

## ATT-15/22, MOISTURE CONTENT, Part IV, Microwave Oven Method

### 1.0 SCOPE

This method describes the procedures for determining the moisture content of soil using a microwave oven. This procedure is used to:

- a) correlate the microwave moisture to the oven dried moisture content,
- b) dry soil samples to the calibrated drying time in a microwave.

### 2.0 EQUIPMENT

Electronic Balance - for measuring the mass of wet and dried samples (sensitive to 0.1 g).  
The balance must be operated as per manufacturer's recommendations.  
Balances must be inspected, cleaned, and calibrated annually.

Microwave Oven - Ovens with variable power controls and input power ratings of about 700 W have been found to be adequate for testing. Variable power controls are important and reduce the potential for overheating or burning of the test specimens.

Lab Oven – thermostatically controlled, capable of maintaining a uniform temperature of  $110 \pm 5^\circ\text{C}$ .

wash basin                      graph paper                      heat resistant gloves  
microwave compatible moisture containers (e.g. paper plates)  
moisture tare pans (for correlation procedure)

Data Sheet: Moisture Content, such as MAT 6-24.

### 3.0 PROCEDURE

#### 3.1 Application

This microwave method is much quicker for drying soils than the oven-drying method and therefore is ideal for rapid moisture content determination. However, there is a concern that the determination of moisture content of soils using a microwave oven may give erroneous results due to the possibility of overheating.

In some soil types, water, in the form of hydroxyl molecules, is present within the mineral phase. These hydroxyl molecules are usually not considered to be part of the water phase. They are removed during microwave drying, but not during conventional oven drying at  $110 \pm 5^\circ\text{C}$ .

Therefore, moisture contents by microwave oven drying are generally higher than those obtained by conventional oven drying. The amount of variance depends on the soil composition.

***Correlation of microwave to conventional oven dried moisture contents*** shall be performed as directed in section 3.2 for each major soil type encountered in the project.

### 3.2 Correlation to Oven Dried Moisture Content

Use this procedure to correct microwave oven moisture contents obtained in Standard Moisture-Density Relation Tests and In-place Density Tests.

**Use only corrected moisture contents for the acceptance or rejection of Contractor's work. Report only corrected moisture contents.**

Correlation of microwave to conventional oven dried moisture contents may not be necessary when there is a need for a quick estimate of the moisture content of a sample. However, the results of this test cannot be used for the acceptance or rejection of the Contractor's work and must not be reported.

#### 3.2.1 Drying Time

***The time required to dry each significant soil type on the project must be established.***

For each soil type, e.g. sands, silts, clays, determine the time that the microwave dried samples take to arrive at the moisture content obtained on the conventional oven dried samples. The time required to get corresponding results is the time of drying. The factors that affect the drying time in the microwave oven are:

1. Soil type.
2. Power level of the microwave.
3. Moisture content of the sample.
4. Number of samples in the oven.
5. Size of the sample.

When determining the drying time, reduce variables as follows:

- a) ***dry only one sample at a time in the microwave,***
- b) ***use the same power level at all times,*** preferably maximum power, and
- c) ***keep sample sizes approximately the same.***

The drying time will remain fairly constant throughout the soil type and moisture content range. However, drying time should be established and checked for each significant soil type and moisture content range encountered on the project. Once a drying time is established, this drying time can be used on subsequent field density tests for the same soil type.

### 3.2.2 Sample Preparation

1. Obtain a sample of at least 1 kg of representative soil of the type and moisture content in which the drying time is to be established.
2. Empty the soil into a wash basin.
3. Perform a conventional oven moisture content on the soil as directed in Section 3.2.3 and a microwave moisture content as directed in Section 3.2.4.

### 3.2.3 Moisture Content by Conventional Oven

1. Complete the "Heading" and "Sample Identification" portions of the data sheet. A typical example of a completed form is shown in Figure 1.
2. Label a drying pan and record as "Container Number".
3. Weigh the pan and record as "Tare of Container" on line "C".
4. Place in the drying pan a minimum of 250 grams of soil obtained randomly throughout the wash basin.
5. Break up the soil into pieces smaller than 15 mm in diameter as the drying pan is being filled. Spread the sample evenly over the bottom of the pan.
6. Weight the pan and its contents immediately and record as "Wt. of Wet Sample + Tare on line "A".
7. Place the sample in the conventional oven set at  $110 \pm 5^{\circ}\text{C}$ .
8. Dry the sample to constant weight. Record as "Wt. of Dry Sample + Tare" on line "B".
9. Calculate the "Weight of Water" removed on line "D" as follows:  
Line A – Line B = Line D


$$\text{Wt. of Water (g)} = \text{Wt. of Wet Sample and Tare} - \text{Wt. of Dry Sample and Tare}$$

