Journal of Engineering Science and Technology
Vol. 15, No. 3 (2020) 2110 - 2118

ASSESSMENT FOR APPLICABILITY OF MICROWAVE OVEN IN RAPID DETERMINATION OF MOISTURE CONTENT IN PEAT SOIL

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Abstract

Peat soil has high water and organic content. The determination of peat soil moisture content using microwave oven method is an alternative to the convection oven-drying method. This result is an ideal for rapid moisture content determination. This study describes the applicability of microwave oven dried method in rapid determination of moisture content for peat soil and determined drying time. However, there is an interest regarding rapid drying time that applied to the organic soil such as peat. Klias peat classified as hemic peat with high organic content at 55.82%. This research observed the physical deformation of peat during drying process. Rapid drying process in peat soil leads crusting, overheating and specimens burnt where peat soil fibre and particles transformed to grey ashes. Peat risked to burn in microwave oven and perceived as unsafe practice for longer periods. Peat soils demanded for specific method to suit the physical properties of peat differ than the existing standard test procedure.

Keywords: Hemic peat, Microwave oven, Moisture, Organic, Peat soil.

1. Introduction

In natural peatlands, water are often become a major part that made up peat properties. The extraordinarily high water content of peat soil and consist organic matter with hemic material making it very soft, crumbly material and uniformly dark brown in colour. Peat soil in natural condition is drained, unfortunately in slower rate of water migration and generally peat deposit occur in low lying areas where the water table is close to the surface and poorly drained, contrarily, more undrained. Peat classified as high organic content under conditions of almost permanent water saturation in most areas in Malaysia. The determination of peat soil moisture content has been established as the primary indicator of the strength and as an influenced key performance to the low strength to the main characteristic. Nowadays, there are so many methods in soil moisture content determination from oven dry method to calcium carbide method and presently leading technologies, the microwave oven moisture content test which was introduced by Miller et al. [1].

The work began with development of rapid method in determining moisture content and devices commercially available for use in identifying soil moisture content, unfortunately are typically designed considering inorganic soils. According to American Society for Testing and Materials [2], referred as Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass commonly used integral with British Standard [3], Methods of test for soils for civil engineering purposes. Classification tests. The mean difference between the value of moisture content tested by the microwave oven method and the convection oven method [2] is 0.24% for micaceous soils (having 5 to 25% mica particles by mass) and 0.61% for other soils.

A microwave oven has been found to be satisfactory for determining soil moisture content gravimetrical [4]. Highly organic soils and those containing oils and coal may ignite and burn during drying [5]. By considering the organic volatile, microwave oven should not be used as definitive method in determining the moisture content of soils containing organic matter such as peat [3]. Below 110 °C, particles are well burning making it difficult to ensure the ideal temperature does not exceed 110 °C. In some soil type 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 ± 5*EC* [6]. However, peat has a high carbon content and can burn under low moisture conditions [7].

The possible use of a microwave oven for soil moisture determination [1] seemed ideal in an introductory soil science laboratory. It was desirable to allow the drying and weighing of the laboratory samples for gravimetric moisture content during only one period and to eliminate the 24-hour drying period required with forced-air drying ovens. This method ideal for sand and clay soil while this study carried out to inspect the element and usability of microwave as an available medium at home to generate quick result for peat moisture content with high content of organic particle.

Microwaves are part of the electromagnetic spectrum and have wavelengths from approximately 1 mm to 1 m (300 GHz to 0.3 GHz). Most domestic microwave ovens in the market have a rated microwave frequency of 2.45 GHz. This frequency is close to the natural frequency of water molecule. Microwaves can either be absorbed by, reflected by or pass through a material. They have good penetration

properties and materials which absorb them are rapidly heated. The increase in temperature of a material resulting from microwave heating depends on the specific heat and density of the material [8].

2. Material and Methods

Disturbed sample used as specimen to determine the moisture content of peat using microwave oven method. Sample was taken from Klias peat, Beaufort, Sabah. Visual observation on the peat soil are done after collecting disturbed sample as mentioned according to Von Post classification system where peat soil possesses to H6, sample is very soft and dark in colour. The samples were first dried out by using a convection oven operated at 105°C ± 5°C [2]. Afterwards, different samples prepared for microwave oven drying process with fan oven setting, specimen placed in ceramic utensils. Figure 1 shows the ceramic utensil with 50 mm diameter and 3.5 mm height. Ceramic and glass utensils is the ideal materials because the microwave cannot penetrate metal while ceramic and glass is transparent to microwave that allows energy to pass through the container and heat the specimens.

