016	0.766	0.513	0.623	0.065	0.409	0.816	
	0.777	0.941	0.140	0.401	0.171	0.139	0.353	0.481	0.209	0.735	
	0.406	0.017	0.252	0.730	0.476	0.188	0.347	0.656	0.945	0.149	
5	0.044	0.413	0.782	0.032	0.459	0.856	0.838	0.594	0.322	0.654	5
	0.980	0.185	0.574	0.166	0.025	0.962	0.588	0.134	0.198	0.704	
	0.237	0.162	0.155	0.373	0.673	0.104	0.665	0.070	0.849	0.957	
	A		B		C		D		E		

Using block D5, we have 10 random numbers that range between 0 and 1 carried to the thousandth decimal place. We will use the multiplication factors in the left-hand column to determine our longitudinal test locations. Transverse locations are determined randomly with one test 12" off each edge, one test in each wheel path, and one test in the center of the lane.

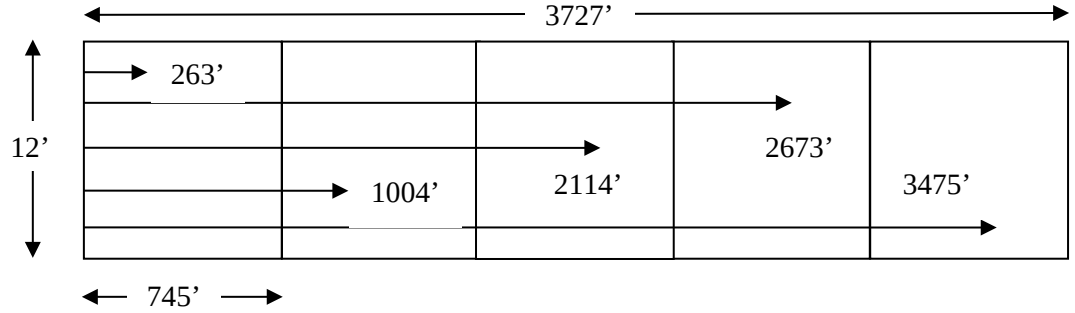
The distances into each sublot,

$$745\,\text{ft} * 0.353 = 263\,\text{ft}$$
$$745\,\text{ft} * 0.347 = 259\,\text{ft}$$
$$745\,\text{ft} * 0.588 = 438\,\text{ft}$$
$$745\,\text{ft} * 0.838 = 624\,\text{ft}$$
$$745\,\text{ft} * 0.665 = 495\,\text{ft}$$



If we wanted to know the total distance into the 3750’ lot for each test:

$$\text{Test } 1 = 263 \text{ ft}$$
$$\text{Test } 2 = 745 \text{ ft} + 259 \text{ ft} = 1004 \text{ ft}$$
$$\text{Test } 3 = 745 \text{ ft} + 745 \text{ ft} + 624 \text{ ft} = 2114 \text{ ft}$$
$$\text{Test } 4 = 745 \text{ ft} + 745 \text{ ft} + 745 \text{ ft} + 438 \text{ ft} = 2673 \text{ ft}$$
$$\text{Test } 5 = 745 \text{ ft} + 745 \text{ ft} + 745 \text{ ft} + 745 \text{ ft} + 495 \text{ ft} = 3475 \text{ ft}$$



Example 3: Slump, temperature, and air content of concrete from mixing trucks delivering concrete to a bridge deck pour that is expected to use 1300 cubic yards of concrete.

According to the Sampling and Testing Schedule (SOP 1-1, Part 2, shown below), one complete set of tests for air content, slump, and temperature are required for the first three loads of concrete delivered.

One pair of cylinders must be cast from one of the three passing loads. For each additional 50 cubic yards of concrete, a pair of cylinders must be made and tests for air content, slump, and temperature must be performed.

Completed Concrete Mix	Cylinders (28-day) Slump, Air Content, and Mix Temperature *All early break cylinders shall comply with acceptance cylinders	Project Inspector	*A complete set of tests and pair of cylinders for each 100 yd^3 placed per critical unit of structure. For Class D or L, One complete set of tests for each of the first three loads. One pair of cylinders shall be cast from one of the first three passing loads; additional tests and sets of cylinders to be made for each additional 50 yd^3.	Randomly selected during placement.	Determine Slump and Air Content from the same sample of concrete that cylinders are made from. For Class D or L, Bridge Deck Concrete per SOP 4-1; concrete placed by pumping shall be checked for air content at the discharge end of the truck chute immediately prior to pumping. ***Complete set of tests shall be performed on the initial load for quality control/ informational purposes, not for acceptance.** The volumes of noncritical items may be combined when utilizing the same ready mix plant.	Completed Concrete Mix

Now we'll use the random number tables in a different way. We must decide which loads of concrete to test. First, we'll assume each truck is hauling 10 cubic yards of concrete. Subsequent to the first 30 cubic yards, we'll test from truck loads by first choosing a random block of numbers from the following table. We'll choose block A3.

	A		B		C		D		E		
	0.818	0.696	0.758	0.117	0.827	0.567	0.974	0.487	0.874	0.665	
	0.565	0.826	0.141	0.229	0.996	0.003	0.783	0.079	0.145	0.827	
1	0.926	0.785	0.743	0.669	0.411	0.702	0.949	0.460	0.434	0.201	1
	0.776	0.529	0.397	0.450	0.851	0.569	0.157	0.571	0.097	0.556	
	0.333	0.996	0.810	0.562	0.053	0.975	0.122	0.055	0.702	0.609	
	0.626	0.783	0.145	0.210	0.591	0.003	0.493	0.136	0.036	0.223	
	0.291	0.607	0.048	0.788	0.764	0.020	0.991	0.719	0.948	0.727	
2	0.950	0.570	0.324	0.232	0.978	0.033	0.803	0.534	0.367	0.897	2
	0.521	0.642	0.912	0.464	0.129	0.047	0.359	0.497	0.382	0.993	
	0.235	0.611	0.262	0.783	0.189	0.047	0.241	0.252	0.706	0.886	
	0.537	0.505	0.557	0.919	0.939	0.579	0.351	0.525	0.304	0.092	
	0.286	0.447	0.366	0.025	0.454	0.643	0.647	0.958	0.887	0.702	
3	0.492	0.633	0.937	0.229	0.556	0.078	0.468	0.850	0.233	0.009	3
	0.428	0.126	0.767	0.250	0.740	0.976	0.835	0.280	0.808	0.401	
	0.443	0.465	0.666	0.947	0.372	0.412	0.408	0.589	0.170	0.211	
	0.970	0.183	0.800	0.534	0.702	0.508	0.295	0.397	0.391	0.421	
	0.198	0.464	0.847	0.596	0.228	0.450	0.671	0.787	0.169	0.648	
4	0.727	0.087	0.544	0.354	0.630	0.454	0.687	0.320	0.852	0.593	4
	0.272	0.647	0.553	0.886	0.761	0.396	0.059	0.207	0.014	0.331	
	0.284	0.210	0.344	0.355	0.060	0.158	0.536	0.940	0.365	0.546	
	0.027	0.134	0.910	0.121	0.186	0.452	0.081	0.231	0.400	0.598	
	0.818	0.052	0.867	0.848	0.497	0.386	0.485	0.976	0.283	0.388	
5	0.010	0.387	0.919	0.694	0.693	0.272	0.859	0.959	0.613	0.065	5
	0.112	0.245	0.158	0.294	0.690	0.704	0.273	0.389	0.075	0.676	
	0.949	0.172	0.810	0.381	0.307	0.129	0.552	0.162	0.016	0.047	
	A		B		C		D		E		

The table below shows one way to determine, using the random numbers above, the truck numbers from which samples will be taken.

SAMPLE NO.	DELIVERED CONCRETE (yd^3)	TOTAL AMOUNT OF CONCRETE (yd^3)	TOTAL LOADS OF CONCRETE (A)	RANDOM NO. (B)	LOAD NUMBER $[(A_n-A_{n-1})xB]+A_{n-1}$
1	10	10	1	NA	1
2	10	20	2	NA	2
3	10	30	3	NA	3
4	50	80	8	0.492	5
5	50	130	13	0.428	10
6	50	180	18	0.443	15
7	50	230	23	0.505	21
8	50	280	28	0.447	25
9	50	330	33	0.633	31
10	50	380	38	0.126	34

Example 4: Slump, temperature, and air content of concrete from mixing trucks delivering concrete to a structural footing that is expected to use 550 cubic yards of concrete.

According to the Sampling and Testing Schedule (SOP 1-1, Part 2, shown below), one complete set of tests for air content, slump, and temperature are required for the first load of concrete delivered each day for quality control/informational purposes. For each additional 100 cubic yards of concrete, a pair of cylinders must be made and tests for air content, slump, and temperature must be performed.

Completed Concrete Mix	Cylinders (28-day) Slump, Air Content, and Mix Temperature *All early break cylinders shall comply with acceptance cylinders	Project Inspector	*A complete set of tests and pair of cylinders for each 100 yd^3 placed per critical unit of structure. For Class D or L, One complete set of tests for each of the first three loads. One pair of cylinders shall be cast from one of the first three passing loads; additional tests and sets of cylinders to be made for each additional 50 yd^3.	Randomly selected during placement.	Determine Slump and Air Content from the same sample of concrete that cylinders are made from. For Class D or L, Bridge Deck Concrete per SOP 4-1; concrete placed by pumping shall be checked for air content at the discharge end of the truck chute immediately prior to pumping. ***Complete set of tests shall be performed on the initial load for quality control/informational purposes, not for acceptance.** The volumes of noncritical items may be combined when utilizing the same ready mix plant.	Completed Concrete Mix

Now we'll use the random number tables in a different way. We must decide which loads of concrete to test. First, we'll assume each truck is hauling 10 cubic yards of concrete. Subsequent to the first 10 cubic yards, we'll test from truck loads by first choosing a random block of numbers from the following table. We'll choose block C1.

