Procedure for Moisture Content Determination for Soils and Aggregate

---

1. Scope:

This test is for determining the moisture content of soils and aggregates by gas pressure, drying on a stove or hot plate, drying in a convection or microwave oven, and the nuclear method of in-place moisture tests.

2. Apparatus:

2.1 Calcium carbide gas pressure moisture tester method.

A. A calcium carbide gas pressure moisture (Speedy) tester.

B. Tared scale.

C. Two 1 1/4 " steel balls.

D. Cleaning brush and cloth.

E. Calcium carbide reagent.

F. Two 13 gram weights.

G. Reagent scoop.

2.2 Stove top or hot plate method.

A. Stove or hot plate.

B. Steel plate(s), approximately ¼" thick to place between the burner(s) and the sample pan.

C. Pan of sufficient size to contain the material and allow room for stirring without loss of material.

D. Spoon or trowel for stirring the material during the drying process.

E. Scale or balance having the capacity to weigh any sample which may be tested utilizing this procedure and readable to the nearest 0.1 gram.

F. Gloves.

2.3 Oven drying method.

A. Drying oven – Thermostatically controlled, preferably of the convection forced-draft type, capable of being heated continuously at a uniform temperature of 230º ± 9ºF throughout the drying chamber.

B. Scale or balance having the capacity to weigh any sample which may be tested utilizing this procedure and readable to the nearest 0.1 gram.

C. Pan of sufficient size to contain the material and allow room for stirring without loss of material.

D. Stirring spoon or trowel.

E. Gloves.

2.4 Nuclear method – In-place moisture test.

A. A nuclear moisture/density gauge capable of determining moisture/densities by the direct transmission method and conforming to the requirements of AASHTO T 310.

B. A reference standard block for taking standard counts.

C. A drill rod, extraction tool and combination guide-scraper plate for preparing the test site and punching the hole for the source rod.

D. A manufacture's instruction manual for the nuclear gauge.

E. A nuclear gauge Information book, transportation documents book, nuclear badge, and metal storage box.

F. A hammer to drive the drill rod, and a shovel and other tools for site preparation.

2.5 Microwave oven method.

A. Microwave oven with vented chamber, variable power controls and output power rating of 1000 watts is adequate. 16

B. Scale or balance having the capacity to weigh any sample which may be tested utilizing this procedure and readable to the nearest 0.1 gram.

C. Containers (Must be suitable for microwave ovens-i.e., nonmetallic and resistant to sudden and extreme temperature change; porcelain, or glass).

D. Glove or holder for handling hot containers.

E. Spatulas, putty knives and glass rods.

3. Procedure:

3.1 Calcium carbide gas pressure method.

A. Place 3 scoops of calcium carbide and two 1 1/4" steel balls in the chamber of the moisture tester.

The shelf life of calcium carbide reagent is limited, thus it should be used according to the manufacturer's recommendations.

B. Using the tared scale, weigh 26 g sample. If the moisture content of the 26 g sample exceeds the limit of the pressure gauge (20%), a one half sized sample must be used. The percentage indicated on the dial is then doubled. Larger samples can be used for low moisture contents (5% or less).

Two or more 26 g samples can be placed in the "CCGP" moisture tester and the resulting dial reading is divided by the number of 26 g samples used.

NOTE: This method shall not be used on granular materials having particles large enough to affect the accuracy of the test. In general, any appreciable amount retained on a #4 sieve.

C. Place the soil sample in the cap. With the pressure vessel in a horizontal position, insert the cap in the pressure vessel and tighten the clamp to seal the unit, taking care that no carbide comes in contact with the soil until a complete seal is achieved.

D. Raise the moisture tester to a vertical position and tap the side of the vessel with the hand so the soil in the cap falls into the pressure vessel.

E. Hold the vessel in a horizontal position and shake, ensuring that the steel balls rotate around the sides of the vessel to break up the soil lumps. (Never shake end to end or the steel balls may damage the dial orifice.) One minute of shaking should be sufficient for granular soils, while 5 minutes or more may be required for highly plastic soils or shale.