Six subsamples of peat soil, firstly specimens heated with constant temperature (*P-Hi*) setting or called high power level and the weight of sample containing 50 g. There are two time intervals used for the comparison purposes, 2 minutes and 5 minutes' time interval to avoid prompt crusting on peat sample. This time interval repeated until the specimens dried out constantly. The time required to dry each significant peat specimens are varied depend on water content and drying time required by each sample. Samples dried to a constant weight. Specimens quickly weight at 2, 4, 6, 8, 10, 12 and 14 minutes or varied until a constant weight is obtained for each sample. Specimens that have been weighted accordingly to time interval are placed back in the microwave oven.

Sample in large size designated to be 5 oz for each sample and naturally saturated with water at starting phase. Sample placed into ceramic utensil and attached standalone to the microwave oven in the middle of turntable. Sample heated from 2 minutes and shrink, when the time completed, sample continued to 4 minutes and started to deform and contracted. Sample heated until 10 minutes where constant weigh detected.

Fig. 1. Ceramic utensil for specimen placed in microwave oven.

3. Result and Discussion

Microwave oven specification that has been used in this assessment are microwave oven with a vented chamber with output power rating of about 900 watts (Kenzo KMO30-G4) with variable power control with turntable system. However, it is preferable the microwave oven has a vented chamber, and a power rating of about 700 watts with variable power control [9]. Specified weighing interval for microwave drying is two minutes for group 1 and five minutes for group 2. Constant weight is defined as when peat drying reached constant moisture content in mass when weighed at specified intervals. Accumulatively, peat soil with high water content and contain a large portion of organic material take a rapid time to dry. The initial heating time seem to be independent and constant weight started after 8 minutes for group 1 and 10 minutes for group 2.

Tables 1 and 2 shows the test results of moisture content determination in group 1 for 2 minutes' interval and group 2 with 5 minutes' interval. Microwave oven dried method compare to the convection oven (Memmert) dried method for constant temperature set at 110EC ± 5*EC* for a period of 24 hours [2].

The acidity of peat soil measured ranges from 3.4 to 4.4. The acidity of peat soil disregarded in this research where the main variable in soil drying process is temperature. Table 1 indicated the microwave oven method for 2 minutes interval reached constant weigh after 8 minutes. From 10, 12 and 14 minutes drying time.

The constant rate of moisture contain readable after three times of drying weight are measured. Water rapidly eliminated during heating process and every stages drying process are measured for performance benchmarking. At the end of test, it can be observed that the differences in moisture content recorded 50% to 70%. Final moisture content measured ranges from *AAPt1* 350%, *AAPt2* is about 333.33% and *AAPt3* 400%. These values are compared to the convection oven dried method results, where the moisture content variously possess at the specimens. For test 1 is 491.16%, test 2 489.09% while test 3 about 461.55%. These results governed by slow drying rate with constant temperature dismissed overheating and crusting factor. Table 2 represented 5 minutes interval specimens. The results described a similar state, specimens have gone through long period of heating process. This method rapidly eliminated water and moisture from peat soil are quite encouraging, where time consuming can be shortened. However, there are some obstacles in determining accuracy rate of moisture content. Transformation of specimen are be depicted rapidly deformed. At 10 minutes of heating process, the rate of moisture content slightly constant, in fact the specimen deformed at 15 minutes. Moisture content quickly changed from 333.33% to 1200%. Whereas, the group 1 with 2 minutes interval at final moisture content measured almost recorded in same class with results in convection oven method.

Technically, microwave oven dried method has the advantages in determining moisture content. Take into consideration, peat has high organic content with carbon. The total carbon is reported to be correlated with the soil organic matter [10]. In natural condition, drained tropical peat soils are extremely flammable even under full blazing continuous direct sun. Thus, from the observation, peat has gone through burning process in microwave oven. At the end of the test at 15 minutes, specimens experienced burning, crusty, extremely deformed and smoky. The organic particles are burns and give a risk in safety to the microwave operator. In some soil type water, in the form of hydroxyl molecules, is present within the mineral phase and they are

removed during microwave drying, but not during conventional oven drying method. Therefore, moisture contents by microwave oven drying are higher than those obtained by conventional oven drying. The amount of variance depends on the soil composition [9].

Table 1. Moisture content for 2 minutes interval.

