WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
MATERIALS CONTROL, SOILS AND TESTING DIVISION

MATERIALS PROCEDURE

NUCLEAR DENSITY TEST BY THE ROLLER PASS METHOD

1.0 PURPOSE

1.1 The purpose of this procedure is to determine the density of construction materials by the roller pass method. The procedure consists of two parts, with Part I to determine the required maximum density and Part II to compare field densities to the required maximum density.

2.0 SCOPE

2.1 This method of test is applicable to treated and untreated aggregate base courses, select backfill, crushed aggregate backfill, granular subgrade, and random material having 40 percent or more of +19 mm material as specified in MP 717.04.21.

3.0 REFERENCES

MP 717.04.21
MP 712.21.26

4.0 EQUIPMENT

4.1 One complete nuclear density gauge unit meeting the requirements specified in MP 717.04.21. This would include the manufacturer's print-out of standard counts.

4.2 One measuring tape (should be a minimum of 20 m)

4.3 Lime or other suitable material to mark test sites

4.4 Dry silica sand

4.5 Supply of data sheets

4.6 One vehicle meeting the safety and security requirements of the Nuclear Regulatory Commission for transporting the nuclear gauge

4.7 Rapid response thermometer (for hot-laid bituminous base items)

5.0 PERSONNEL TRAINING

5.1 All personnel performing the testing must meet the minimum training requirements specified in MP 717.04.21.

5.2 All personnel must know and follow the requirements of the Nuclear Regulatory Commission.

6.0 ROUNDING OF DATA

6.1 Test values and calculations are to be rounded according to the following procedure:

6.1.1 If the figure following the last significant number to be retained is larger than five, increase the last significant number to be retained by one.

6.1.2 If the figure following the last significant number to be retained is five and there are no figures beyond five except zeros, the last significant number to be retained is increased by one if odd, or left unchanged if even.

6.1.3 If the figure following the last significant number to be retained is five and there are figures following the five, the last significant number to be retained is increased by one.

6.1.4 If the figure following the last significant number to be retained is less than five, the last significant number is left unchanged.

6.2 Test values and calculations shall be rounded to the following nearest significant digit.

6.2.1 Test Section

Lift Thickness Compacted:	10 mm
Depth Below Grade:	0.25 m
Length Of Test Section:	1 m
Width Of Test Section:	0.1 m
Station Number:	0.25 m
Offset:	0.25 m
Wet Density (DA):	1 kg/m^3
Dry Density (DB):	1 kg/m^3
Mat Temperature:	1°C
Average Density (DC):	1 kg/m^3
Maximum Density (DD):	1 kg/m^3

6.2.2 Quality Control Tests

Station Number:	0.25 m
Offset:	0.25 m
Depth Below Grade:	0.25 m
Lift Thickness Compacted:	10 mm
Maximum Density (DD):	1 kg/m^3
Wet Density (DE):	1 kg/m^3
Dry Density (DF):	1 kg/m^3
Relative Density (DG):	1%
Average DG (X):	0.1%
Target (T):	1%
Quality Index (QL):	0.01
Within Tolerance (DH):	1%
Minimum Percent For 100% Pay (DI):	1%
Mat Temperature:	1°C

7.0 PREPARATION FOR TESTING

7.1 Standardization of the nuclear gauge

7.1.1 Warm up the gauge for a minimum of 20 minutes.

7.1.2 Standardization of the gauge must be performed away from metal and other objects.

7.1.3 Clean the top of the standard block and the bottom of the gauge with a cloth.

7.1.4 Place the gauge on the standard block with the gauge turned the correct way. For the Troxler 3411 gauge, the scaler end of the gauge must be tight against the standard block flange.

7.1.5 Make the necessary adjustments on the gauge for standardization. Take a 4 minute count for density and moisture. The standard count for moisture does not have to be recorded or meet the tolerance in 7.1.6 if the gauge is to be used to test bituminous materials.