F. Cool the gas. When the needle has stopped moving shake the "SPEEDY" for at least a half minute, in order to cool the gas produced. Read the dial while holding the instrument in a horizontal position at eye level.

G. Record the sample weight and the dial reading on a DOT-35 or a DOT-41.

H. Point the instrument away from the operator and slowly release the gas pressure, then empty the contents. When the sample is dumped, it should be examined for lumps. If the sample is not completely broken down, the test is not valid. Repeat the test, with a new test sample increasing the shaking time by one minute.

I. The pressure vessel should be brushed out and the cap wiped clean after each test.

J. The tester shall be checked by comparison with oven dry samples, at the start of use and at least once per week thereafter, if in constant use.

K. The material for oven drying shall weigh at least 100 g and be weighed to the nearest 0.1 gram.

L. The results of the oven dry moisture test must be within one percentage point for soils and 0.6 of a percentage point for sand.

M. If a discrepancy exists, contact the Region Materials Engineer.

3.2 Stove top or hot plate method.

A. Obtain a sample of wet material weighing a minimum of 100 grams for soils and a minimum of 500 grams for granular materials.

B. Weigh the material to the nearest 0.1 gram and dry it to a constant weight. Constant weight is achieved when two successive periods of drying indicate no change in the weight of the material. Check the first two samples tested on a project and an occasional sample thereafter for constant weight, to insure that sufficient drying time is being allowed.

NOTE: The sample usually has been dried to constant weight, when, using a cool metal spoon or spatula, the sample is briefly stirred and there is no evidence of moisture or material sticking to the metal of the stirring instrument.

C. Place the steel plate on the burner of the stove or gas hot plate. Steel plates are not required on electric hot plates. Place the pan holding the material on the steel plate.

D. Stir the material during drying to prevent the temperature of the sample from exceeding 230° ± 9°F.

E. If it is found that samples dried in an oven and those dried on top of the stove do not give test results that compare satisfactorily, use the oven dried method.

NOTE: Cool until the container can be handled comfortably with bare hands and the operation of balance or sieves on which sample is placed are not affected by heat convection from material/pan. 16

3.3 Oven drying method.

A. Obtain a sample of wet material weighing a minimum of 100 g for soils and a minimum of 500 g for granular material. Weigh wet material and record to the nearest 0.1 g.

B. Place in dry, clean pan and place in the oven maintained at 230° ± 9°. Stirring the sample periodically during drying accelerates the process. 16

C. Dry the material to a constant weight and weigh to the nearest 0.1 gram. Constant weight is achieved when two successive periods of drying indicate no change in the weight of the material. Check the first two samples tested on a project and occasional sample thereafter for constant weight, to insure that sufficient drying time is established for material being tested and apparatus being used.

NOTE: Cool until the container can be handled comfortably with bare hands and the operation of balance or sieves on which sample is placed are not affected by heat convection from material/pan.

3.4 Nuclear method – In-place moisture test.

A. Calibration and performing the standard count of the nuclear gauge shall be in accordance with SD 114, paragraph 3.1 and 3.2.

B. Select a location for the test where the gauge will be at least 2’ away from any vertical projection, at least 10’ away from any vehicle and at least 30’ away from another nuclear gauge.

C. Remove material, as necessary, to reach the top of the compacted lift to be tested. Prepare a horizontal area, sufficient in size to accommodate the gauge, using the scraper plate supplied with the gauge, by planing to a smooth condition to obtain maximum contact between the gauge and the material being tested. Make sure the gauge sits solidly on the site without rocking.

D. The maximum depressions beneath the gauge shall not exceed 1/8”. Use native fines or fine sand to fill voids and level the excess with the scraper plate. The total areas thus filled with fines or sand should not exceed 10% of the bottom area of the gauge.

E. Place the guide scraper plate on the prepared test site and drive the drill rod with the extraction tool attached through the guide to a depth at least 2" below the depth of material to be measured. Remove the drill rod by pulling straight up and twisting the extraction tool, in order to avoid disturbing the hole.