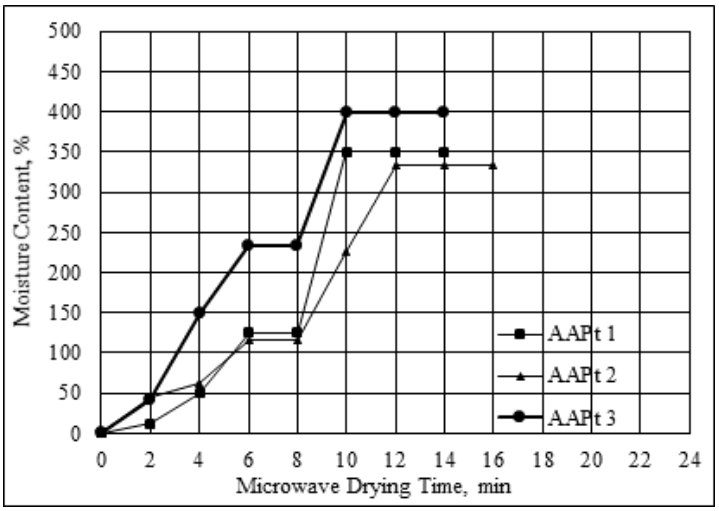
Soil Type	Temperature ^{0}C	Time, (min)	Microwave Oven Method			Convection Oven Method		
			AAPt 1	*AAPt 2*	*AAPt 3*	Test 1	Test 2	Test 3
			m.c (%)	*m.c* (%)	*m.c* (%)	*m.c* (%)	*m.c* (%)	*m.c* (%)
Peat	*P-Hi*	0						
	P-Hi	2	12.5	44.44	42.86			
	P-Hi	4	50	116.67	150			
	P-Hi	6	125	116.67	233.33			
	P-Hi	8	125	225	233.33	Dried for 24 hours		
	P-Hi	10	350	333.33	400			
	P-Hi	12	350	333.33	400			
	P-Hi	14	350	333.33	400			
	105	1440				491.16	489.09	461.65
Total Drying Time (min)			14	14	14	1440	1440	1440
Final Moisture Content (%)			350	333.33	400	491.16	489.09	461.65

Table 2. Moisture content for 5 minutes Interval.

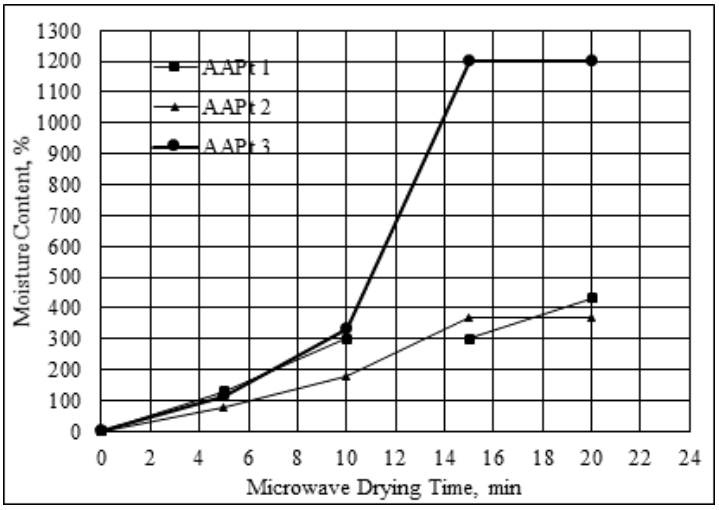
Soil Type	Temperature ^{0}C	Time, (min)	Microwave Oven Method			Convection Oven Method		
			AAPt 1	*AAPt 2*	*AAPt 3*	Test 1	Test 2	Test 3
			m.c (%)	*m.c* (%)	*m.c* (%)	*m.c* (%)	*m.c* (%)	*m.c* (%)
Peat	*P-Hi*	0						
	P-Hi	5	128.5	75	116.67			
	P-Hi	10	300	180	333.33	Dried for 24 hours		
	P-Hi	15	300	366.67	1200			
	P-Hi	20	433.3	366.67	1200			
	105	1440				448.32	480.51	466.61
Total Drying Time (min)			14	14	14	1440	1440	1440
Final Moisture Content (%)			350	333.33	400	491.16	489.09	461.65