10. Determine the "Wt. of Dry Sample" on line "E" as follows:  
Line E = Line B – Line C

$$\text{Wt. of Dry Soil (g)} = \text{Wt. of Dry Sample and Tare} - \text{Wt. of Tare}$$

11. Calculate the Moisture Content in percent (Line "E") of the sample using the formula:

$$\text{Moisture Content (\%)} = \frac{\text{Wt. of Water}}{\text{Wt. of Dry Sample}} \times 100\%$$

 Transportation <b>MAT 6-24/22</b>	<b>MOISTURE CONTENT</b>			
	PROJECT :	Hwy 36:04	Contractor :	ABC Const.
	CONTRACT NO. :	12345	DATE :	18-Aug-2021
	<i>ATT-15 MOISTURE CONTENT, Part I, Oven Method</i>		TECH :	J. Jones

SAMPLE IDENTIFICATION					
DATE	18-Aug-2021				
SOIL TYPE	CH, dk brown				
TEST NUMBER	1				
SAMPLE SOURCE	Windrow				
STATION	9+183				
LOCATION	2.0m Rt				
DEPTH BELOW GRADE OR LIFT	m				

MOISTURE CONTENT					
CONTAINER NUMBER	g	X			
A. WEIGHT OF WET SAMPLE + TARE	g	475.1			
B. WEIGHT OF DRY SAMPLE + TARE	g	404.5			
C. TARE OF CONTAINER	g	125.4			
D. WEIGHT OF WATER	A - B	g	70.6		
E. WEIGHT OF DRY SAMPLE	B - C	g	279.1		
F. <b>MOISTURE CONTENT</b>	<b>(D/E) x 100</b>	%	<b>25.3</b>		

REMARKS: Oven dried at 110 ± 0.5° C**FINE GRAINED SOIL SAMPLES**

FIGURE 1


**3.2.4 Moisture Content by Microwave Oven**

**Do Not Operate** the microwave oven if it is damaged. It is particularly important that the oven door close properly and that there is no damage to the door (bent), hinges and latches (broken or loosened), or door seals and sealing surfaces.

Perform microwave moisture content tests as follows:

1. Set the microwave at the maximum power level.
2. Complete the "Heading" and "Sample Identification" portions of the data sheet. An example is illustrated in Figure 2.
3. Label a microwave container and record as Container Number. Disposable Paper plates work well as tare containers for the microwave.
4. Weigh the microwave container and record as "Tare" on line "C".
5. Place a randomly obtained 250 ± 5 gram sample of soil from the wash basin into the microwave container.
6. While filling the container, break up the soil into pieces smaller than 15 mm in diameter.
7. Weigh the container and its contents immediately and record as "Wt. of Wet Sample + Tare" on line "A".
8. Place the sample in the microwave oven.

FIGURE 2

 MAT 6-24/22	<b>MOISTURE CONTENT</b>			
	PROJECT :	Hwy 36:04	Contractor :	ABC Const.
	CONTRACT NO. :	12345	DATE :	18-Aug-2021
	<i>ATT-15 MOISTURE CONTENT, Part IV, Microwave MC</i>		TECH :	J. Jones

SAMPLE IDENTIFICATION									
DATE	19-Aug-2021								
SOIL TYPE	CH, dark brn								
TEST NUMBER	1								
SAMPLE SOURCE	Windrow								
STATION	9+183								
LOCATION	2.5m Rt								
<b>MICROWAVE OVEN DRYING TIME</b>	<i>min.</i>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>	<b>9</b>	<b>10</b>	<b>11</b>

