Rapid Determination of Moisture Content of Soil Using Microwave Oven

Barnali Ghosh [1]

Abstract

Generally, moisture content of soil is determined by heating the soil sample in a hot air oven. As per IS 2720, it takes 24 hrs time at 105°C + – 5°C. The present study shows that a microwave oven is more convenient in determining the water content as it takes much lesser time than conventional hot air oven. A known quantity of water is added to 25 g and 50 g of dry soil for this. The samples with known water content are then heated in microwave oven for 5, 10, 15 and upto 30 minutes for every 5 minutes interval. Water content determined from microwave woven heating is compared with conventional oven water content. Many experiments are conducted with black cotton soil as well as red sandy soil with different water content and it is seen that the results are similar. Thus, we can state that water content can be found out by using a microwave oven and the results are as accurate when we conduct the tests as per IS 2720 Part II and the experiments takes much lesser time. Hence, we can recommend it as an alternate method of determining water content rapidly. It costs much less as power consumption and initial installation cost is less.

Keywords : **Micro wave oven, rapid determination, water content**

I. INTRODUCTION

Generally, moisture content determination of soil in 24 hrs time in the laboratory requires students to come back to the laboratory more than their regular laboratory time. This reason leads us to think about possible use of a microwave oven for moisture content determination [1] of soil in Geotechnical Engineering laboratory. The soil natural moisture content test is one of the basic and the most common research conducted in geotechnical laboratories around the world. The purpose of the article is to study the process of determining the moisture content of soils in microwave oven in a much lesser time compared to hot air oven. It can be also mentioned that in Geotechnical Engineering Laboratory microwave wave can be used not only for determining soil moisture content, but also in drying soils for other laboratory tests, sieve analysis, bulk density and Proctor compaction test [2]. Miller et al. [4] showed that the drying time in microwave oven increased with increasing water content and increasing sample size. In this paper, conventional and microwave oven moisture content test findings are compared to find out the accuracy of the microwave drying technique. It is seen that the results are quite similar. It is also shown that although differences exist between conventional and microwave oven moisture contents, the two values are strongly correlated, and one can be generally predicted from the other [3]. So it can be noted that the microwave oven method to find reliable water content is a robust method, especially for its accuracy and faster performance [4]. Two soils were selected for evaluation. The soil types were two black cotton soil and red sandy soil. Each soil was examined in its natural state. The devices used in the evaluation program are listed as follows:

Paper Submission Date : April 12, 2023 ; Paper sent back for Revision : April 25, 2023 ; Paper Acceptance Date : April 28, 2023 ; Paper Published Online : June 5, 2023

[1] B. Ghosh *(Corresponding Author), Associate Professor,* East Point College of Engineering and Technology. Jnana Prabha, Virgo Nagar Post, Bangalore - 560 049 ; Email : barnalighosh08@gmail.com ;
ORCID iD : https://orcid.org/0000-0002-3949-0022

DOI: https://doi.org/10.17010/ijce/2023/v6i1/173001

1) Convection Oven: The convection oven used was GS Blue M STAT 1900

2) Standard Microwave Oven: The standard microwave oven used was a BAJAJ 1701 MT.

Fig. 1, 2, and 3 show the photograph of microwave oven, black cotton soil, and red sandy soil used for the experiments respectively.

Fig. 1. BAJAJ 1701 MT Microwave Oven

Fig. 2. Dried Black Cotton Soil

Fig. 3. Dried Red Sandy Soil

II. EXPERIMENTAL PROCEDURE

For this study, the moisture content of different soil materials was calculated. For conventional oven, the sample should be placed in the oven for 24 hrs at a temperature of 105°C + –5°C. and the water content is determined using the formula:

$$\text{Water content} = (W2 - W3)/(W3 - W1) \times 100\% \quad (1)$$

Where,

(W2 – W3) is the weight of water present in soil sample and (W3 – W1) is the weight of dry soil mass.