7.1.6 Compare the standard counts to the manufacturer's standard counts using tolerances acceptable to the Division. For the Troxler 3411 gauge, the standard counts must be within ±2 percent for density and ±4 percent for moisture from the manufacturer's standards.

7.1.7 If the gauge is not within the specified tolerances for either moisture or density, repeat Sections 7.1.5 - 7.1.6. If the gauge will not standardize for either moisture or density after 4 attempts, there is probably something wrong with the gauge. There may be electronics problems, the gauge needs calibrated, or a stability check needs to be performed. Refer to MP 717.04.21 for a more detailed explanation. In any case, do not use a gauge for testing that will not standardize.

7.1.8 When a gauge is to be used for testing pipe or structure backfill in a trench, first check the standardization of the gauge according to Sections 7.1.3 - 7.1.6. If the gauge is functioning properly, standardize the gauge in the trench. The standard counts in the trench are used for testing in the trench only and the tolerances are not applicable to the standard counts taken in the trench. When the gauge is moved to a non-trench condition for testing, new standard counts are required.

7.1.9 A gauge must be standardized before testing and at least every 4 hours during testing.

8.0 PART I PROCEDURE FOR DETERMINING THE MAXIMUM DENSITY

8.1 All data and calculations for Part I of this procedure will be recorded on the attached form. Record the project number, lab number, etc. before starting the test.

8.2 The test is to be performed at the beginning of placement of an item. However, any problems with the material, placement or compaction equipment shall be corrected prior to performing the test.

8.3 The test section will be 30 m long by the width being placed in one operation except in restricted areas.

8.3.1 In restricted areas where the 30 m length can not be obtained, check the project's records to determine if a maximum density for the material has been determined on the project. The maximum density shall be used for Part II of this procedure, if available. However, a maximum density determined in a restricted area shall not be used in a non-restricted area. If a maximum density is not available for the material, obtain as large a test section as possible. For pipe backfill a lift on both sides of the pipe can be used.

8.4 Divide the test section into 5 equal subsections and number the test sections. Randomly locate a test site within each of the subsections according to MP 712.21.26.

8.5 Water shall be added to untreated aggregates, if necessary, in a quantity satisfactory to the Engineer. The aggregate must visually appear wet in order to properly compact.

8.6 Once the material has been placed in the test section, the material shall be rolled with compaction equipment meeting the following requirements:

8.6.1 All compaction equipment must be in good working condition.

8.6.2 The materials shall be compacted with rollers providing a minimum mass of 9.07 Mg.

8.6.3 In restricted areas inaccessible to conventional rollers, the compaction equipment must be satisfactory to the Engineer to provide the desired compactive effort.

8.6.4 The Division may request verification that the above compaction equipment meets the specified requirements.

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8.5 Water shall be added to untreated aggregates, if necessary, in a quantity satisfactory to the Engineer. The aggregate must visually appear wet in order to properly compact.

8.6 Once the material has been placed in the test section, the material shall be rolled with compaction equipment meeting the following requirements:

8.6.1 All compaction equipment must be in good working condition.

8.6.2 The materials shall be compacted with rollers providing a minimum applied force of .907 Mg.

8.6.3 In restricted areas inaccessible to conventional rollers, the compaction equipment must be satisfactory to the Engineer to provide the desired compactive effort.

8.6.4 The Division may request verification that the above compaction equipment meets the specified requirements.

8.7 For hot-laid bituminous base courses a temperature measurement will be taken and recorded on the form during each rolling sequence. The test section must be rolled before the temperature falls below the minimum specification requirements. If the Contractor finds that the temperature will reach the minimum specification requirements before final rolling is completed, stop the test procedure, and roll the area to achieve compaction. Establish a new test section and make adjustments, such as adding additional rollers etc., so that the test can be completed within the temperature requirements. If the temperature requirements still can not be met, the Division should evaluate the situation.

8.8 The test section shall be rolled with 12 roller passes. A roller pass is one complete coverage over the material. In restricted areas, where conventional rollers can not be used, the material shall be compacted until it appears well densified.