F. Place the nuclear gauge over the test site and extend the source rod into the hole to the desired depth. Release the trigger at the desired depth and listen for the "Click" indicating that the source rod is properly locked into position on the index rod. Verify the depth shown on the display of the gauge agrees with the actual depth of the source rod. Slide the gauge so the surface of the source rod nearest the keypad is in contact with the edge of the hole.

G. Take a one-minute reading to determine the % moisture and record this number. It is recommended that you take more than one reading and average the results. At the completion of the % moisture measurements, dig up the area beneath the gauge to collect the moisture specimen if a comparison is to be performed and visually check for large voids or inconsistent material which may give inaccurate results. If a large void or inconsistent material is encountered, disregard the test and move to a nearby location. 16

H. Correction determination: At least five tests must be performed using the nuclear gauge on mechanically compacted material and compared against oven dry moisture tests to compute a moisture correction. Take the moisture sample from the top of the lift to the depth of the source rod directly below the nuclear gauge and immediately place in an airtight container for moisture testing using the oven dry method. Use the DOT-39 to calculate the moisture correction. If an individual comparison is determined which is not within 2.0 % of the correction (Running average) calculated from the previous five individual comparisons, the results shall be considered suspect and additional checks should be run to determine if the material has changed.

I. After the moisture correction is determined, it is applied to future tests performed with the nuclear gauge. Each type of material shall have a different correction. Embankment material shall have a correction determination separate from surfacing material. Corrections are not interchangeable between nuclear gauges, and must be individually determined. If a change in project, change in material source, unusually high or low % moisture readings, considerable changes in sieve analysis, or visual change in material, additional checks should be completed and documented on a DOT-39.

NOTE: THE nuclear gauge moisture reading shall never be used for determination of in-place dry density.

J. Additional comparison checks against the oven dry method shall be performed at a minimum of at least once per 20 moisture tests. Results shall be documented on the DOT-39 worksheet and the correction (Running average) reevaluated for the five most recent in place moisture comparison tests performed.

K. If a discrepancy exists, contact the Region Materials Engineer.

3.5 Microwave oven moisture test method.

A. Determine the weight of a clean, dry container or dish, and record it on the applicable worksheet as "Wt. of container".

B. Cut or break up the soil into small size aggregations to aid in obtaining quicker and more uniform drying of the specimen. Obtain a sample of wet material weighing a minimum of 100 grams for soils and a minimum of 500 grams for aggregates. Place the sample in the container, and immediately determine and record the weight to the nearest 0.1 gram.

C. Place the sample and container in a microwave oven and turn the oven on for 3 minutes. If experience with a particular soil type and specimen size indicates shorter or longer initial drying times can be used without overheating, the initial and subsequent drying times may be adjusted.

NOTE: The 3-minute initial setting is for a minimum sample size of 100 grams. Smaller samples are not recommended when using the microwave oven because drying may be too rapid for proper control. Large samples may need to be split into segments and dried separately.

Most ovens have a variable power setting. For the majority of soils tested, a setting of "High" should be satisfactory; however, for some soils such a setting may be too severe. The proper setting can be determined only through the use of and experience with a particular oven for various soil types and sample sizes. The energy output of microwave ovens may decrease with age and usage; therefore, power settings and drying times should be established for each oven.

D. After the set time has elapsed, remove the container and soil from the oven, weigh the specimen as soon as the container may be handled safely to the nearest 0.1 gram and record the weight.

E. With a small spatula, knife, or short length of glass rod, carefully mix the soil, taking special precaution not to lose any soil.

F. Return the container and soil to the oven and reheat for 1 minute.

G. Repeat (D) through (F), until a constant weight has been achieved as per SD 108.

H. Use the final weight to calculate the moisture content. Obtain this value immediately after the heating cycle, as soon as the container may be handled safely.

NOTE: Incremental heating, together with stirring, will minimize overheating and localized drying of the soil. The recommended time increments have been suitable for most specimens having particles smaller than a #4 sieve and with a sample of approximately 200 g; however, they may not be appropriate for all soils and ovens, and adjustment may be necessary.