Soil sample with pre-determined water content of 10% was kept for the microwave oven as well as conventional oven method and experiments were done for every 5 minutes interval upto 30 mins time duration like 5, 10, 15, 20, 25, and 30 minutes for microwave oven. It was kept for 24 hrs in the conventional oven and it was seen that after 10 minutes duration the change in moisture content was not very significant in microwave oven. So, we kept the 10 minutes time as optimum and for further narrowing down the time, the experiment was done every 2 mintues upto 10 minutes duration. This time a series of experiments were done for soil of pre-determined water content of 10%, 15%, and 20%. The actual time of drying may be slightly less than stated here since the samples cooled between weighings and when placed back into the oven, it had to be heated again. Thus, a slight

overestimation in drying time could have resulted [6]. Results of the moisture content tests are presented and compared to the individual moisture contents results obtained using the microwave oven or conventional oven dried method.

Samples were saturated with water before placing them in microwave oven and heated to time accordingly. Cracks, overheated, and crusty particles were tracked and could be seen after drying in the microwave oven.

III. RESULTS AND DISCUSSION

Results of the moisture content tests are presented and compared to the individual moisture contents. Table I shows the results obtained using the microwave oven or conventional oven dried method.

From Table I it is seen that for 10% pre-determined moisture content of red sandy soil conventional oven shows a moisture content of 9.87%, which is very close to

TABLE I.

CONVENTIONAL VERSUS MICROWAVE OVEN MOISTURE CONTENTS FOR RED SANDY SOIL WITH 5 MINS TIME INTERVAL

No. of Samples	Soil Type	Time (min)	Water (%)	Temperature (°C)	Moisture Content (%)	Conventional oven method moisture content (%)
1	Red sandy soil	5	10	110	9.17	Dried for 24 hours
2	Red sandy soil	10	10	110	10.02	
3	Red sandy soil	15	10	110	10.03	
4	Red sandy soil	20	10	110	10.23	
5	Red sandy soil	25	10	110	10.30	9.87