Figure 2 shows the moisture percentage versus time for microwave oven method. It can be seen from the Figs. 2(a) and (b), that percentage terms of the changing

patterns of moisture content to time interval. The graph shows the upward trend of moisture content, there is an increase in the time required to dry the peat soil samples. Drying times were 2, 4, 6, 8, 10, 12 and 14 minutes for the group 1 and 5, 10, 15, and 20 minutes for group 2 respectively. For final moisture content test measurement, there are three consecutive times where constant rate recorded for group 1, and 2 consecutive times constant for group 2. Temperature are set to be assigned at *P-Hi* level for all samples, time variables makes the things different to be measured. Based on the time measurement, deformation of organic to ash content formed at prolonged heating conditions at 15 minutes. Samples burns and it can be shown that there has been a decrease in mass that changed the results to a higher moisture content.



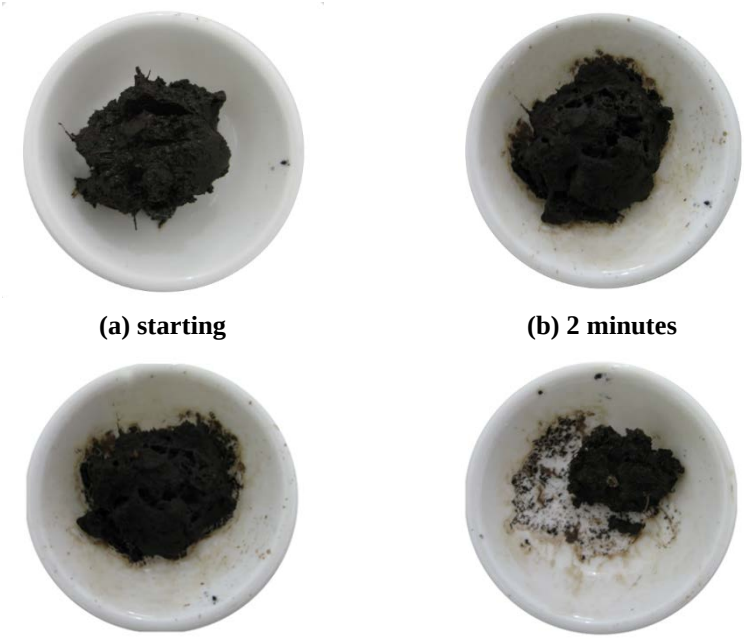
(a) 2 minutes interval



(b) 5 minutes interval

Fig. 2. Moisture percentage changes with microwave oven.

Figure 3 shows the drying phase of peat sample by using microwave oven. Sample began to fully contacted, colour turn to dark and blackish. Sample deformed from large size to extra small which indicates, the moisture and water has been removed from peat soil. Figure 4 shows the peat soil sample crusted, burns and overheated through a prolonged heating time. This stage where organic particle burnt and makes the moisture less effective.



(a) starting **(b) 2 minutes**

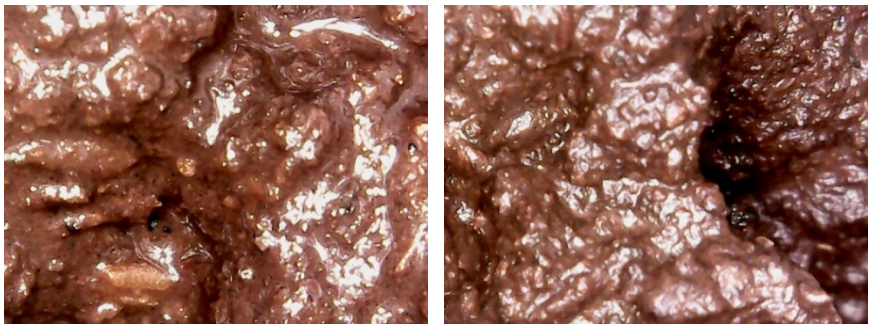
(c) 4 minutes **(d) 10 minutes**

Fig. 3. Specimen drying phase with microwave oven.

Fig. 4. Peat specimen crusting and burning in microwave oven after 10 minutes.