Cool until the container can be handled comfortably with bare hands and the operation of balance or sieves on which sample is placed are not affected by heat convection from material/pan. 16

Moisture content specimens should be discarded after testing and not used in any other tests due to particle breakdown, chemical changes or losses, melting, or losses of organic constituents.

4. Report:

4.1 Calculations for speedy moisture testers.

The dial on the moisture tester reads directly in percent moisture by wet weight. The reading must be converted to percent moisture by dry weight. The computation is made by using the conversion table which equates moisture contents by wet weight and dry weight in the normal range that will be encountered on grading projects, or by using the following formula:

$$\% \text{ Moisture by dry weight} = \frac{\% \text{ moisture by wet weight}}{1 - (\% \text{ moisture by wet weight divided by } 100)}$$

Example: % moisture by wet weight is 14.8

$$\frac{14.8}{1 - (14.8 \text{ divided by } 100)} =$$

$$\frac{14.8}{1 - .148} = \frac{14.8}{.852} = 17.4\%$$

See “Speedy Conversion Chart”. (Figure 2)

4.2 Calculations for stove top or hot plate, oven drying, and microwave oven methods.

Calculate the percent of moisture for the drying on a stove or hot plate, oven drying and microwave oven methods as follows:

Moisture content =

$$\frac{\text{Weight wet material – weight dry material x 100}}{\text{Weight dry material}}$$

16

4.3 Calculations for the nuclear method – In-place moisture test on DOT-39.

A = % moisture determined by oven dried method. 16

B = % moisture determined by the nuclear gauge.

C = A - B

D = Correction (Running average) of 5 most recent valid values of C in %

Moisture content = nuclear moisture + correction (Running average).

5. References:

AASHTO T 310
AASHTO T 265
SD 114
SD 311
DOT-35
DOT-39
DOT-41
DOT-208

Sample ID 2205174 **Moisture - Density Worksheet** DOT - 35
File No. 9-15

County Aurora, Ziebach PCN/PROJECT B015 PH 0066(00)15
Tested By: Tester, One Checked By: Tester, Two Test Date: 04/27/2015
Material Type Unclassified Excavation

Test No.	E021	E022	023E	E024	E025	E026	
Sampled at Station	44+25	36+57	34+75	37+30	41+30	36+25	
Distance from CL	22' L	10' L	15 L	17 R	22 R	13' R	
Represents Sta. - Sta.	27+00	27+00	27+00	27+00	27+00	27+00	
	53+40	53+40	53+40	53+40	53+40	53+40	
Depth Below Grade or Top of Pipe	4.5'	6'	5.5'	5'	2'	4.5'	
	Below Grade	Below Grade	Below Grade	Below Grade	Below Grade	Below Grade	
1-Point not made - Refer to Moisture or Density No.			E022			E024	
Correction							
Field Comparison							

Field Moisture

		Nuclear Test...	☐	☐	☐	☑	☑	☑	☐
Time		7:35 am	9:30 am	11:30 am	1:30 pm	3:30 pm	5:30 pm	
Wt. of Can and Material	Meter No.	155.7	120.8	142.5	MQ 778	MQ 778	MQ 778	
Wt. of Can and Dry Material		133.7	99.6	119.6				
Wt. Loss (Moisture) Speedy Reading	Standard Moisture Count	22.0	21.2	22.9	656	656	656	
Wt. of Can/ Wt. of Speedy Sample	Pct. Moisture from Meter				21.6	20.8	20.6	
Wt. of Dry Material	Moisture Correction (±)	133.7	99.6	119.6				
Percent Moisture		16.5	21.3	19.1	21.6	20.8	20.6	

1-Point Determinations

A-2-4 or A-3 Soil or QC/QA Asphalt Concrete	☐	☐	☐	☐	☐	☐	☐
Wt. of Can and Wet Material	157.8	134.8	134.8	112.7	126.2	112.7	
Wt. of Can and Dry Material	135.8	115.0	115.0	93.6	105.7	93.6	
Wt. Loss Speedy Reading	22.0	19.8	19.8	19.1	20.5	19.1	
Wt. of Can							
Wt. of Dry Material	135.8	115.0	115.0	93.6	105.7	93.6	
Percent Moisture	16.2	17.2	17.2	20.4	19.4	20.4	
Wt. of Mold and Wet Specimen	13.32	13.37	13.37	13.40	13.37	13.40	
Wt. of Mold	9.23	9.23	9.23	9.23	9.23	9.23	9.23
Wt. of Wet Specimen	4.09	4.14	4.14	4.17	4.14	4.17	
Mold No.	P-1885	P-1885	P-1885	P-1885	P-1885	P-1885	P-1885
Factor of Mold	30.01	30.01	30.01	30.01	30.01	30.01	30.01
Wet Density Lbs/cuft (Kg/m)	122.7	124.2	124.2	125.1	124.2	125.1	
Dry Density Lbs/cuft (Kg/m)	105.6	106.0	106.0	103.9	104.0	103.9	
Curve Used / Curve Family	0 0	o 0	o 0	P 0	p 0	P 0	0
Max Dry Dens. from Ohio Curve Lbs/cuft (Kg/m)	107.1	105.9	105.9	104.7	103.5	104.7	
Optimum Moisture from Ohio Curve	18.1	18.6	18.6	19.2	19.7	19.2	
Pass/Fail	✓	✓	✓	✓	✓	✓	

Figure 1

Speedy Reading	Percent Moisture Dry Weight	Speedy Reading	Percent Moisture Dry Weight	Speedy Reading	Percent Moisture Dry Weight	Speedy Reading	Percent Moisture Dry Weight	Speedy Reading	Percent Moisture Dry Weight	Speedy Reading	Percent Moisture Dry Weight
5.0 - 5.3		9.1 - 10.0		13.1 - 15.1		17.1 - 20.6		21.1 - 26.7		25.1 - 33.5	
5.1 - 5.4		9.2 - 10.1		13.2 - 15.2		17.2 - 20.8		21.2 - 26.9		25.2 - 33.7	
5.2 - 5.5		9.3 - 10.2		13.3 - 15.3		17.3 - 20.9		21.3 - 27.1		25.3 - 33.9	
5.3 - 5.6		9.4 - 10.4		13.4 - 15.5		17.4 - 21.1		21.4 - 27.2		25.4 - 34.0	
5.4 - 5.7		9.5 - 10.5		13.5 - 15.6		17.5 - 21.2		21.5 - 27.4		25.5 - 34.2	
5.5 - 5.8		9.6 - 10.6		13.6 - 15.7		17.6 - 21.4		21.6 - 27.6		25.6 - 34.4	
5.6 - 5.9		9.7 - 10.7		13.7 - 15.9		17.7 - 21.5		21.7 - 27.7		25.7 - 34.6	
5.7 - 6.0		9.8 - 10.9		13.8 - 16.0		17.8 - 21.7		21.8 - 27.9		25.8 - 34.8	
5.8 - 6.2		9.9 - 11.0		13.9 - 16.2		17.9 - 21.8		21.9 - 28.0		25.9 - 35.0	
5.9 - 6.3		10.0 - 11.1		14.0 - 16.3		18.0 - 22.0		22.0 - 28.2		26.0 - 35.1	
6.0 - 6.4		10.1 - 11.2		14.1 - 16.4		18.1 - 22.1		22.1 - 28.4		26.1 - 35.3	
6.1 - 6.5		10.2 - 11.4		14.2 - 16.6		18.2 - 22.2		22.2 - 28.5		26.2 - 35.5	
6.2 - 6.6		10.3 - 11.5		14.3 - 16.7		18.3 - 22.4		22.3 - 28.7		26.3 - 35.7	
6.3 - 6.7		10.4 - 11.6		14.4 - 16.8		18.4 - 22.5		22.4 - 28.9		26.4 - 35.9	
6.4 - 6.8		10.5 - 11.7		14.5 - 17.0		18.5 - 22.7		22.5 - 29.0		26.5 - 36.0	
6.5 - 7.0		10.6 - 11.9		14.6 - 17.1		18.6 - 22.8		22.6 - 29.2		26.6 - 36.2	
6.6 - 7.1		10.7 - 12.0		14.7 - 17.2		18.7 - 23.0		22.7 - 29.4		26.7 - 36.4	
6.7 - 7.2		10.8 - 12.1		14.8 - 17.4		18.8 - 23.2		22.8 - 29.5		26.8 - 36.6	
6.8 - 7.3		10.9 - 12.2		14.9 - 17.5		18.9 - 23.3		22.9 - 29.7		26.9 - 36.8	
6.9 - 7.4		11.0 - 12.4		15.0 - 17.6		19.0 - 23.5		23.0 - 29.9		27.0 - 37.0	
7.0 - 7.5		11.1 - 12.5		15.1 - 17.8		19.1 - 23.6		23.1 - 30.0		27.1 - 37.2	
7.1 - 7.6		11.2 - 12.6		15.2 - 17.9		19.2 - 23.8		23.2 - 30.2		27.2 - 37.4	
7.2 - 7.8		11.3 - 12.7		15.3 - 18.1		19.3 - 23.9		23.3 - 30.4		27.3 - 37.6	
7.3 - 7.9		11.4 - 12.9		15.4 - 18.2		19.4 - 24.1		23.4 - 30.5		27.4 - 37.7	
7.4 - 8.0		11.5 - 13.0		15.5 - 18.3		19.5 - 24.2		23.5 - 30.7		27.5 - 37.9	
7.5 - 8.1		11.6 - 13.1		15.6 - 18.5		19.6 - 24.4		23.6 - 30.9		27.6 - 38.1	
7.6 - 8.2		11.7 - 13.2		15.7 - 18.6		19.7 - 24.5		23.7 - 31.1		27.7 - 38.3	
7.7 - 8.3		11.8 - 13.4		15.8 - 18.8		19.8 - 24.7		23.8 - 31.2		27.8 - 38.5	
7.8 - 8.4		11.9 - 13.5		15.9 - 18.9		19.9 - 24.8		23.9 - 31.4		27.9 - 38.7	
7.9 - 8.6		12.0 - 13.6		16.0 - 19.0		20.0 - 25.0		24.0 - 31.6		28.0 - 38.9	
8.0 - 8.7		12.1 - 13.8		16.1 - 19.2		20.1 - 25.2		24.1 - 31.8		28.1 - 39.1	
8.1 - 8.8		12.2 - 13.9		16.2 - 19.3		20.2 - 25.3		24.2 - 31.9		28.2 - 39.3	
8.2 - 8.9		12.3 - 14.0		16.3 - 19.5		20.3 - 25.5		24.3 - 32.1		28.3 - 39.5	
8.3 - 9.0		12.4 - 14.2		16.4 - 19.6		20.4 - 25.6		24.4 - 32.3		28.4 - 39.7	
8.4 - 9.2		12.5 - 14.3		16.5 - 19.8		20.5 - 25.8		24.5 - 32.4		28.5 - 39.9	
8.5 - 9.3		12.6 - 14.4		16.6 - 19.9		20.6 - 25.9		24.6 - 32.6		28.6 - 40.1	
8.6 - 9.4		12.7 - 14.5		16.7 - 20.0		20.7 - 26.1		24.7 - 32.8		28.7 - 40.3	
8.7 - 9.5		12.8 - 14.7		16.8 - 20.2		20.8 - 26.3		24.8 - 33.0		28.8 - 40.4	
8.8 - 9.6		12.9 - 14.8		16.9 - 20.3		20.9 - 26.4		24.9 - 33.2		28.9 - 40.6	
8.9 - 9.8		13.0 - 14.9		17.0 - 20.5		21.0 - 26.6		25.0 - 33.3		29.0 - 40.8	
9.0 - 9.9											

Speedy Conversion Chart

Figure 2