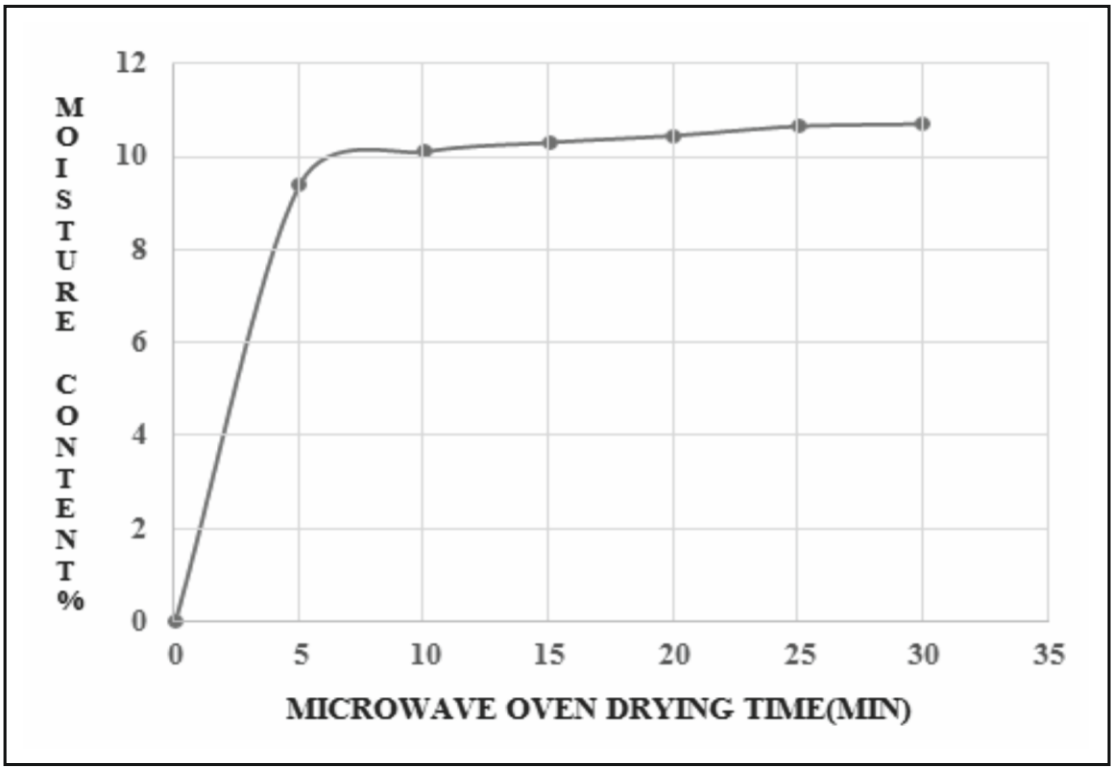

Fig. 4. Time vs Moisture Content curve with 5 mins time interval for Red Sandy soil

10%. Microwave oven shows a moisture content of 10.02% after a heating time of 10 mins.

It is understood from the curve that till 10 mins of time interval there is significant change in moisture content and after 10 mins of time it is almost constant. Further experiments were carried out for every 2 mins time interval and with water content of 10%, 15%, and 20%.

From Table II, it is seen that for all different percentages of water content (10%, 15%, and 20%), 8 mins and 10 mins time interval for microwave oven shows very close results to the actual, whereas, in the conventional oven results are always consistent. After investigation and a series of experiments, it can be decided that the best results can be found out in microwave oven when the sample is heated for 10 mins time and it holds good for all 10%, 15%, and 20%). These experiments were conducted for red sandy soil.

Fig. 5 shows the curves for different moisture content (10%, 15%, and 20%). It is seen that from 8 mins time duration only samples gain uniform pattern, and at 10 mins it becomes optimum.

Similar experiments were conducted for black cotton soil and the results are shown in Table III.

From Table III it is seen that for 10% pre-determined moisture content of Black Cotton soil conventional oven shows a moisture content of 10%, which is very close to 10%. Microwave oven shows a moisture content of 10.1% after heating for 10 mins.

From the curve it is understood that till 10 mins of time interval there is significant change in moisture content and after 10 mins of time it is almost constant. Further experiments were carried out for 2 mins time interval as it was done for red sandy soil with 10%, 15%, and 20% water content.

From Table IV it is seen that for all different percentages of water content (10%, 15%, and 20%), 8 mins and 10 mins time interval for microwave oven shows very close result to the actual as it was seen in red sandy soil. Similar series of experiments were conducted for black cotton soil also and the best results were found in water content in microwave oven when the sample is heated for 10 mins and it holds good for 10%, 15%, and 20% moisture content.

TABLE II.

CONVENTIONAL VERSUS MICROWAVE OVEN MOISTURE CONTENTS FOR RED SANDY SOIL WITH 2 MINS TIME INTERVAL

No. of Samples	Soil Type	Time (min)	Water (%)	Temperature (°C)	Moisture Content (%)	Conventional oven method moisture content (%)
1	Red sandy soil	2	10	110	3.305	Dried in 24 hours
			15		4.01	
			20		7.99	
2	Red sandy soil	4	10	110	9.409	
			15		6.15	
			20		14.6	
3	Red sandy soil	6	10	110	9.64	
			15		11.11	
			20		18	
4	Red sandy soil	8	10	110	10.04	
			15		14.41	
			20		19.85	
5	Red sandy soil	10	10	110	10.28	9.17
			15		15.74	14.5
			20		20.95	18.98

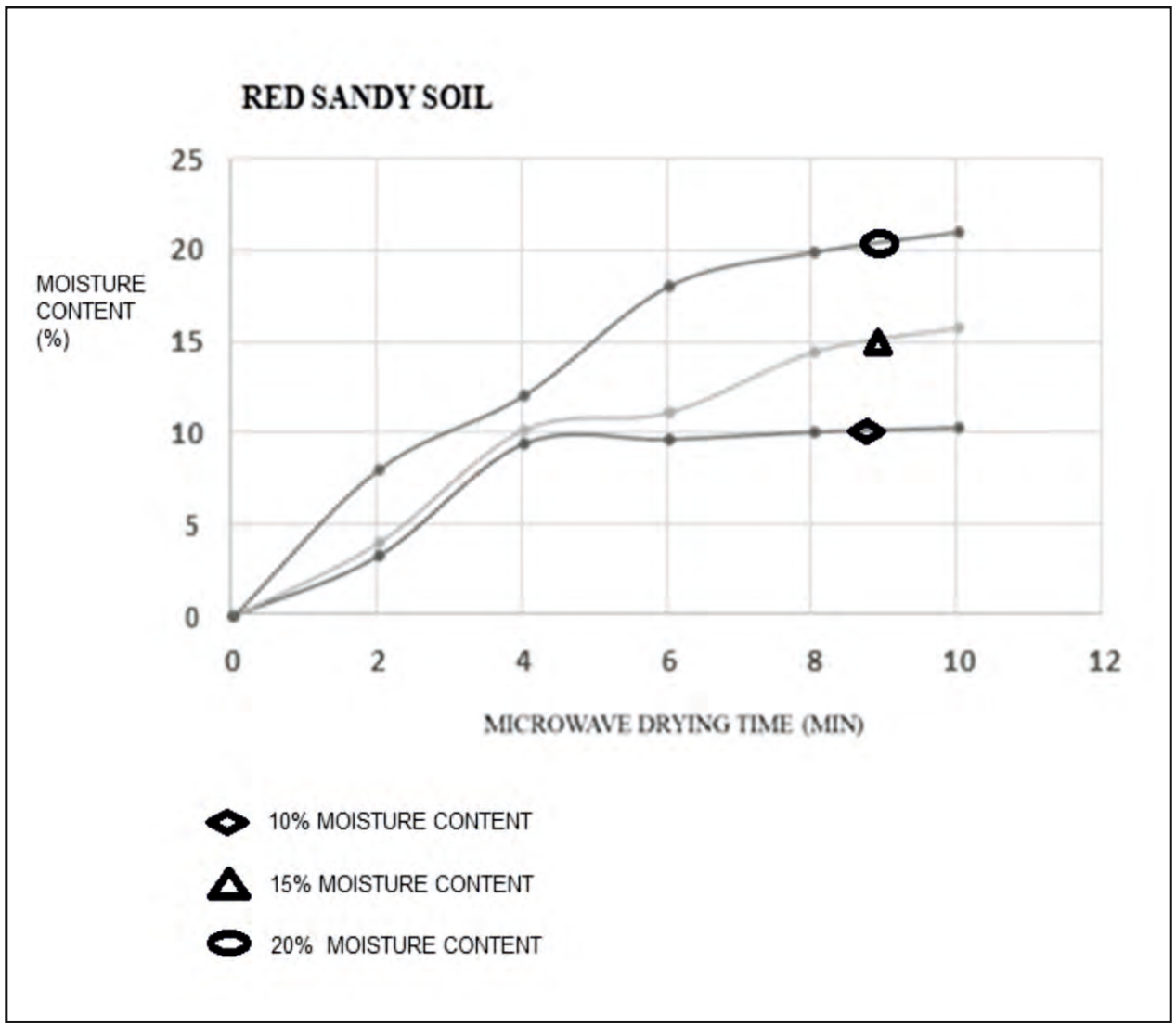

Fig. 5. Time vs moisture content curve for 2 mins time interval

TABLE III.

CONVENTIONAL VERSUS MICROWAVE OVEN MOISTURE CONTENTS FOR BLACK COTTON SOIL WITH 5 MINS TIME INTERVAL

No. of Samples	Soil Type	Time (min)	Water (%)	Temperature (°C)	Moisture Content (%)	Conventional oven method moisture content (%)
1	Black cotton soil	5	10	110	9.409	Dried for 24 hours
2	Black cotton soil	10	10	110	10.10	
3	Black cotton soil	15	10	110	10.30	
4	Black cotton soil	20	10	110	10.45	
5	Black cotton soil	25	10	110	10.60	10.00

TABLE IV.