	A		B		C		D		E		
	0.815	0.125	0.006	0.653			0.968	0.103	0.150	0.154	
	0.872	0.226	0.619	0.637			0.331	0.028	0.369	0.751	
1	0.685	0.964	0.937	0.948			0.194	0.425	0.852	0.500	1
	0.427	0.348	0.222	0.129			0.996	0.115	0.681	0.569	
	0.181	0.115	0.519	0.715			0.525	0.584	0.694	0.427	
	0.917	0.628	0.054	0.928	0.817	0.812	0.264	0.776	0.756	0.610	
	0.759	0.891	0.311	0.612	0.247	0.044	0.668	0.389	0.953	0.931	
2	0.510	0.632	0.371	0.037	0.667	0.681	0.730	0.638	0.965	0.925	2
	0.836	0.525	0.342	0.752	0.638	0.403	0.687	0.245	0.403	0.785	
	0.669	0.875	0.824	0.842	0.565	0.756	0.401	0.371	0.576	0.689	
	0.931	0.450	0.955	0.323	0.696	0.790	0.021	0.127	0.753	0.550	
	0.771	0.631	0.896	0.968	0.870	0.312	0.764	0.665	0.113	0.610	
3	0.855	0.525	0.056	0.255	0.921	0.282	0.301	0.401	0.775	0.246	3
	0.897	0.753	0.246	0.763	0.259	0.293	0.613	0.154	0.743	0.574	
	0.393	0.878	0.401	0.459	0.134	0.655	0.433	0.323	0.393	0.038	
	0.965	0.130	0.181	0.909	0.940	0.399	0.200	0.724	0.673	0.397	
	0.745	0.233	0.460	0.361	0.935	0.018	0.405	0.945	0.183	0.576	
4	0.204	0.623	0.771	0.120	0.859	0.314	0.880	0.447	0.680	0.938	4
	0.804	0.213	0.903	0.488	0.425	0.685	0.584	0.676	0.717	0.220	
	0.526	0.018	0.323	0.978	0.407	0.197	0.827	0.102	0.641	0.302	
	0.620	0.343	0.587	0.878	0.922	0.977	0.162	0.523	0.011	0.409	
	0.558	0.383	0.880	0.541	0.422	0.466	0.186	0.004	0.457	0.446	
5	0.128	0.893	0.685	0.864	0.349	0.413	0.273	0.971	0.970	0.311	5
	0.455	0.032	0.141	0.835	0.705	0.898	0.958	0.945	0.095	0.779	
	0.790	0.312	0.258	0.518	0.141	0.448	0.185	0.599	0.546	0.751	
	A		B		C		D		E		

The table below shows one way to determine, using the random numbers above, the truck numbers from which samples will be taken for acceptance.

SAMPLE NO.	TOTAL AMOUNT OF CONCRETE (yd^3)	TOTAL LOADS OF CONCRETE (A)	RANDOM NO. (B)	LOAD NUMBER $[(A_n-A_{n-1}) \times B]+A_{n-1}$
1	0-100	10	0.273	3
2	101-200	20	0.614	16
3	201-300	30	0.585	26
4	301-400	40	0.969	40
5	401-500	50	0.690	47
6	501-550	55	0.383	52

	A		B		C		D		E		
	0.678	0.694	0.141	0.441	0.836	0.182	0.274	0.829	0.365	0.881	
	0.023	0.158	0.948	0.763	0.555	0.741	0.157	0.869	0.811	0.789	
1	0.504	0.635	0.730	0.899	0.719	0.357	0.284	0.140	0.644	0.082	**1**
	0.704	0.941	0.361	0.863	0.882	0.404	0.704	0.933	0.667	0.571	
	0.830	0.617	0.154	0.081	0.109	0.741	0.503	0.974	0.301	0.911	
	0.247	0.737	0.402	0.169	0.871	0.830	0.069	0.276	0.998	0.499	
	0.710	0.346	0.012	0.836	0.233	0.885	0.077	0.341	0.607	0.719	
2	0.205	0.290	0.040	0.804	0.638	0.987	0.353	0.539	0.208	0.676	**2**
	0.980	0.629	0.424	0.081	0.002	0.761	0.185	0.940	0.997	0.568	
	0.360	0.766	0.117	0.032	0.588	0.049	0.407	0.388	0.535	0.464	
	0.120	0.852	0.163	0.852	0.201	0.487	0.713	0.696	0.914	0.080	
	0.413	0.327	0.839	0.949	0.724	0.728	0.508	0.471	0.327	0.850	
3	0.955	0.924	0.285	0.028	0.299	0.064	0.953	0.791	0.437	0.745	**3**
	0.131	0.616	0.223	0.213	0.027	0.024	0.484	0.030	0.533	0.552	
	0.037	0.500	0.803	0.546	0.093	0.401	0.750	0.189	0.417	0.078	
	0.096	0.483	0.713	0.576	0.935	0.281	0.506	0.994	0.014	0.491	
	0.818	0.855	0.950	0.195	0.142	0.392	0.380	0.786	0.063	0.423	
4	0.689	0.685	0.742	0.863	0.906	0.966	0.617	0.375	0.908	0.685	**4**
	0.443	0.857	0.239	0.770	0.181	0.241	0.982	0.373	0.150	0.316	
	0.020	0.898	0.158	0.365	0.497	0.139	0.864	0.937	0.392	0.026	
	0.245	0.510	0.670	0.082	0.483	0.403	0.524	0.338	0.387	0.406	
	0.658	0.596	0.690	0.737	0.899	0.567	0.655	0.231	0.508	0.374	
5	0.107	0.682	0.077	0.763	0.593	0.877	0.094	0.929	0.268	0.973	**5**
	0.057	0.478	0.230	0.623	0.339	0.942	0.239	0.839	0.074	0.854	
	0.312	0.193	0.428	0.947	0.185	0.197	0.642	0.537	0.590	0.876	
	A		**B**		**C**		**D**		**E**		

	A		B		C		D		E		
	0.439	0.107	0.450	0.340	0.181	0.794	0.186	0.814	0.350	0.112	
	0.460	0.661	0.706	0.123	0.648	0.988	0.750	0.968	0.955	0.196	
1	0.631	0.799	0.355	0.746	0.842	0.268	0.445	0.942	0.430	0.324	**1**
	0.398	0.177	0.993	0.666	0.377	0.609	0.533	0.840	0.271	0.270	
	0.258	0.732	0.905	0.314	0.200	0.640	0.736	0.970	0.804	0.352	
	0.099	0.586	0.938	0.597	0.883	0.855	0.489	0.003	0.290	0.397	
	0.024	0.789	0.120	0.111	0.274	0.627	0.731	0.654	0.482	0.637	
2	0.536	0.280	0.146	0.968	0.044	0.326	0.097	0.326	0.228	0.370	**2**
	0.087	0.955	0.770	0.328	0.492	0.940	0.554	0.913	0.888	0.758	
	0.192	0.771	0.968	0.688	0.247	0.770	0.194	0.621	0.847	0.848	
	0.183	0.040	0.020	0.172	0.625	0.262	0.170	0.501	0.930	0.626	
	0.605	0.948	0.688	0.893	0.686	0.840	0.799	0.047	0.936	0.752	
3	0.924	0.795	0.113	0.148	0.316	0.956	0.536	0.701	0.440	0.702	**3**
	0.569	0.213	0.626	0.960	0.240	0.823	0.196	0.335	0.663	0.630	
	0.799	0.128	0.560	0.843	0.951	0.600	0.609	0.256	0.292	0.681	
	0.597	0.815	0.412	0.439	0.189	0.094	0.782	0.515	0.809	0.303	
	0.014	0.033	0.240	0.170	0.824	0.248	0.118	0.570	0.344	0.203	
4	0.916	0.958	0.802	0.089	0.958	0.677	0.515	0.843	0.127	0.868	**4**
	0.989	0.291	0.184	0.927	0.089	0.780	0.214	0.277	0.105	0.138	
	0.545	0.849	0.884	0.192	0.617	0.416	0.763	0.558	0.027	0.098	
	0.227	0.322	0.069	0.477	0.984	0.112	0.207	0.110	0.196	0.615	
	0.342	0.472	0.531	0.716	0.337	0.880	0.593	0.881	0.195	0.188	
5	0.059	0.058	0.688	0.504	0.418	0.197	0.894	0.298	0.843	0.959	**5**
	0.056	0.926	0.214	0.016	0.050	0.692	0.256	0.966	1.000	0.084	
	0.033	0.489	0.768	0.354	0.855	0.839	0.670	0.853	0.934	0.012	
	A		**B**		**C**		**D**		**E**		