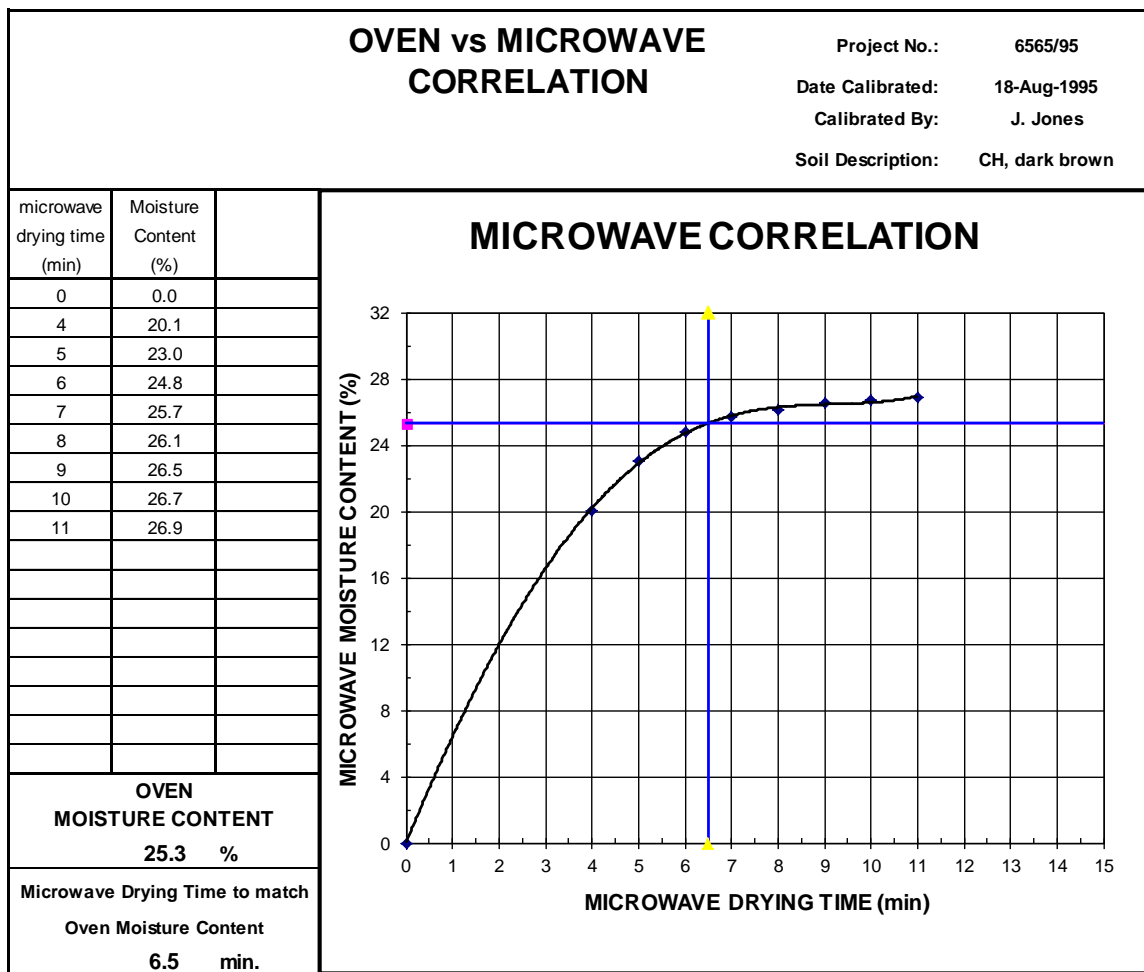
MOISTURE CONTENT									
CONTAINER NUMBER	g	A	B	C	D	E	F	G	H
A. WEIGHT OF WET SAMPLE + TARE	g	453.6	453.6	453.6	453.6	453.6	453.6	453.6	453.6
B. WEIGHT OF DRY SAMPLE + TARE	g	399.0	392.5	388.7	386.8	386.0	385.2	384.8	384.4
C. TARE OF CONTAINER	g	127.1	127.1	127.1	127.1	127.1	127.1	127.1	127.1
D. WEIGHT OF WATER	A - B	g	54.6	61.1	64.9	66.8	67.6	68.4	68.8
E. WEIGHT OF DRY SAMPLE	B - C	g	271.9	265.4	261.6	259.7	258.9	258.1	257.7
F. <b>MOISTURE CONTENT</b>	<b>(D/E) x 100</b>	%	<b>20.1</b>	<b>23.0</b>	<b>24.8</b>	<b>25.7</b>	<b>26.1</b>	<b>26.5</b>	<b>26.7</b>

REMARKS: Microwave Moisture Content results of soil tested at 1 min intervals from 4 to 11 minutes.  
These numbers are used to determine the correlation between the Microwave & Conventional Oven Moisture Content.