CONVENTIONAL VERSUS MICROWAVE OVEN MOISTURE CONTENTS FOR RED SANDY SOIL WITH 2 MINS TIME INTERVAL

No. of Samples	Soil Type	Time (min)	Water (%)	Temperature (˚C)	Moisture Content (%)	Conventional oven method moisture content (%)
1	Black cotton soil	2	10	110	9.409	Dried for 24 hours
			15		12.35	
			20		12.86	
2	Black cotton soil	4	10	110	9.45	
			15		13.70	
			20		14.06	
3	Black cotton soil	6	10	110	9.85	
			15		14.89	
			20		17.80	
4	Black cotton soil	8	10	110	10.05	
			15		15.55	
			20		19.66	
5	Black cotton soil	10	10	110	10.10	10
			15		15.98	14.80
			20		20.45	19.65

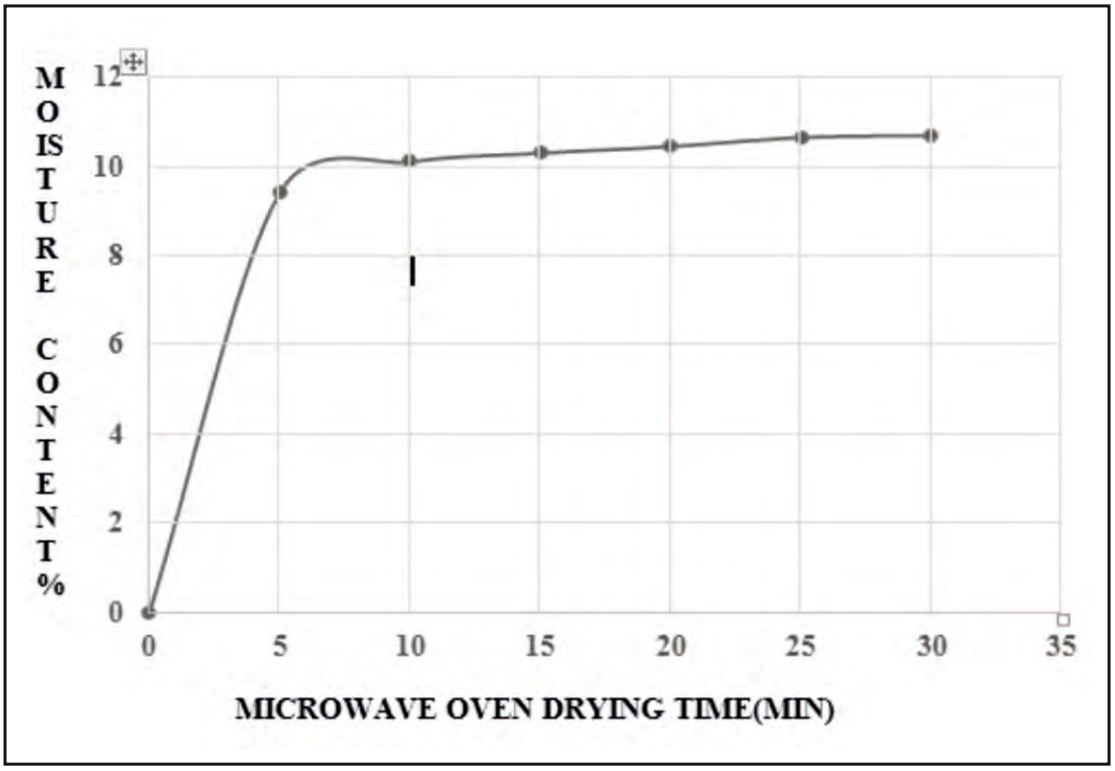

Fig. 6. Time vs moisture content curve with 5 mins time interval for Black Cotton soil