8.9 If the material shears or shoves during rolling, the number of roller passes may need to be reduced. The designated number of roller passes must not be changed without the approval of the Engineer.

8.10 Once the material has been rolled, testing will be performed on test Site Numbers 1 and 2.

8.11 The method of test will depend on the type material being placed. Record only the density (wet or dry) that applies to the material being tested.

8.11.1 Bituminous base courses

8.11.1.1 Check the test site to determine if the surface is smooth. Voids in the surface would be filled with silica sand. Avoid a build-up of fines on the surface (no more than 3 mm).

8.11.1.2 Place the gauge on the test site and take a one minute density reading with the source in the backscatter position. The gauge must be sitting flush on the material. Mark the test site with lime or other suitable material.

8.11.1.3 Record the wet density (DA) in Section A on the form. Perform the same testing on Site 2.

8.11.2 All materials except bituminous base course

8.11.2.1 Smooth the test site and fill any voids with fines scraped from the surface. Avoid a build-up of fines on the surface (no more than 3 mm).

8.11.2.2 Place the guide plate on the test site. Next, place the drive rod in the plate guide and while standing on the plate, drive the rod at least 50 mm deeper than the location where the end of the gauge source rod will be when testing. The gauge source rod can be extended in 50 mm increments. The source rod must be as deep as possible within the lift but must not extend beyond the lift. For example, a 125 mm lift would be tested with the source rod in the 100 mm position and the hole would be 150 mm deep. Carefully remove the drive rod to prevent material from falling into the hole.

8.11.2.3 Place the gauge over the test site and insert the source rod to the desired depth. Pull the gauge tight against the side of the hole toward the scaler. Make sure the gauge is sitting flush on the material. Mark the outline of the gauge with lime or other suitable material so the test sites can be relocated.

8.11.2.4 Take a one minute density and moisture reading.

8.11.2.5 Record the dry density (DB) in Section A of the form. Perform the same testing on Site 2.

8.12 Average the two wet densities (DC) obtained in 8.11.1.3 or the two dry densities obtained in 8.11.2.5.

8.13 Roll the material in the Test Section 2 additional roller passes. In restricted areas, the compaction equipment would pass over the material the above indicated number of passes.

8.14 After the material has been rolled the additional number of passes, perform tests again on Sites 1 and 2 according to 8.11.1 through 8.11.1.2 or 8.11.2 through 8.11.2.4 and record the values in Section B.

8.15 Average the two densities according to 8.12.

8.16 Compare the value in 8.15 to the value obtained in 8.12. If the increase in density is 16 kg/m³ or less, the material is considered to have achieved its maximum density. If the increase in density is greater than 16 kg/m³, roll the material additional passes according to 8.13 and repeat the testing on Sites 1 and 2. Continue the rolling and testing sequence until the increase in density between two consecutive rolling sequences is 16 kg/m³ or less. The Division may request the Contractor to cease rolling even though the increase is more than 16 kg/m³ if the material is breaking down.

8.17 Once the increase in density is 16 kg/m³ or less, move the last two density readings to the maximum density determination section on the form. Then take density measurements on Sites 3, 4, and 5.

8.18 Average the five density readings and the average (DD) is the maximum density for the material.

8.19 The maximum density will be used to control the material for Part II of this procedure.

9.0 PART II QUALITY CONTROL TESTING

9.1 All test data and calculations for Part II of this procedure will be recorded on the attached form for quality control tests. Record the project number, item number, etc. on the form before starting the testing.

9.2 The lot number would have a prefix letter based on the following designations for the use of the material being tested.

Embankment	F
Subgrade	S
Base	B
Pipe and Structure Backfill	P

9.3 Transfer the maximum density (DD) and the lab number from the test section form to the quality control form. Record the lab number in the section for reference lab number.