9. Dry the sample for 4 minutes, then at intervals of one minute until a constant weight is obtained. After heating, allow the container to stand in the microwave oven for a short time before removing the container. Remove the sample from the microwave, place it on the balance, then weigh and record the weight. After each weighing, place the sample back in the microwave oven for the next 1 min. time interval.
10. Record as "Wt. of Dry Sample + Tare" on line "B", for each weight at the given time interval.
11. For each weighing period, determine the moisture content of the soil sample by repeating steps 9 to 11 of section 3.2.3.

**3.2.5 Microwave Drying Time**

1. Plot on the graph paper the microwave moisture contents on the vertical ordinate versus the corresponding microwave drying times on the horizontal ordinate, as shown in Figure 3, using the data obtained during microwave drying.
2. Connect the points with smooth flowing curves.
3. Plot on the vertical ordinate, the **oven** moisture content.



**FIGURE 3**


4. Draw a horizontal line connecting the oven moisture content with the drawn microwave moisture content curve.
5. Where the two intercept, draw a vertical line to the bottom of the graph.
6. The microwave drying time is the time picked off the graph where the vertical line intercepts the horizontal scale. This is the time required for that particular soil type to approximate the oven dry moisture content.

***This time period must be used to dry all samples of that soil type when determining the moisture content of the soil using the microwave method.***

**NOTE: *This time period is valid only when drying a single sample.***

**3.3 Microwave Moisture Content**

1. Ensure the microwave is at the maximum power level, or at the same level as the correlation has been done at.
2. Obtain a representative 1 kg sample of soil and empty the contents into a wash basin.
3. Complete the “Heading” and “Sample Identification” portions of the data sheet. An example is shown in Figure 4.
4. Label a microwave container and record as “Container Number”.
5. Weigh the microwave container and record as “Tare of Container on line “C”.

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SAMPLE IDENTIFICATION					
DATE	19-Aug-2021				
SOIL TYPE	CH, dark brn				
TEST NUMBER	1				
SAMPLE SOURCE	Windrow				
STATION	9+183				
LOCATION	2.5m Rt				
DEPTH BELOW GRADE OR LIFT	m				

MOISTURE CONTENT					
CONTAINER NUMBER	g	A			
A. WEIGHT OF WET SAMPLE + TARE	g	310.7			
B. WEIGHT OF DRY SAMPLE + TARE	g	270.2			
C. TARE OF CONTAINER	g	28.9			
D. WEIGHT OF WATER	A - B	g	40.5		
E. WEIGHT OF DRY SAMPLE	B - C	g	241.3		
F. <b>MOISTURE CONTENT</b>	<b>(D/E) x 100</b>	<b>%</b>	<b>16.8</b>		

REMARKS: Microwave oven dried for 6.5 minutes, as per the Microwave Correlation test for this soil type

FIGURE 4

6. Place in the microwave container a sample size of  $250 \pm 5$  grams of soil obtained randomly throughout the wash basin.
7. While filling the microwave container, break up the soil into pieces smaller than 15 mm in diameter.
8. Weigh the microwave container and its contents immediately and record as "Wt. of Wet Sample + Tare" on line "A".
9. Place the sample in the microwave oven.
10. Dry the sample for the drying time determined in section 3.2.5.
11. Record as "Wt. of Dry Sample + Tare" on line "B".
12. Determine the moisture content of the sample in percent by repeating steps 9 to 11 of section 3.2.3.

#### 4.0 HINTS AND PRECAUTIONS

1. Use only ***microwave compatible moisture containers*** in the microwave.
2. ***Place only one moisture content sample in the microwave at a time***, the same as was done to determine the "Microwave Correlation" graph.
3. When using the moisture content by microwave method, ***ensure that a "Microwave Correlation" graph is determined for EACH DIFFERENT SOIL TYPE.***
4. ***The SAME TIME PERIOD and the SAME SAMPLE SIZE must be used to dry all samples of the same soil type.***
5. Keep the field laboratory counter tops clean at all times so that any spilled samples will be readily noticed and can be retrieved.
6. Use caution if you are using paper plates in the microwave, as they may catch fire if you overheat the sample, or if rocks are in the soil sample absorb too much energy and cause localized hot spots.
7. Do not operate the microwave oven if it is damaged. It is particularly important that the oven door closes properly and that there is no damage to the:
  - Door (bent)
  - Hinges and latches (broken or loosened)
  - Door seals and sealing surfaces
8. ***Do not operate the microwave oven while it is empty.*** If food or water is not present inside the microwave to absorb energy during its operation, microwave energy will continuously reflect throughout the oven causing overheating and damage to the microwave. This could damage the oven and result in a risk of fire.