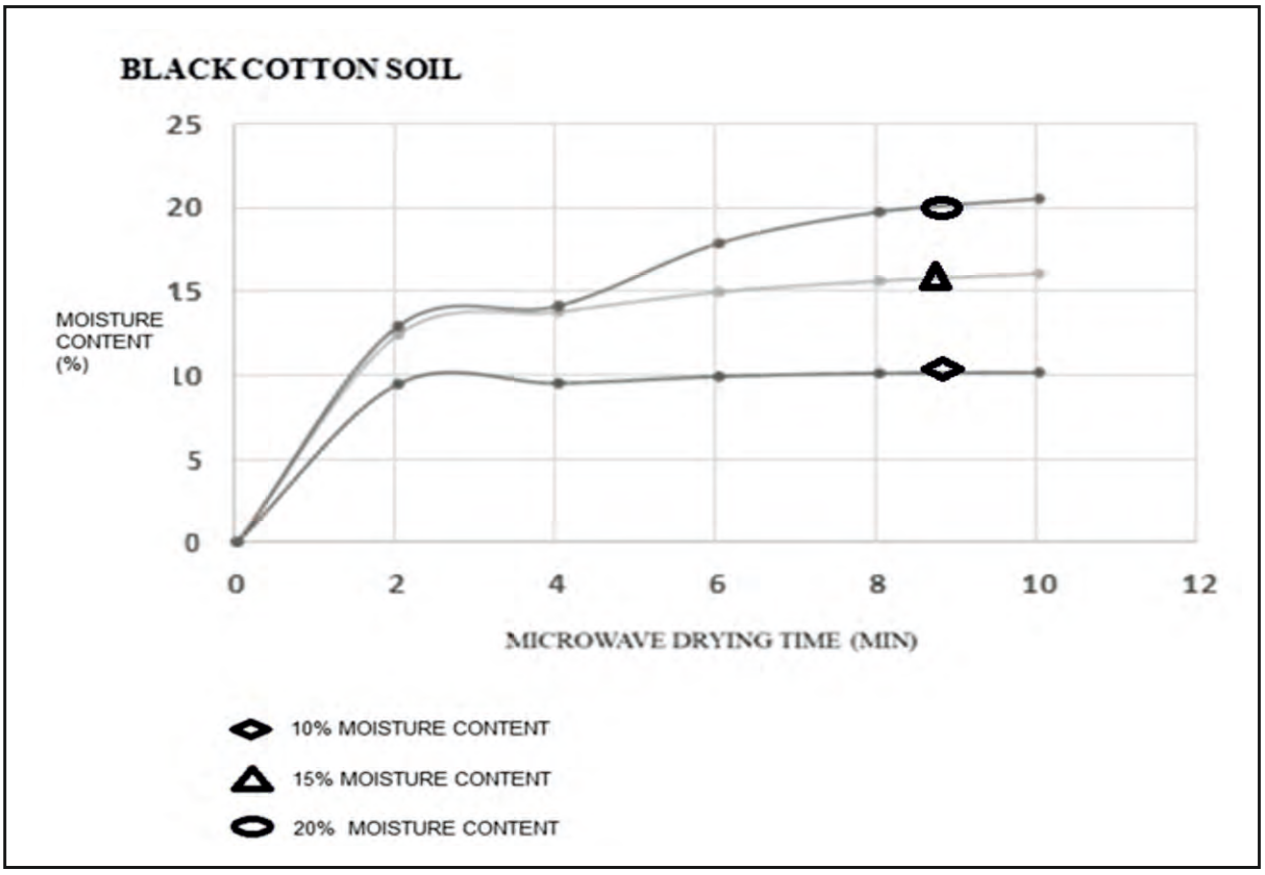

Fig. 7. Time vs moisture content curve for 2 mins time interval for Black Cotton soil

IV. CONCLUSION

Results of the moisture content tests are presented and compared to the individual moisture contents results obtained using the microwave oven or conventional oven dried method.