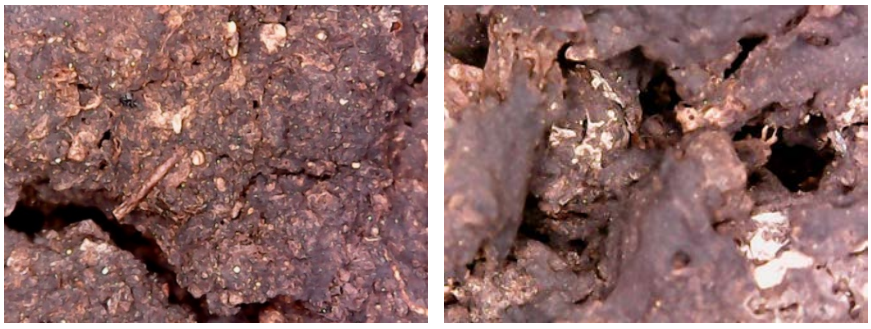
Results of the moisture content tests are presented and compared to the individual moisture contents results obtained using the standard laboratory oven or convection oven dried method. Figure 5 shows the photograph of peat soil organic particle condition before and after dried with microwave oven. Samples appeared moister and saturated with water before placed in microwave oven and heated to time accordingly. Cracks, overheated and crusty particles tracked and can be seen after dried in microwave oven. Sample shrink while partially turns black in colour and burns

spotted. Highly organic soils and soils containing oils and coal may ignite and burn during microwave drying. Continued operation of the oven after the soil has reached constant weight may also cause damage or premature failure of the microwave oven [2, 11]. Hydrated materials, highly organic soils or soils in which the pore water contains dissolved solids, this test method may not yield reliable moisture content values [8]. Peat contains high water content hence causing the material to be very sensitive and soft [12].



2 minutes **5 minutes**

(a) Before specimens dried.



2 minutes **5 minutes**

(b) After specimens dried.

Fig. 5. Organic particle condition before and after dried with microwave oven.

4. Conclusions

From the results of the tests conducted for peat soil, microwave oven are proven to be quick method for moisture content determination. This is done using microwave oven method and convection oven method where both results are compared. Some concluding observations from the research are given below.

- Peat possess high organic content make it a less ideal method for organic soil. Thus, the possibility of overheating of a peat soil sample are greatly high.
- Care should be taken to reduce rapid drying and prevent crusting or overheating of peat soil sample.
- For safety reason, determination of moisture content of peat soil in prolonged time are not recommended.

Nomenclatures

EC	Oven temperature
P-Hi	Constant temperature setting

Abbreviations

AAPt	Peat sample from Bukau Api-Api area, Klias
m.c	Moisture content
UMS	Universiti Malaysia Sabah
UTHM	Universiti Tun Hussein Onn Malaysia

References

1. Miller, R.J.; Smith, R.B; and Biggar, J.W. (1974). Soil water content microwave oven method. *Soil Science Society of America Proceedings*, 38(3), 535-537.
2. ASTM, D2216. (2019). *Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass.* ASTM International, West Conshohocken, PA.
3. BS, 1377-2. (1990). *Methods of test for soils for civil engineering purposes. Classification tests.* BSI, 93.020, BS 1377-2:1990.
4. Darlene, B.R.; and Sabey, B.R. (2014). Use of a microwave oven for moisture determination in a soil science laboratory. *Journal of Agronomic Education*. 5(1), 25-27.
5. Texas, Dot. (1999). *Determining moisture content in soil materials.* TxDOT Designation: Tex-103-E.
6. Government of Alberta Ministry of Transportation. (1996) *Moisture Content, Part IV, Microwave Oven Method*. ATT-15/96.
7. Revolt, P. (2019). Retrieved January 31, 2019 from https://www.newworldencyclopedia.org/entry/Peat.
8. Philip, W.K.C; and Tony, Y.K.H. (2006). Study on The determination of Moisture Content of Soils by Microwave Oven Method. *Geo Report* No. 221.
9. ASTM, D4643. (2008) *Standard Test Method for Determination of Water (Moisture) Content of Soil by Microwave Oven Heating*. ASTM International, West Conshohocken, PA.
10. Tie Y.L.; and Kueh, H.S. (1979). A review of lowland organic soils of Sarawak, *Department of Agriculture, Technical Paper 4*, Research Branch, Sarawak, Malaysia.
11. Kevin, J.G. (2002). Rapid Drying Soils with Microwave Ovens. *Louisiana Department of Transportation and Development.* Louisiana Transportation Research Center. No. 99-3GT, 736-99-0893.
12. Zainorabidin, A.; and Habib, M.M. (2016). Preliminary Peat Surveys in Ecoregion Delineation of North Borneo: Engineering Perspective. *Electronic Journal of Geotechnical Engineering*, 21(12), 4485-4493.