9.4 Randomly locate the test site according to MP 712.21.26.

9.5 Mat temperature measurements for hot-laid bituminous base course items would be taken at the frequency specified in MP 717.04.21. The values would be recorded on the form.

9.6 The method of test will depend on the material being tested. Record only the density (wet or dry) that applies to the material being tested.

9.6.1 Bituminous base course material

9.6.1.1 Determine the wet density with the nuclear gauge according to the procedure described in Sections 8.11.1 through 8.11.1.2. The test sites do not have to be marked on the roadway. Record the wet density (DE) in the section for Test Number One.

9.6.2 All other materials

9.6.2.1 Determine the dry density (DF) with the nuclear gauge according to the procedure described in sections 8.11.2 through 8.11.2.3. The test sites do not have to be marked on the roadway.

9.7 Calculate the percent relative density (DG) by using the equation on the form.

9.8 Perform the remaining four tests in the lot. Five tests are always required to evaluate a lot.

9.9 Calculate the average relative density (X) for the five tests in the lot.

9.10 Obtain the target percentage of dry density (T) from the project's governing specifications.

9.11 Determine the range (R) of the relative densities (DG) by subtracting the smallest value from the largest.

9.12 Calculate the quality index (QL) by using the equation on the form.

9.13 Enter the table for estimating the percent of a lot within tolerance (copy attached). Determine the percent within tolerance (DH) which corresponds to the QL value calculated in 9.12 above.

9.14 Obtain the minimum percent for 100 percent pay (DI) from the project's governing specifications.

9.15 In order for a lot to meet specifications, the percent within tolerance (DH) must be equal to or greater than the minimum percent for 100 percent pay (DI).

10.0 GENERAL

10.1 Independent tests for similarity checks can be recorded on the quality control data form. Use only the applicable sections of the form.

10.2 If the material changes or the material is supplied from a new source, repeat Part I to obtain new control data.

10.3 If the percent relative densities are consistently above 105 percent or below 95 percent, and there is no apparent cause for the high or low values, repeat Part I to obtain new control data.

10.4 Division personnel may request that Part I be repeated if the test was not performed properly or the maximum density obtained does not appear to be realistic.

10.5 Test data for several lots can be recorded on the quality control data form, however, only lots completed during one day can be recorded on the same form.

Gary L. Robson, Director
Materials Control, Soils
and Testing Division

GLR:Srab

Attachments

WEST VIRGINIA ACCEPTANCE PLAN "A"

TABLE FOR ESTIMATING PERCENT OF LOT WITHIN TOLERANCE FROM MP 106.00.20 FOR 5 TEST VALUES

Quality Index (QL) Positive Values	Percent Within Tolerance	Quality Index (QL) Negative Values	Percent Within Tolerance
.66	99	00	50
.65	98		49
.62	97		48
.60	96		47
.58	95		46
.57	94	.06	45
.55	93		44
.53	92		43
.51	91		42
.50	90		41
.48	89	.11	40
.46	88	.13	39
.45	87	.14	38
.44	86	.15	37
.42	85	.16	36
.41	84	.17	35
.40	83	.18	34
.38	82	.19	33
.37	81	.21	32
.36	80	.22	31
.34	79	.23	30
.33	78	.24	29
.32	77	.25	28
.30	76	.27	27
.29	75	.28	26
.28	74	.29	25
.27	73	.30	24
.25	72	.32	23
.24	71	.33	22
.23	70	.34	21
.22	69	.36	20
.21	68	.37	19
.19	67	.38	18
.18	66	.40	17
.17	65	.41	16
.16	64	.42	15
.15	63	.44	14
.14	62	.45	13
.13	61	.46	12
.11	60	.48	11
	59	.50	10
	58	.51	9
	57	.53	8
	56	.55	7
.06	55	.57	6
	54	.58	5
	53	.60	4
	52	.62	3
	51	.63	2
0	50	.66	1

West Virginia Division of Highways

Materials Control Soil and Testing Div.