From the results of the tests conducted for red sandy soil and black cotton soil, microwave oven is proven to be a quick method for moisture content determination. This is done using microwave oven method and conventional oven method where both results are compared. Hence, the research results have proved that microwave ovens are an effective means to rapidly determine water content in sandy and organic soil. Since tests are carried out in shorter time and the results obtained are as accurate as they are when using drying ovens. The procedures developed and used for drying soils with microwave oven are timely, efficient, accurate, and safe. The power consumed by microwave is 1 kWh per hour but the power consumed by conventional oven is 4 kWh per hour. So, the benefit to cost analysis indicated that the microwave oven is the most feasible device. As the implementation is simple and it saves energy, this method can be very useful for earthworks contractors to control the quality of performed works [5]. However, the implementation of such new method should be preceded by multiple tests with the use of an air dryer in order to determine the time of heating the samples in the oven [5].

V. SCOPE FOR FUTURE STUDY

As we already know, a wide variety of materials including inorganic and organic clays, bentonite etc. have already been tested in microwave oven for the determination of water content. However, according to Gilbert [7], soil with organic materials exhibit smoking and ignition problems when heated in traditional microwave ovens and is not suitable for microwave oven drying. So, future studies can be done with soil which is having organic materials such as peat.

AUTHOR'S CONTRIBUTION

Barnali Ghosh is the sole author and she has performed the entire work described in the paper. She herself has conducted testsand analyzed the results.

CONFLICT OF INTEREST

There is no conflict of interest regarding any involvement of any person and organization.

FUNDING ACKNOWLEDGEMENT

The author has not received any financial support for the research, authorship, and/or the publication of the article.

REFFERENCES

[1] D. B. Routledge and B. R. Sabey, "Use of a microwave oven for moisture determination in a soil science laboratory," *J. Agr. Education*, 5, pp. 25–27, 1976. [Online]. Available: https://www.agronomy.org/files/publications/nse/pdfs/jnr005/005-01-0025.pdf

[2] M. Jastrzębska, "Practical application of the microwave oven in the geotechnical laboratory," *Architecture Civil Engineering Environment*, vol. 12, no. 2, pp. 91–104. , 2019, doi: 10.21307/acee-2019-026.

[3] M. A. Usmen and H. Y. Kheng, "Use of microwave oven for rapid determination of moisture content of highway materials," Transportation Research Record 1056, pp. 68–75. [Online]. Available: https://onlinepubs.trb.org/Onlinepubs/trr/1986/1056/1056-009.pdf

[4] R. J. Miller, R. B. Smith, and J. W. Biggar, "Soil water content-microwave oven method," *Soil Sci. Soc. Am. Proc.* 1974, 38, no. 3, pp. 535–537. [Online]. Available: https://doi.org/10.2136/sssaj1974.03615995003800030042x

[5] P. Prokopowicz, P. Pires, A. Michalek, A. Rybak, and A. M. Khairutdinov, "Time necessary for microwave drying of mineral soils," *J. Physics: Conf. Series*, 1614 01202, 2020, doi: 10.1088/1742-6596/1614/1/012021.

[6] D. B. Routledge and B. R. Sabey, "Use of a microwave oven for moisture determination in a soil science laboratory," *J. Agronomic Educ.* pp. 25–27. [Online]. Available: https://www.agronomy.org/files/publications/nse/pdfs/jnr005/005-01-0025.pdf

[7] P. A. Gilbert, "Rapid water content by computer-controlled microwave drying," *J. Geotechnical Eng.*, vol. 117, no. 1, pp. 118–138. [Online]. Available: https://trid.trb.org/view/351954

About the Author

Barnali Ghosh has more than 19 years of experience in teaching in different Engineering Colleges. She completed B.E. (Civil Engineering) from Tripura Engineering College (currently NIT Agartala), and M. Tech. (Soil Mechanics and Foundation Engineering) from Jadavpur University, Calcutta. She is currently pursuing Ph.D. from VTU, Belgaum in Geotechnical Earthquake Engineering. She has published papers in various national and international journals and conferences. She is a Life member of Indian Society for Technical Education (ISTE) and Institute of Engineers and is working as an Associate Professor at East Point College of Engineering and Technology, Bengaluru.