	A		B		C		D		E		
	0.001	0.411	0.562	0.371	0.511	0.010	0.189	0.340	0.529	0.991	
	0.095	0.690	0.070	0.561	0.412	0.123	0.060	0.580	0.614	0.151	
1	0.742	0.355	0.526	0.217	0.848	0.774	0.923	0.542	0.653	0.385	**1**
	0.914	0.676	0.912	0.868	0.085	0.281	0.924	0.704	0.371	0.600	
	0.257	0.536	0.951	0.713	0.939	0.987	0.637	0.536	0.129	0.917	
	0.586	0.163	0.710	0.254	0.744	0.846	0.979	0.344	0.333	0.481	
	0.271	0.577	0.487	0.484	0.408	0.704	0.901	0.347	0.850	0.286	
2	0.480	0.538	0.017	0.074	0.427	0.225	0.452	0.049	0.233	0.846	**2**
	0.967	0.187	0.657	0.775	0.251	0.877	0.169	0.977	0.879	0.635	
	0.471	0.416	0.107	0.334	0.565	0.735	0.549	0.763	0.850	0.113	
	0.398	0.095	0.496	0.726	0.650	0.498	0.266	0.727	0.355	0.209	
	0.265	0.801	0.509	0.718	0.181	0.286	0.928	0.200	0.588	0.881	
3	0.937	0.348	0.446	0.688	0.955	0.834	0.796	0.045	0.292	0.019	**3**
	0.999	0.804	0.217	0.945	0.601	0.122	0.897	0.535	0.170	0.606	
	0.871	0.270	0.269	0.056	0.555	0.907	0.732	0.709	0.224	0.424	
	0.550	0.650	0.779	0.280	0.914	0.303	0.377	0.896	0.428	0.791	
	0.262	0.325	0.785	0.248	0.748	0.291	0.552	0.560	0.806	0.450	
4	0.194	0.754	0.700	0.244	0.521	0.673	0.196	0.495	0.227	0.995	**4**
	0.484	0.315	0.295	0.267	0.637	0.202	0.082	0.750	0.626	0.107	
	0.925	0.002	0.940	0.406	0.756	0.942	0.745	0.665	0.398	0.519	
	0.769	0.126	0.227	0.521	0.395	0.853	0.606	0.467	0.716	0.376	
	0.786	0.339	0.246	0.850	0.310	0.413	0.966	0.387	0.222	0.035	
5	0.121	0.278	0.807	0.006	0.872	0.081	0.317	0.163	0.942	0.763	**5**
	0.794	0.721	0.766	0.883	0.285	0.936	0.363	0.154	0.021	0.304	
	0.138	0.381	0.875	0.566	0.802	0.077	0.888	0.634	0.880	0.916	
	A		**B**		**C**		**D**		**E**		

	A		B		C		D		E		
	0.213	0.416	0.998	0.713	0.003	0.826	0.353	0.763	0.835	0.398	
	0.761	0.812	0.959	0.598	0.771	0.105	0.414	0.251	0.305	0.385	
1	0.071	0.848	0.185	0.978	0.881	0.329	0.822	0.690	0.779	0.126	**1**
	0.745	0.888	0.662	0.041	0.589	0.145	0.125	0.617	0.474	0.200	
	0.619	0.972	0.230	0.780	0.224	0.463	0.846	0.098	0.541	0.002	
	0.770	0.801	0.055	0.852	0.289	0.381	0.023	0.911	0.736	0.387	
	0.794	0.193	0.499	0.827	0.235	0.046	0.168	0.789	0.543	0.594	
2	0.768	0.053	0.915	0.063	0.541	0.687	0.848	0.742	0.891	0.091	**2**
	0.752	0.363	0.172	0.583	0.183	0.234	0.105	0.650	0.456	0.330	
	0.746	0.920	0.088	0.285	0.125	0.514	0.795	0.366	0.144	0.758	
	0.676	0.579	0.181	0.237	0.249	0.376	0.805	0.306	0.050	0.951	
	0.524	0.502	0.975	0.401	0.741	0.518	0.312	0.284	0.444	0.002	
3	0.408	0.575	0.505	0.360	0.774	0.546	0.635	0.758	0.440	0.299	**3**
	0.875	0.176	0.145	0.011	0.174	0.516	0.317	0.560	0.775	0.488	
	0.045	0.320	0.449	0.079	0.726	0.455	0.934	0.341	0.912	0.963	
	0.589	0.945	0.644	0.339	0.984	0.115	0.517	0.414	0.834	0.261	
	0.338	0.428	0.777	0.803	0.755	0.264	0.481	0.030	0.186	0.953	
4	0.034	0.715	0.499	0.896	0.934	0.827	0.601	0.527	0.282	0.758	**4**
	0.642	0.976	0.896	0.449	0.361	0.777	0.297	0.484	0.949	0.629	
	0.864	0.440	0.059	0.265	0.072	0.879	0.779	0.421	0.657	0.146	
	0.979	0.318	0.153	0.682	0.066	0.806	0.003	0.163	0.249	0.012	
	0.253	0.995	0.678	0.459	0.166	0.223	0.132	0.558	0.377	0.663	
5	0.922	0.764	0.313	0.247	0.330	0.167	0.098	0.416	0.378	0.585	**5**
	0.711	0.516	0.731	0.061	0.387	0.520	0.865	0.596	0.456	0.745	
	0.341	0.350	0.431	0.984	0.583	0.321	0.142	0.508	0.040	0.741	
	A		**B**		**C**		**D**		**E**		

	A		B		C		D		E		
	0.764	0.375	0.774	0.880	0.109	0.349	0.121	0.861	0.612	0.200	
	0.614	0.527	0.172	0.266	0.018	0.374	0.036	0.623	0.341	0.427	
1	0.017	0.694	0.456	0.638	0.812	0.271	0.423	0.329	0.644	0.041	**1**
	0.823	0.132	0.112	0.039	0.319	0.312	0.565	0.634	0.124	0.199	
	0.001	0.938	0.180	0.639	0.207	0.918	0.905	0.490	0.938	0.019	
	0.281	0.761	0.733	0.457	0.424	0.063	0.159	0.247	0.546	0.975	
	0.503	0.360	0.556	0.533	0.829	0.490	0.527	0.286	0.557	0.078	
2	0.689	0.948	0.589	0.816	0.370	0.794	0.913	0.324	0.529	0.041	**2**
	0.260	0.313	0.841	0.771	0.752	0.282	0.669	0.749	0.420	0.451	
	0.204	0.118	0.165	0.209	0.865	0.429	0.366	0.493	0.509	0.945	
	0.546	0.394	0.643	0.855	0.104	0.120	0.201	0.987	0.640	0.240	
	0.230	0.569	0.865	0.696	0.044	0.494	0.030	0.699	0.204	0.105	
3	0.808	0.107	0.645	0.308	0.094	0.288	0.391	0.885	0.069	0.994	**3**
	0.423	0.022	0.370	0.008	0.125	0.774	0.091	0.523	0.700	0.599	
	0.819	0.415	0.405	0.856	0.065	0.079	0.408	0.541	0.723	0.309	
	0.212	0.347	0.045	0.359	0.420	0.422	0.720	0.767	0.983	0.589	
	0.444	0.389	0.427	0.634	0.055	0.337	0.519	0.444	0.644	0.703	
4	0.224	0.571	0.271	0.859	0.636	0.175	0.255	0.080	0.027	0.877	**4**
	0.840	0.401	0.917	0.099	0.600	0.715	0.332	0.335	0.405	0.983	
	0.233	0.580	0.966	0.419	0.092	0.243	0.175	0.179	0.743	0.611	
	0.668	0.678	0.304	0.650	0.646	0.623	0.290	0.246	0.680	0.359	
	0.430	0.392	0.388	0.807	0.455	0.004	0.586	0.442	0.179	0.162	
5	0.309	0.373	0.239	0.392	0.490	0.549	0.773	0.695	0.917	0.797	**5**
	0.681	0.901	0.637	0.195	0.392	0.093	0.091	0.642	0.389	0.492	
	0.134	0.119	0.276	0.503	0.096	0.319	0.135	0.225	0.953	0.169	
	A		**B**		**C**		**D**		**E**		

	A		B		C		D		E		
	0.975	0.023	0.046	0.500	0.806	0.260	0.202	0.319	0.813	0.862	
	0.600	0.130	0.373	0.995	0.048	0.501	0.552	0.519	0.846	0.403	
1	0.536	0.018	0.935	0.372	0.090	0.931	0.311	0.579	0.466	0.979	**1**
	0.567	0.042	0.182	0.483	0.143	0.473	0.838	0.578	0.894	0.070	
	0.956	0.913	0.130	0.915	0.895	0.415	0.558	0.554	0.975	0.636	
	0.348	0.419	0.682	0.262	0.536	0.984	0.886	0.878	0.009	0.877	
	0.141	0.217	0.422	0.261	0.384	0.716	0.326	0.212	0.353	0.610	
2	0.625	0.370	0.164	0.966	0.722	0.236	0.548	0.137	0.851	0.053	**2**
	0.357	0.688	0.676	0.757	0.630	0.527	0.817	0.041	0.235	0.790	
	0.114	0.741	0.129	0.805	0.802	0.800	0.615	0.417	0.741	0.455	
	0.515	0.566	0.935	0.755	0.055	0.412	0.083	0.253	0.174	0.826	
	0.557	0.484	0.163	0.242	0.221	0.150	0.397	0.763	0.868	0.113	
3	0.787	0.758	0.735	0.302	0.391	0.540	0.043	0.991	0.537	0.459	**3**
	0.111	0.507	0.695	0.634	0.251	0.587	0.386	0.533	0.585	0.449	
	0.824	0.682	0.521	0.056	0.088	0.302	0.128	0.562	0.334	0.244	
	0.597	0.828	0.318	0.337	0.736	0.029	0.891	0.709	0.700	0.134	
	0.768	0.644	0.400	0.481	0.528	0.573	0.928	0.824	0.537	0.445	
4	0.778	0.664	0.687	0.607	0.493	0.515	0.269	0.363	0.662	0.947	**4**
	0.833	0.812	0.289	0.346	0.923	0.478	0.941	0.580	0.976	0.509	
	0.635	0.995	0.723	0.558	0.349	0.432	0.155	0.276	0.129	0.326	
	0.880	0.025	0.952	0.801	0.596	0.565	0.407	0.303	0.620	0.153	
	0.624	0.276	0.934	0.715	0.372	0.111	0.823	0.740	0.650	0.676	
5	0.084	0.459	0.616	0.230	0.955	0.787	0.486	0.817	0.420	0.599	**5**
	0.028	0.943	0.707	0.336	0.442	0.751	0.009	0.025	0.406	0.638	
	0.257	0.953	0.580	0.071	0.474	0.137	0.481	0.277	0.533	0.292	
	A		**B**		**C**		**D**		**E**		

	A		B		C		D		E		
	0.772	0.571	0.975	0.511	0.489	0.398	0.089	0.964	0.379	0.313	
	0.838	0.849	0.592	0.814	0.914	0.928	0.438	0.875	0.712	0.507	
1	0.447	0.478	0.176	0.084	0.317	0.169	0.755	0.741	0.821	0.134	**1**
	0.960	0.192	0.970	0.442	0.856	0.621	0.500	0.912	0.814	0.895	
	0.941	0.780	0.393	0.912	0.252	0.713	0.386	0.158	0.941	0.599	
	0.819	0.432	0.555	0.447	0.866	0.737	0.363	0.382	0.615	0.705	
	0.937	0.970	0.331	0.751	0.633	0.711	0.234	0.174	0.518	0.644	
2	0.408	0.983	0.714	0.499	0.782	0.417	0.849	0.013	0.325	0.064	**2**
	0.848	0.718	0.096	0.035	0.021	0.484	0.146	0.233	0.744	0.090	
	0.814	0.540	0.268	0.199	0.913	0.387	0.614	0.335	0.493	0.194	
	0.373	0.229	0.458	0.544	0.138	0.753	0.825	0.441	0.521	0.304	
	0.748	0.235	0.421	0.304	0.568	0.329	0.098	0.348	0.371	0.646	
3	0.365	0.098	0.826	0.053	0.931	0.166	0.835	0.384	0.716	0.951	**3**
	0.711	0.021	0.531	0.549	0.727	0.539	0.111	0.627	0.036	0.867	
	0.111	0.106	0.980	0.418	0.757	0.475	0.157	0.525	0.793	0.326	
	0.171	0.226	0.276	0.734	0.265	0.190	0.452	0.998	0.520	0.857	
	0.749	0.458	0.832	0.004	0.218	0.492	0.375	0.428	0.966	0.285	
4	0.074	0.807	0.868	0.560	0.526	0.077	0.236	0.430	0.861	0.112	**4**
	0.463	0.256	0.120	0.567	0.237	0.012	0.136	0.075	0.617	0.974	
	0.903	0.948	0.531	0.315	0.050	0.839	0.977	0.882	0.196	0.982	
	0.611	0.524	0.293	0.749	0.367	0.958	0.348	0.109	0.780	0.254	
	0.438	0.791	0.982	0.027	0.170	0.127	0.820	0.943	0.075	0.887	
5	0.973	0.410	0.313	0.035	0.949	0.848	0.720	0.672	0.530	0.799	**5**
	0.382	0.458	0.800	0.781	0.242	0.564	0.019	0.139	0.338	0.176	
	0.751	0.263	0.344	0.467	0.941	0.795	0.019	0.880	0.515	0.415	
	A		**B**		**C**		**D**		**E**		

	A		B		C		D		E		
	0.817	0.093	0.254	0.779	0.563	0.409	0.263	0.244	0.026	0.340	
	0.267	0.817	0.444	0.908	0.830	0.238	0.270	0.990	0.287	0.607	
1	0.287	0.574	0.016	0.879	0.159	0.232	0.440	0.553	0.799	0.461	**1**
	0.416	0.330	0.913	0.890	0.426	0.746	0.078	0.374	0.190	0.396	
	0.116	0.197	0.178	0.223	0.794	0.327	0.401	0.499	0.666	0.475	
	0.554	0.784	0.841	0.113	0.606	0.687	0.319	0.268	0.793	0.461	
	0.777	0.671	0.420	0.990	0.215	0.825	0.222	0.591	0.264	0.230	
2	0.215	0.696	0.455	0.127	0.976	0.774	0.761	0.437	0.664	0.164	**2**
	0.174	0.315	0.788	0.300	0.037	0.258	0.464	0.286	0.575	0.581	
	0.262	0.845	0.246	0.789	0.815	0.539	0.766	0.646	0.034	0.860	
	0.372	0.973	0.530	0.319	0.021	0.337	0.755	0.423	0.182	0.877	
	0.696	0.264	0.848	0.895	0.963	0.121	0.620	0.738	0.446	0.657	
3	0.551	0.612	0.469	0.596	0.767	0.900	0.050	0.859	0.210	0.652	**3**
	0.940	0.828	0.328	0.224	0.861	0.612	0.640	0.783	0.952	0.292	
	0.493	0.163	0.854	0.979	0.858	0.562	0.690	0.143	0.796	0.904	
	0.963	0.877	0.075	0.714	0.414	0.351	0.829	0.246	0.447	0.060	
	0.441	0.183	0.880	0.986	0.755	0.034	0.642	0.540	0.393	0.665	
4	0.558	0.228	0.709	0.238	0.572	0.599	0.504	0.971	0.698	0.744	**4**
	0.811	0.758	0.092	0.848	0.312	0.436	0.017	0.438	0.916	0.304	
	0.017	0.260	0.953	0.564	0.947	0.011	0.425	0.468	0.083	0.789	
	0.178	0.881	0.468	0.731	0.604	0.324	0.398	0.753	0.278	0.130	
	0.979	0.811	0.476	0.125	0.423	0.314	0.456	0.090	0.189	0.066	
5	0.057	0.136	0.483	0.100	0.712	0.204	0.372	0.385	0.918	0.405	**5**
	0.717	0.633	0.348	0.744	0.255	0.781	0.443	0.625	0.300	0.705	
	0.305	0.247	0.661	0.493	0.889	0.764	0.577	0.169	0.261	0.398	
	A		**B**		**C**		**D**		**E**		

	A		B		C		D		E		
	0.815	0.125	0.006	0.653	0.614	0.455	0.968	0.103	0.150	0.154	
	0.872	0.226	0.619	0.637	0.585	0.566	0.331	0.028	0.369	0.751	
1	0.685	0.964	0.937	0.948	0.969	0.454	0.194	0.425	0.852	0.500	**1**
	0.427	0.348	0.222	0.129	0.690	0.911	0.996	0.115	0.681	0.569	
	0.181	0.115	0.519	0.715	0.508	0.308	0.525	0.584	0.694	0.427	
	0.917	0.628	0.054	0.928	0.817	0.812	0.264	0.776	0.756	0.610	
	0.759	0.891	0.311	0.612	0.247	0.044	0.668	0.389	0.953	0.931	
2	0.510	0.632	0.371	0.037	0.667	0.681	0.730	0.638	0.965	0.925	**2**
	0.836	0.525	0.342	0.752	0.638	0.403	0.687	0.245	0.403	0.785	
	0.669	0.875	0.824	0.842	0.565	0.756	0.401	0.371	0.576	0.689	
	0.931	0.450	0.955	0.323	0.696	0.790	0.021	0.127	0.753	0.550	
	0.771	0.631	0.896	0.968	0.870	0.312	0.764	0.665	0.113	0.610	
3	0.855	0.525	0.056	0.255	0.921	0.282	0.301	0.401	0.775	0.246	**3**
	0.897	0.753	0.246	0.763	0.259	0.293	0.613	0.154	0.743	0.574	
	0.393	0.878	0.401	0.459	0.134	0.655	0.433	0.323	0.393	0.038	
	0.965	0.130	0.181	0.909	0.940	0.399	0.200	0.724	0.673	0.397	
	0.745	0.233	0.460	0.361	0.935	0.018	0.405	0.945	0.183	0.576	
4	0.204	0.623	0.771	0.120	0.859	0.314	0.880	0.447	0.680	0.938	**4**
	0.804	0.213	0.903	0.488	0.425	0.685	0.584	0.676	0.717	0.220	
	0.526	0.018	0.323	0.978	0.407	0.197	0.827	0.102	0.641	0.302	
	0.620	0.343	0.587	0.878	0.922	0.977	0.162	0.523	0.011	0.409	
	0.558	0.383	0.880	0.541	0.422	0.466	0.186	0.004	0.457	0.446	
5	0.128	0.893	0.685	0.864	0.349	0.413	0.273	0.971	0.970	0.311	**5**
	0.455	0.032	0.141	0.835	0.705	0.898	0.958	0.945	0.095	0.779	
	0.790	0.312	0.258	0.518	0.141	0.448	0.185	0.599	0.546	0.751	
	A		**B**		**C**		**D**		**E**		

	A		B		C		D		E		
	0.982	0.498	0.720	0.906	0.269	0.565	0.296	0.393	0.537	0.124	
	0.636	0.192	0.769	0.017	0.448	0.457	0.458	0.148	0.917	0.987	
1	0.499	0.185	0.016	0.919	0.847	0.967	0.794	0.258	0.641	0.288	**1**
	0.364	0.861	0.261	0.407	0.639	0.643	0.277	0.830	0.989	0.178	
	0.141	0.417	0.721	0.393	0.860	0.021	0.952	0.944	0.606	0.721	
	0.947	0.752	0.693	0.734	0.577	0.119	0.499	0.032	0.834	0.328	
	0.923	0.669	0.770	0.400	0.790	0.700	0.758	0.099	0.198	0.201	
2	0.885	0.025	0.563	0.815	0.063	0.269	0.244	0.711	0.418	0.517	**2**
	0.925	0.002	0.216	0.406	0.812	0.309	0.596	0.883	0.385	0.725	
	0.793	0.877	0.783	0.064	0.047	0.225	0.891	0.588	0.179	0.565	
	0.397	0.152	0.590	0.640	0.534	0.558	0.191	0.466	0.655	0.062	
	0.366	0.478	0.991	0.455	0.152	0.652	0.480	0.136	0.072	0.729	
3	0.537	0.039	0.970	0.382	0.927	0.865	0.663	0.873	0.119	0.835	**3**
	0.211	0.621	0.042	0.023	0.155	0.347	0.124	0.371	0.589	0.016	
	0.103	0.030	0.040	0.042	0.556	0.822	0.376	0.970	0.938	0.386	
	0.773	0.420	0.378	0.039	0.905	0.484	0.544	0.225	0.554	0.459	
	0.543	0.777	0.482	0.921	0.940	0.841	0.738	0.763	0.096	0.528	
4	0.996	0.200	0.554	0.421	0.334	0.556	0.359	0.592	0.237	0.736	**4**
	0.799	0.698	0.399	0.104	0.422	0.949	0.157	0.505	0.772	0.341	
	0.309	0.918	0.954	0.852	0.639	0.035	0.226	0.409	0.116	0.945	
	0.109	0.364	0.613	0.650	0.741	0.248	0.628	0.157	0.318	0.069	
	0.362	0.657	0.943	0.683	0.948	0.675	0.367	0.288	0.914	0.896	
5	0.651	0.328	0.501	0.552	0.218	0.951	0.936	0.198	0.531	0.307	**5**
	0.770	0.936	0.461	0.907	0.282	0.864	0.880	0.444	0.499	0.223	
	0.800	0.658	0.705	0.107	0.561	0.076	0.355	0.604	0.847	0.205	
	A		**B**		**C**		**D**		**E**		

REV NOV 2, 2017

Tennessee Department of Transportation
Division of Materials and Tests

Nuclear Density Testing (SOP 7-1)

Purpose: The purpose of this document is to provide guidance for conducting nuclear density tests on hot mix asphalt, backfill, soil, aggregate base, embankments, and other materials requiring density tests in accordance with SOP 1-1.

Discussion: Many compacted materials on TDOT projects are accepted by means of testing with nuclear density gauges. This document intends to provide guidance and define best practices for operation of these gauges to unify testing operations statewide. Testing details of common concern include proper setup of gauge information, depth of test probes, time length of tests, and recording of data.

Basic Procedure: All test procedures shall be in accordance with AASHTO T310, "*In-Place Density and Moisture Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)"* and ASTM D2950, "*Standard Test Method for Density of Bituminous Concrete In-Place by Nuclear Methods"* except as revised herein.

Specific instructions on conducting standard counts, entering maximum specific gravity values, offsets, correction factors, and proctor information can be found in the users' manuals corresponding to the make and model of the gauge in use.

PART ONE – ACCEPTANCE TESTING

Hot Mix Asphalt

Mixtures: 307-A, 307-B, 307-BM, 307-BM2, 307-C, 307-CW, 411-D, 411-Es

Step 1: Conduct Standard Count

Step 2: Enter maximum specific gravity (Gmm) value from asphalt mix design.

Step 3: Enter gauge correction factor from test strip. See Part Two for determining correction factors. (Note: testing may be done prior to obtaining the correction factor, however all tests done during this time must be corrected as soon as possible and prior to finalizing the records for acceptance or assurance tests.)

Step 4: Set gauge setting to Backscatter.

Step 5: Place gauge in location to be tested.

Footnote 1: For guidance on testing frequencies, random numbers, and selecting test locations, see SOP 1-1.

Step 6: Activate a test. When collecting a density test, the following approach **shall** be used:

- *"Four Nineties" Test:* Four tests shall be conducted at a single location, rotating around the test location 90 degrees at a time, as shown in Figure 1. The four test results will then be averaged to obtain a single test value for that location. Test counts for this approach shall be 15 seconds or longer.

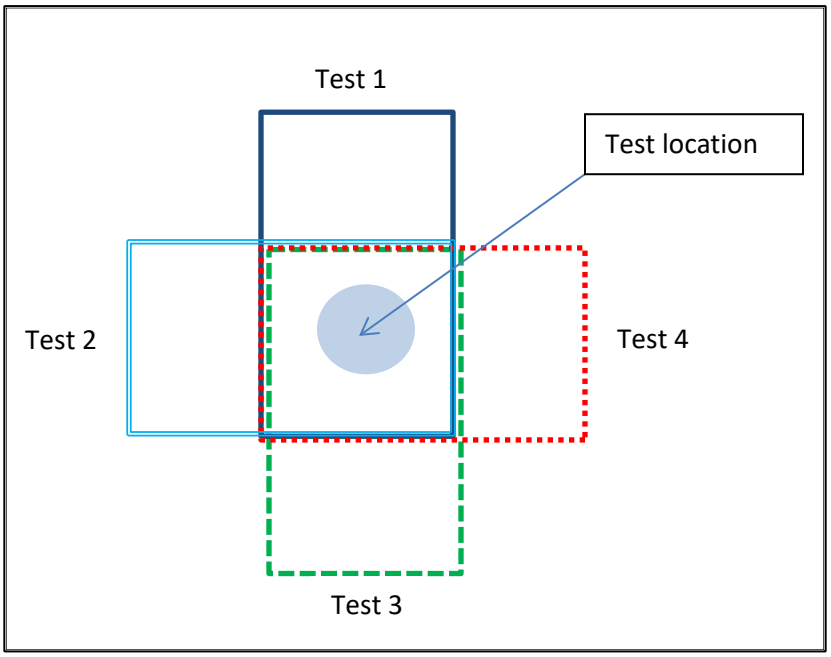


Figure 1. Testing at four 90° locations

Step 7: Record the test value into the appropriate paperwork.

- DT-0315, Daily Asphalt Density Report

Soil and Aggregate Materials

Materials: Backfill (Earth retaining structures), Select granular backfill (Earth retaining structures), Embankments, Subgrade preparation, Lime-treated subgrade, Soil-Cement Base, Mineral Aggregate Base and Surface, Aggregate for Underdrains, Aggregate-Cement base course, Aggregate Lime fly ash base course, & Conditioned mineral aggregate base.

Step 1: Conduct Standard Count

Step 2: Enter maximum dry density and optimum moisture content from Proctor Density report.

Step 3: Select Test location. Create a test hole using the scraper plate and drill rod provided with the gauge.

Footnote 2: For guidance on selecting test locations, see SOP 1-1.

Step 4: Set gauge setting to Direct Transmission at a depth reasonably close to one half the depth of the compacted lift.

Step 5: Place gauge in location to be tested and insert test probe into test hole at a depth reasonably close to one half the depth of the compacted lift. Pull gauge back to ensure probe makes contact with material being tested.

Step 6: Activate a test. When collecting a density test, the following approach shall be used:

Single Count Test: A single test shall be conducted at any test location, given that the test count is greater than or equal to 60 seconds.

Step 7: Record the test value into the appropriate paperwork.

- DT-0298, Daily Report on Soil and Aggregate Stabilization
- DT-0304, Daily Report on Embankment
- DT-0307, Daily Report on Mineral Aggregate Base
- DT-0314, Density Worksheet – Nuclear Method (Aggregate, Soil)

PART TWO – DETERMINATION OF ASPHALT CALIBRATION FACTORS

- Conduct test strips in accordance with most current version of TDOT Standard specifications, subsection 407.15. Nuclear Gauge readings are not valid on Asphalt until the gauge is correlated to the mix and project location. A new test strip shall be required for each project and each mix design used on the project (for mix types that require density testing as noted above). Uncorrelated gauges shall not be used for acceptance or assurance testing.
- Test strips are required for the following mixtures:
  307-A, 307-B, 307-BM, 307-BM2, 307-C, 307-CW, 411-D, 411-Es
- The minimum size of a single test strip is 400 yd^2, but a larger area is recommended. The following roadway lengths provide an area of 400 yd^2 :
  - 9’ wide= 400’ long
  - 10’ wide= 360’ long
  - 11’ wide= 330’ long
  - 12’ wide= 300’ long
- Compaction of the test strip shall commence immediately after placement of the bituminous mixture.
- TDOT form DT-0316, Density and Roller Pattern Test Strip

Step 1: Compact test strip area

Step 2: Layout ten test strip test locations such that the full length and width of the test strip is covered. Mark test location and test number on pavement with spray paint

Step 3: Conduct and record ten sets of uncorrected density (4 90s test method) tests on the compacted test strip area and record test information

Step 4: Cores shall be cut at same locations as nuclear density tests and tested by TDOT Plant Technician for laboratory density in accordance with AASHTO T166. (NOTE: The contractor’s technician shall not conduct this testing)

Footnote 3: Only Method A of T166 shall apply when testing test strip cores for density. Cores shall be COMPLETELY DRY before testing. Accelerated drying in accordance with ASTM D 7227 (core drying device) is permitted.

Step 5: The nuclear gauge correction factor shall be the difference between the average of ten nuclear gauge readings and the average of ten core density values.

Additional notes on test strips and correction factors:

- Nuclear gauges are specific to an individual gauge, mix, and project. DO NOT develop a correction factor with a different gauge unit than the one to be used during mainline acceptance testing.
- Developing correction factors based on cores that were not allowed to dry completely will influence results in a manner that can mislead test results into appearing as if they are higher than they actually are. In other words, wet cores appear heavier or denser than they actually are.
- In accordance with TDOT Specifications, a new test strip is required when:
    - There is a change in job mix formulas
    - A change in the source of materials occurs
    - A change in the material from the same source is observed
    - There is reason to believe that the test strip density is not representative of the mixture being placed. For example, test results are consistently above 100% density or test results have been consistent for a steady number of days and had suddenly changed significantly.
    - A change in paving or compaction equipment occurs.

May 1, 2017
Feb 14, 2018

Tennessee Department of Transportation
Division of Materials and Tests
Standard Operating Procedure 7-2
Nuclear Gauge Safety Plan

Purpose - The purpose of this document is to establish guidelines on nuclear density gauge daily usage, gauge transportation, and outline an Emergency Response Plan for TDOT Radiation Safety Technicians. A TDOT Radiation Safety Technician is an individual who has successfully completed the TDOT Radiation Safety training and demonstrated a basic understanding of: radiation safety and compliance, nuclear density gauge operation, testing procedures, and maintenance.

Background- Tennessee Radioactive Material License No. R-19017-K16 requires that TDOT technicians attend the appropriate training to operate and transport nuclear density gauges. The license also requires TDOT to have a radiation safety emergency response plan.

Each Regional Materials and Tests Office has a regional Radiation Safety Officer (RSO) in the Materials and Tests Office as well as the Statewide RSO in Headquarters Materials and Tests. Each gauge operator is responsible for knowing the current contact information of their regional RSO.

1 Storage Site

1.1 The handle shall be locked and the gauge stored in its transport case.

1.2 The transport case shall be locked.

1.3 The gauge and transport case shall be stored at least 15ft (5 m) from work areas, in a locked closet/storage area in a dry location (indoors).

1.4 The storage area shall be marked with a radiation sign that reads "CAUTION RADIOACTIVE MATERIALS" (can be obtained from HQ RSO).

1.5 Do not store a nuclear gauge in a motor vehicle except:

1.5.1 The nuclear gauge may be stored inside the gauge operator's truck when not in use on a construction site or at a location in transit between the permanent storage site and the project site. With permission of the gauge operator's supervisor, the gauge operator may store the gauge overnight in their truck, provided it is secured per section 4, at a location between the permanent storage site and the project site. In all other cases the gauge operator shall return the gauge to the permanent storage location.

1.5.2 Any time the gauge is stored in the truck it shall be secured for transport per section 4.

1.6 A log of all gauges stored at the site will be maintained at the storage site. All gauges must be checked in when not stored and checked out by the operator when in use.

1.7 Storage site must be enclosed (four walls and a roof) and it must protect gauges from the elements.

1.8 Only nuclear gauges are allowed to be stored inside the storage site. No tools/equipment/debris of any kind is allowed to be place inside the storage site.

2 Inspections:

2.1 Inspect the gauge before use to ensure proper operation of all safety features as follows:

2.1.1 Push the source rod down into the backscatter position, and then raise it back to the SAFE (shielded) position. The source rod opening in the bottom of the gauge is equipped with a spring- loaded tungsten sliding block that shuts when the source rod is in the SAFE position. Turn the gauge over and verify that the sliding block is completely shut.

If any portion of the opening is uncovered, the clean the sliding block before using, transporting, or storing the gauge.

2.1.2 Do not store or transport the gauge unless the sliding block is completely closed. Increased radiation levels may violate transportation regulations and cause excessive personal radiation exposure.

2.1.3 If a radiation survey instrument is available, verify that the radioactive gamma source is in place by measuring the exposure rate at the surface of the gauge. If the exposure rate is not in the approximately range of 10 - 20 mrem per hour contact the regional RSO and discontinue use of the gauge until further notice.

2.2 Biannual Inspection

2.2.1 Gauges shall be leak tested every April and October. The Regional RSO shall conduct a 'swipe' test and submit the sample to the HQ RSO who will submit all samples to the lab for testing. In conjunction with the 'swipe' test, an inventory check must be completed. This means that the gauge must be physically located and accounted for.

3 Operator Certification and Monitoring:

3.1 Anyone operating a nuclear gauge shall be a certified TDOT Radiation Safety Technician.

3.2 The technician must wear their assigned dosimeter while operating or transporting the nuclear gauge. Dosimeter may not be shared between individuals and may only be used by the person who is named on the dosimeter.

3.3 Badges shall be turned in every March, June, September, and December to the regional RSO to be checked for individual exposure.

4 Transporting Nuclear Gauge to Project

4.1 The handle for the gauge shall be locked into the safe position during transport.

4.2 The nuclear gauge shall be locked inside the transport case during transport.

4.3 Transport the nuclear gauge in the rearmost part of the bed of a truck inside either:

4.3.1 a locked bed cover with the device secured in place with heavy chain to prevent the case from moving or

4.3.2 a mounted transportation box, specifically designed for the nuclear gauge case.

4.4 No one other than DOSIMETER BADGE WEARER with HAZMAT TRAINING is allowed in the vehicle while the nuclear gauge is in the vehicle.

4.5 While in transit the following paperwork must be in the vehicle and readily accessible by the driver:

- nuclear gauge bill of lading (BOL),
- operator's nuclear safety certificate,
- nuclear gauge shipping paper,
- TDOT Radiation Safety Plan (SOP 7-2),

4.6 At any time the vehicle is parked while the gauge is stowed for transit, the shipping paper must be place face up in the driver's seat.

5 Operating Nuclear Gauge at the Project

5.1 See SOP 7-1 for instructions on how to calibrate and run tests.

5.2 Only remove the nuclear gauge from the truck when testing is eminent.

5.3 If the gauge is unsecured (i.e. not stored for transport per section 4 or stored per section 1), it shall be in the possession of the operator. The nuclear gauge shall never be left unattended on site.

5.4 If it becomes necessary to move between locations inside the project, lock the handle into the SAFE position and replace the nuclear gauge into the transport case and place in the rear of truck bed. At no time shall the nuclear gauge be placed into the cab of the tuck.

5.4.1 It is not necessary to lock the case and bed cover for short trips inside the project limits

5.5 When the nuclear gauge is in operation all personnel must be a minimum of 30' away from the gauge except if they are wearing a dosimeter badge.

5.6 Once the operator has set the gauge and it is reading, the operator shall walk a minimum distance of 3' away from the gauge.

6 Emergency Response Plan: In the case of accident, damage, loss, or theft of nuclear gauge adhere to the following procedure:

6.1 Priority Response Actions To Be Taken By Gauge Operator

6.1.1 FIRST PRIORITY: Render aid as necessary for lifesaving, first aid, control of fire and other hazards. (Note: Radiation presents minimal risks to lives of persons during transportation accidents. Packages identified as "Type A" by markings on the shipping containers contain only non-life endangering amounts of radioactive materials.)

6.1.2 ADDITIONAL ACTIONS BY GAUGE OPERATOR:

6.1.2.1 Visually inspect gauge for damage, including visual inspection of source rod. Determine if sources are, or can be placed in their shielded positions.

6.1.2.2 Locate sources if separated from the gauge. **DO NOT TOUCH OR MOVE RADIOACTIVE SOURCES.** Locate, mark, and secure but do not pick up with bare hands.

6.1.2.3 Secure Area – Evacuate an area of at least a 15 ft. radius around the damaged gauge and/or radioactive sources. (Note: if a source cannot be located, THEN evacuate and secure an area large enough to include any possible locations where the source might be located. Prevent entry by all unauthorized persons into the evacuated area.

6.1.2.4 If a vehicle or construction equipment is involved in the incident, detain the equipment until it is determined that there is no contamination.

6.1.2.5 As soon as possible after these actions have been accomplished, notify the RSO of the incident.

6.1.2.6 Describe in detail the incident, condition of the gauge, and actions taken. Follow any additional instructions given by the RSO as soon as possible.

6.2 **Response Actions to Be Taken By the Regional RSO**

6.2.1 Give additional advice to gauge operator (if needed).

6.2.2 Notify the police, fire, or other emergency agencies as needed or required.

6.2.3 Notify the HQ RSO

6.2.4 The HQ RSO will notify the Tennessee Department of Environmental Conservation Division of Radiological Health at (615) 532-0364.

6.2.5 The HQ RSO will notify the following as needed or if required:

TEMA
1 (800) 262-3300
Troxler 24-Hour Hazmat Emergency
(919) 549-9539

Humboldt 24-Hour Hazmat Emergency
1 (800) 535-5053
U.S. DOT
1 (800) 424-8802

6.2.6 Travel to the accident site and perform the following:
- 6.2.6.1 Confirm the actions taken by the operator to be correct.
- 6.2.6.2 Conduct a visual inspection of the gauge, shielding, and source rod to determine if radioactive sources are still in the gauge.
- 6.2.6.3 If radioactive sources are found to be missing, or damage to the shielding is suspected:
  - 6.2.6.3.1 Use survey meter to conduct a radiation survey of the gauge to assess the integrity of the source encapsulation and shielding. Compare the survey radiation levels to the gauge radiation profile. If the any reading is greater than the listed values you can suspect that the source shielding has been violated.
  - 6.2.6.3.2 If source(s) are not present in the gauge, perform the necessary surveys to locate and properly secure the source(s). (Note: DO NOT pick up radioactive sources with your hands. Use tongs or pliers to place the source in a properly shielded container. Container may be a source “pig”. The source may also be returned to the gauge shielding if uncompromised.
  - 6.2.6.3.3 Perform a leak test on the gauge and source rod.
  - 6.2.6.3.4 With gauge sources at least 30 feet away, check leak test filters with a survey meter and proceed as follows: If the wipe shows a reading greater than background reading, STOP all other actions. Leave any suspected contaminated material in the secured area and notify the appropriate regulatory agency. Increase the secured area and maintain security until proper authorities arrive.
  - 6.2.6.3.5 If no contamination is found, notify the Regional RSO and request permission to transport the gauge. Once gauge has been approved for transporting, any involved vehicle or equipment may be released and the secure area re-opened.
  - 6.2.6.3.6 Document all actions taken, or not taken, and provide sketches and/or photos.

6.3 **Follow Up Actions Taken By Regional Radiation Safety Officer**
- 6.3.1 Take photos of the damaged gauge prior to shipping for repairs or disposal.
- 6.3.2 Place gauge in secure storage location until approved for shipment to manufacturer if needed.
- 6.3.3 Notify the gauge manufacturer of gauge damage and accident.
- 6.3.4 Send photos of the gauge along with leak test info to the manufacturer for clearance and shipping instructions.
- 6.3.5 Document any actions and instructions given for records.
- 6.3.6 Notify by telephone or mail/email ALL regulatory agencies as required of post-accident corrective actions and safety precautions taken.
- 6.3.7 Ship the damaged gauge to manufacturer per instructions given. (Note: NEVER ship a damaged nuclear gauge until it has been leak tested and the wipe cleared.

6.3.8 Review accident causes and measures taken. Establish new or revised guidelines to prevent similar future occurrences.

407.15 Compaction

A. General

After spreading and striking-off the bituminous mixture and adjusting surface irregularities, thoroughly compact the mixture using methods approved by the Engineer and that are capable of achieving the specified density while the material is in a workable condition. When no density requirements are specified, use a system of compaction for roadway pavements that has previously produced the required bituminous pavement densities. The Engineer may require a control strip and random density samples to evaluate the system.

In general, accomplish compaction using a combination of the equipment specified in **407.07**. As a minimum, meet the following roller requirements, but increase the number of rollers if the required results are not being obtained.

1. Except as noted below, each paving train shall consist of a minimum of three rollers meeting **407.07**. The intermediate roller in each train shall be a pneumatic type. If the surface course contains a latex or polymer additive, the Contractor may use a steel wheel type roller for intermediate rolling instead of a pneumatic type provided the surface course meets density requirements.

2. Provide a minimum of two rollers when placing 307 CS, 411 TL, or 411 TLD mixtures. Perform breakdown rolling, as soon as possible and while the mixture is sufficiently hot, using a pneumatic tire roller having a minimum contact pressure of 85 pounds per square inch. Do not substitute a combination roller for a pneumatic roller when placing CS mix. Regulate the paver speed so rollers can maintain proper compaction of the mixture as determined by the Engineer.

3. With the Engineer's approval, the Contractor may reduce the minimum number of rollers listed above to one roller of either the steel-wheel or vibratory type on the following types of construction and projects:

    a. Shoulder construction,

b. Incidental construction such as bridge approaches and driveways, and

c. Projects containing less than 10,000 square yards of bituminous pavement.

4. Compaction of 411-OGFC mixtures shall consist of a minimum of two passes with a steel double drum asphalt roller with minimum weight of 10 tons, before the material temperature has fallen below 185 °F. Provide a minimum of two roller units so as to accomplish the compaction promptly following the placement of the material. At no time shall a pneumatic tire roller be used or a steel wheel roller be used in vibratory mode. If the roller begins to break the aggregate, immediately stop rolling.

Unless otherwise directed by the Engineer, begin rolling at the low side and proceed longitudinally parallel to the road centerline. When paving in echelon or abutting a previously placed lane, roll the longitudinal joint first, followed by the regular rolling procedure. When paving in echelon, rollers shall not compact within 6 inches of an edge where an adjacent lane is to be placed. Operate rollers at a slow uniform speed with the drive wheels nearer the paver, and keep the rollers as nearly as possible in continuous operation. Continue rolling until all roller marks are eliminated. Do not park rollers on the bituminous pavement.

To prevent adhesion of the mixture to the rollers, keep the wheels properly moistened with water or water mixed with very small quantities of detergent or other approved material. Limit excess use of liquid.

Do not refuel rollers on bituminous pavements.

Along forms, curbs, headers, walls and other places not accessible to the rollers, compact the mixture thoroughly using hot hand tampers, smoothing irons, or with mechanical tampers. On depressed areas, the Contractor may use a trench roller to compact the mix.

B. Density Requirements

Meet the applicable density requirements specified in Tables 407.15-1 to 407.15-4.

Table 407.15-1: Density Requirements for ADT 1,000 or less

Mix Type	% of Maximum Theoretical Density (Average)	No Single Test Less Than, %
A	90	87
B, BM & BM2	90	87
C & CW	90	87
D	90	87
E	90	87

Table 407.15-2: Density Requirements for ADT 1,000 to 3,000

Mix Type	% of Maximum Theoretical Density (Average)	No Single Test Less Than, %
A	91	89
B, BM & BM2	91	89
C & CW	91	89
D	91	89
E	91	89

Table 407.15-3: Density Requirements for ADT 3,000 or greater

Mix Type	% of Maximum Theoretical Density (Average)	No Single Test Less Than, %
A	92	90
B, BM & BM2	92	90
C & CW	92	90
D	92	90
E	92	90

Table 407.15-4: Density Requirements for any ADT

Mix Type	% of Maximum Theoretical Density (Average)	No Single Test Less Than, %
Shoulder Mix (B, BM, BM2, D or E)	88	85
AS and A-CRL	None [1]	None
CS	None [1]	None
TL, TLD, and OGFC	None	None

[1] The Department will waive density requirements on Bituminous Plant Mix Base Grading ACRL, Grading AS and Bituminous Plant Mix Leveling Course, Grading CS; however, the Contractor shall use a system of compaction for roadway pavements that has been approved by the Engineer. When placing Bituminous Plant Mix Base Grading ACRL and Grading AS, the Contractor may replace the specified intermediate roller (pneumatic tire) with a steel-wheel type if irreparable damage to the pavement is occurring.

Correct base or surface course that tests below the minimum density so that the density of the area is equal to or above the minimum, at which point it can be used to determine the average density of the lot. Do not place any successive layers until the area has been corrected. As necessary to determine the classification of open graded or dense graded mixes and to measure segregation, use AASHTO T 269 or ASTM D3203.

Repair or replace defective mixture to the satisfaction of the Engineer and at no cost to the Department.

The Department will perform density testing in accordance with **407.20.B.5**.

C. Test Strips

Construct test strips for all A, B, BM, BM2, C, CW, D, and E mixes to establish rolling patterns, to calibrate nuclear gauges, to verify that the base course or surface course meets the density requirements of the specifications, and for mix design and production verification as required.

Before constructing the test strip, obtain the Engineer's approval of the underlying base or other pavement course. Compact the test strip using equipment as specified in this subsection and **407.07**.

Construct the test strip at the beginning of work on the pavement course. Prepare new test strips when:

1. A change in the JMF is necessary;

2. A change in the source of materials occurs;

3. A change in the material from the same source is observed;

4. There is reason to believe that the test strip density is not representative of the bituminous mixture being placed; and when

5. A change in paving or compaction equipment occurs.

With the approval of the Engineer, the Contractor may construct additional test strips.

Construct each test strip with approved bituminous mixture. The test strip shall remain in place as a section of the completed work. Construct each test strip to be 1 paver width wide, with an area of at least 400 square yards and of the depth specified for the pavement course concerned.

Immediately after placing the bituminous mixture, begin compacting the test strip. Perform compaction in a continuous and uniform manner over the entire test strip.

Continue compacting the test strip until additional roller coverage will produce no appreciable increase in density (1 pound per cubic foot), as measured using a nuclear gauge. Use the roller coverage necessary to obtain this maximum density as the rolling pattern for the remainder of the project.

Take cores on the test strip at ten randomly selected locations as designated by the Engineer. Do not take cores within 2 feet of the longitudinal edges for calibration. Provide these cores to the Department for use in calibrating the nuclear gauge and to verify that

the average density of the test strip meets the density requirements of the specifications. The Department will report all densities using the corrected nuclear gauge readings. Correction factors are specific to the nuclear gauges used during the test strip construction. If a different nuclear gauge needs to be used for acceptance, it will be necessary to cut new cores from the ongoing pavement construction to calibrate the new gauge.

When testing test strip cores, the Department will determine density (bulk specific gravity) in accordance with AASHTO T 166, Method A only. All core samples shall be completely dry before testing. Air drying is permitted provided core samples are weighed at 2-hour intervals until dry in accordance with AASHTO T166, Section 6.1. Cores may also be dried in accordance with ASTM D7227.

If the density of the asphaltic concrete in the test strip does not meet specification requirements, make whatever changes are necessary to obtain the specified density. Use other sources and combinations of aggregates as necessary, subject to the Engineer's approval, to produce a mix meeting the required density.

407.16 Joints

Place bituminous paving as continuously as possible. Do not pass rollers over the unprotected end of a freshly laid mixture unless approved by the Engineer. Form transverse joints by cutting back on the previous run to expose the full depth of the course. Use a brush or sprayed coat of bituminous material on contact surfaces of longitudinal and transverse joints just before placing additional mixture against the previously rolled material.

407.17 Pavement Samples

When directed, cut samples from the compacted pavement for testing by the Engineer. Take samples of the mixture for the full depth of the course at locations selected by the Engineer. Cut the samples with a power saw or core drill. Samples shall have a top surface area of at least 10 inches.

Fill holes left by taking samples with the same type mixture that was used to construct the course sampled, and compact to conform to the surrounding pavement. Cut samples and repair sample holes at no cost to the Department.

a Cold Weather Paving and Compaction Plan. All projects requiring a Cold Weather Paving and Compaction Plan shall utilize Intelligent Compaction to demonstrate proper coverage and compaction temperature at no additional cost to the Department; with the exception of small quantity projects, such as, but not limited to, bridge approaches, intersections, and temporary traffic shifts. Upon completion, the documentation showing appropriate coverage and compaction temperature shall be provided to the Department. Submit requests in writing at least one week before the anticipated need, and include a Paving and Compaction Plan for Cold Weather that meets the Department's Procedure. The plan shall identify what practices and precautions the Contractor intends to use to ensure the mixture is placed and compacted to meet the specifications. The plan shall include compaction cooling curves estimating the time available for compaction, the intended production, haul, and compaction rates, with paver and roller speeds estimated. The Contractor may consider using such practices as the addition of rollers, reduced production and paving rates, insulated truck beds, and heating the existing surface.

In no cases will a cold weather paving and compaction plan or seasonal limitation waiver be approved for 411-OGFC, 411-TL, or 411-TLD.

If the specified densities are not obtained, stop all paving operations and develop a new plan. All mixture failing to meet specifications will be subject to price adjustments or removal and replacement at no cost to the Department.

Subsection 407.11 (pg. 332) 12-2-16; Add the following to the paragraph below Table 407.11-1:

"Minimum temperature for OGFC mixes shall be 280º."

Subsection 407.15, C. Test Strips. (pg. 340-341) 11-16-15; Add the following paragraph after the 7th paragraph of the subsection:

"Take an additional 3 cores after placement of the surface layer on the tack coat test strip described in subsection **403.05.B**. Include the underlying pavement layer for shear testing. These cores will be for informational testing only. Not required for mats less than one inch thick"

Subsection 407.15 (pg. 341) 6-27-16; remove the 2nd sentence of the 8th paragraph:

"Take cores on the test strip at ten randomly selected locations as designated by the Engineer. Provide these cores to the Department for use in calibrating the nuclear gauge and to verify that the average density of the test strip meets the density requirements of the specifications. The Department will report all densities using the corrected nuclear gauge readings. Correction factors are specific to the nuclear gauges used during the test strip construction. If a different nuclear gauge needs to be used for acceptance, it will be necessary to cut new cores from the ongoing pavement construction to calibrate the new gauge."

Subsection 407.15 (pg. 341) 12-2-16; remove "randomly selected" from 1st sentence of the 8th paragraph as follows:

"Take cores on the test strip at ten locations as designated by the Engineer."

Subsection 407.15 A. 3. c. (pg. 337-338) 5-15-17; update 10,000 square yards to 1,000 tons:

STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION
DIVISION OF MATERIALS AND TESTS
6601 CENTENNIAL BLVD.
NASHVILLE, TENNESSEE 37243-0360

DENSITY WORKSHEET - NUCLEAR METHOD

Project Reference No. _____ Date _____
Project No. _____ County _____ Region _____
Nuclear gauge no. _____ Contract No. _____
Item Number _____

Lot No.					
Test No.					
Station					
Offset (ft.)					
Feet Below Grade					
Thickness					
Moisture Standard Count					
Moisture Count					
Moisture Count Ratio					
Probe Depth					
Density Standard Count					
Density Count					
Density Count Ratio					
Unit Weight Wet (pcf)					
Moisture (pcf)					
Unit Weight Dry (pcf)					
Percent Moisture					
Cut Station					
Sample Number					
Proctor Density (pcf)					
Optimum Moisture, %					
Dry Weight of +4 Material					
Dry Weight of Total Material					
Percent +4 Material					
Sp. Gravity of +4 Material					
Corrected Proctor Density					
Corrected Optimum Moisture					
Percent Compaction					

Signature _____
Title _____

STATE OF TENNESSEE
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NASHVILLE, TENNESSEE 37243-0360

Item No. _____ Grading _____

Report No. _____ ASPHALT DENSITY REPORT Date _____

Contract No. _____

Project Reference No. _____ County _____ Region _____

Project No. _____ Contractor _____

Gauge No.	Standard Count	Theoretical or Laboratory Density	Core Correction	Percent Required Density
		5.0		

Lot No. _____ From Sta. _____ To Sta. _____ Lin. M (ft.) _____ Width _____ Lift _____ Lane _____

Date	Test No	Sta No	Location	Den. Test 1	Den. Test 2	Den. Test 3	Den. Test 4	Avg	Corrected Density	Density (%)
			1' From Left							
			Left Wheel							
			Center							
			Right Wheel							
			1' From Right							

Tons in Lot _____ Mix Running Total _____

Lot No. _____ From Sta. _____ To Sta. _____ Lin. M (ft.) _____ Width _____ Lift _____ Lane _____

Date	Test No	Sta No	Location	Den. Test 1	Den. Test 2	Den. Test 3	Den. Test 4	Avg	Corrected Density	Density (%)
			1' From Left							
			Left Wheel							
			Center							
			Right Wheel							
			1' From Right							

Tons in Lot Mix Running Total

Lot No. _____ From Sta. _____ To Sta. _____ Lin. M (ft.) _____ Width _____ Lift _____ Lane _____

Date	Test No	Sta No	Location	Den. Test 1	Den. Test 2	Den. Test 3	Den. Test 4	Avg	Corrected Density	Density (%)
			1' From Left							
			Left Wheel							
			Center							
			Right Wheel							
			1' From Right							

Tons in Lot _____ Mix Running Total _____

Remarks:

lb/yd^2 (kg/yd^2) _____	
Lot No.	Avg. % Density

Original to:
Headquarters Materials and Tests
Copies to:
Regional Materials and Tests
Project Supervisor
Form DT-0315 (Rev. 07-17)

Signature _____

Title _____

STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION
DIVISION OF MATERIALS AND TESTS
6601 CENTENNIAL BLVD.
NASHVILLE, TENNESSEE 37243-0360

DAILY REPORT ON SOIL AND AGGREGATE STABILIZATION

Date _____

Project Reference No. _____ County _____ Region _____

Project No. _____ Contract No. _____

Report No. _____ Contractor _____

Producer _____ Producer Location _____

Item Numbers _____ Temp. Max _____ ^{O}F Min. _____ ^{O}F

Type of Construction _____ Type of Mixing _____

Percent Cement Design _____ Design Depth _____ Average Depth _____

Lbs./Square Yd. Cement Design _____ Lbs./Square Yd. Cement Used _____

From Station _____ To Station _____ Excluding Stations _____

Linear Feet _____ Width _____ Square Yards _____

Tons of Cement _____ Tons of Aggregate Delivered _____

Quantity (moisture in excess of 3% of optimum moisture content has been deducted): _____ Tons

SCREEN ANALYSIS

Percent Passing Square Sieves

3"	2-1/2"	2"	1-1/2"	1"	3/4"	1/2"	3/8"	4	8	16	40	100	200	% Moisture at Plant

COMPACTION DATA

Lot No.	No. of Tests	STATION		Lane	Lift	Test Depth	Field Density	Theoretical Density	Optimum Moisture	Ave. Percent Theoretical Density
		From	To							

Remarks:

Original to:
Headquarters Materials and Tests
Copies to:
Regional Materials and Tests
Project Supervisor
Form DT-0298 (Rev. 11-12)

Approved:

_____ Project Supervisor

_____ Project Inspector

Original to:
Headquarters Materials and Tests
Copies to:
Regional Materials and Tests
Project Supervisor
Form DT-0304 (Rev. 08-17)

STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION
DIVISION OF MATERIALS AND TESTS
6601 CENTENNIAL BLVD.
NASHVILLE, TENNESSEE 37243-0360

FIELD DENSITY REPORT ON SOILS OR AGGREGATES

Type of Material _____

Project Reference No. _____
Project No. _____ Contract No. _____
Contractor _____ Density Report No. _____ Region _____
Subcontractor _____ County _____

FIELD TESTS							INFORMATION FROM EMBANKMENT FORM DT-0332			Percent Proctor Density DT-0314
Date	Test No.	Station	Offset	Feet Below Grade	Percent Moisture	Field Density	Lab Serial **OR** Report Number	Optimum Moisture	Proctor Density	
RETEST AFTER WORKING AREA THAT FAILED										

Remarks:

Approved by _____
Project Supervisor

_____
Project Inspector

STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION
DIVISION OF MATERIALS AND TESTS

6601 CENTENNIAL BLVD.
NASHVILLE, TENNESSEE 37243-0360

Item No. _____ DAILY REPORT ON MINERAL AGGREGATE BASE Date _____

Contract No. _____

Report No. _____ County _____ Region _____

Project Reference No. _____

Project No. _____

From Sta. _____ To Sta. _____ Lin M (ft.) _____ Width _____ Lift _____ Lane _____

m^2 _____ Method of Mixing _____ Type _____ Class _____ Grading _____

Contractor _____ Producer and Location _____

Tons of Aggregate Delivered _____ Tonnes (Tons)

Quantity (moisture in excess of 3% of optimum moisture content has been deducted): _____ Tonnes (Tons)

SCREEN ANALYSIS

Percent Passing Square Sieve

75.0 mm 3"	63.0 mm 2.5"	50.0 mm 2"	37.5 mm 1.5"	25.0 mm 1"	19.0 mm 3/4"	12.5 mm 1/2"	9.5 mm 3/8"	4.75 mm #4	2.36 mm #8	1.18 mm #16	0.425 mm #40	0.15 mm #100	0.075 mm #200	% Moisture at Plant

Sampled from _____ Signature _____

Title _____

COMPACTION DATA

Lot No.	No. of Tests	Station		Lane	Lift	Test Depth	Theoretical Density	Average Field Density	Average % Theoretical
		From	To						

Remarks:

Original to:
Headquarters Materials and Tests
Copies to:
Regional Materials and Tests
Project Supervisor
Form DT-0307 (Rev. 11-12)

Signature _____

Title _____

Approved _____