FORM ST-10

Lab. Number _____

Project Number _____

District Number _____

Item Number _____

Date _____

Source of Material				Length of Test Section		
Roller Type				Width of Test Section		
Roller Weight	Static	Working		Manufacturer's Standards		
Lift Thickness Compacted				Density	Moisture	
Depth Below Grade				Standard Counts		
Observed	Yes	No		Density	Moisture	
Depth of Gauge Source						
Test Site Number	1	2	3	4	5	
Station Number						
Offset						

A	Number of Passes			
Mat Temperature				
Test Site	DA	Wet Density	DB	Dry Density
1				
2				
DC	Average			

B	Number of Passes			
Mat Temperature				
Test Site	DA	Wet Density	DB	Dry Density
1				
2				
DC	Average			

C	Number of Passes			
Mat Temperature				
Test Site	DA	Wet Density	DB	Dry Density
1				
2				
DC	Average			

D	Number of Passes			
Mat Temperature				
Test Site	DA	Wet Density	DB	Dry Density
1				
2				
DC	Average			

$DC = \frac{\Sigma DA}{2}$ or $\frac{\Sigma DB}{2}$

$DD = \frac{\Sigma DA}{5}$ or $\frac{\Sigma DB}{5}$

Maximum Density Determination				
Test Site	DA	Wet Density	DB	Dry Density
1				
2				
3				
4				
5				
DD	Max Density			

Technician's Signature _____

Project's Evaluation	
Checked by	Date

WEST VIRGINIA DIVISION OF HIGHWAYS
MATERIALS CONTROL, SOILS AND TESTING DIVISION

LAB NUMBER: _____ MP 700.00.24
PROJECT NUMBER: _____
DISTRICT NUMBER: _____
ITEM NUMBER: _____
DATE: _____

GAUGE NO.	LOT NUMBER							
MANUFACTURER'S DENSITY STD. COUNT	BEGINNING STATION	m						
	ENDING STATION	m						
	OFFSET	m						
MANUFACTURER'S MOISTURE STD. COUNT	DEPTH BELOW GRADE	mm						
	DEPTH GAUGE SOURCE	mm						
	LIFT THICKNESS COMP.	mm						
DD FROM TEST SECTION	DENSITY STANDARD							
	MOISTURE STANDARD							

$DG = \frac{DE \text{ OR } DF\ (100)}{DD}$

$\bar{X} = \frac{AVE.\ DG}{5}$

$QL = \frac{\bar{X} - T}{R}$

DD	MAXIMUM DENSITY	kg/m ^{3}						
	REFERENCE LAB NO.							
TEST NUMBER 1	DE	WET DENSITY	kg/m ^{3}					
	DF	DRY DENSITY	kg/m ^{3}					
	DG	RELATIVE DENSITY						
TEST NUMBER 2	DE	WET DENSITY	kg/m ^{3}					
	DF	DRY DENSITY	kg/m ^{3}					
	DG	RELATIVE DENSITY						
TEST NUMBER 3	DE	WET DENSITY	kg/m ^{3}					
	DF	DRY DENSITY	kg/m ^{3}					
	DG	RELATIVE DENSITY						
TEST NUMBER 4	DE	WET DENSITY	kg/m ^{3}					
	DF	DRY DENSITY	kg/m ^{3}					
	DG	RELATIVE DENSITY						
TEST NUMBER 5	DE	WET DENSITY	kg/m ^{3}					
	DF	DRY DENSITY	kg/m ^{3}					
	DG	RELATIVE DENSITY						
LOT EVALUATION	$\bar{X}$	AVERAGE DG	%					
	T	TARGET	%					
	QL	QUALITY INDEX						
	DH	WITHIN TOLERANCE	%					
	DI	MIN. FOR 100% PAY	%					
	DJ	PASS / FAIL						

MAT TEMP.	TIME	MAT TEMP.	TIME	
				TECHNICIAN'S SIGNATURE. _____
				PROJECT'S EVALUATION
				CHECKED BY: DATE: