International Journal of Architectural, Civil and Construction Sciences
ISSN: 2415-1734
Vol:6, No:7, 2012

Determination of Moisture Content and Liquid Limit of Foundations Soils, using Microwave Radiation, in the Different Locations of Sulaimani Governorate, Kurdistan Region-Iraq

Heyam Daod

***Abstract*—**Soils are normally dried in either a convection oven or stove. Laboratory moisture content testing indicated that the typical drying durations for a convection oven were, 24 hours. The purpose of this study was to determine the accuracy and soil drying duration of both, moisture content and liquid limit using microwave radiation. The soils were tested with both, convection and microwave ovens. The convection oven was considered to produce the true values for both, natural moisture content and liquid limit of soils; it was, therefore, used as a basis for comparison for the results of the microwave ovens. The samples used in this study were obtained from different projects of Consulting Engineering Bureau of College of Engineering of Sulaimani University. These samples were collected from different locations and at the different depths and consist mostly of brown and light brown clay and silty clay. A total of 102 samples were prepared. 26 of them were tested for natural moisture determination, while the other 76 were used for liquid limits determination.

***Keywords*—**Fine-grained soils, liquid limit, microwave drying, moisture content

I. Introduction

MICROWAVE radiations are a viable means of rapidly drying soils. The procedures developed and used for drying soils with a microwave oven are timely, efficient, accurate, and safe [7].

The microwave radiations were used as early as 1939 during the Second World War to detect Nazi aircrafts. Military officers discovered that cold coffee near a microwave radar became hot and hence recognized the heating effect of microwaves [4]. The use of microwave heating to measure the moisture content of soil has been investigated by engineers since 1960s.

Creelman and Vaughan, 1966 in [7] claimed that they could obtain fairly accurate results for some Canadian soils by heating samples in microwave oven for 10 minutes. According to [8] for most soils, the microwave oven drying method gives a result accurate to within 0.4% moisture content. He used the microwave oven of output power of 500-2000 Watts, for time drying of 10 to 15 minutes.

Heyam Daod is with University of Sulaimani, Faculty of Engineering, Dams and Water Resources Department., Sulaimani, Kurdistan Region-Iraq. dhyam12@yahoo.com

Reference [2] reported that the difference in moisture content between microwave heating and conventional heating ranges from 0.01% (for sand) to 1.4% (for clay with Plasticity Index = 53%). He used the output power of 700 Watts of microwave oven and the time drying from 10 to 24 minutes. [6] tried two different procedures to dry soil samples. In the first one the time drying in the convection oven was 30 hours and 15 minutes in microwave oven. In the second procedure the time drying in the convection oven was 24 hours and 35 minutes in microwave oven. He found that the two procedures yielded different moisture content values and required drying time increased with specimen size and initial moisture content.

Reference [5] also studied soil drying by microwave oven method and noticed that soil with higher moisture content required longer microwave drying time. They used microwave of output power 970 Watts and 20 minutes time drying. Output power of 700 Watts of microwave oven and the time drying 8 to 28 minutes were used by [3].

In 1987, American Society for Testing and Materials [1] published for the first time a standard test method, for determining moisture content of soil using a microwave oven. ASTM stated that the microwave oven method is intended not as a replacement for the conventional oven method, but rather as a supplement when rapid results are needed to expedite other phases of testing.

II. Materials And Methodology

The main devices used in this study to determine the moisture content and liquid limit of the foundations soils are: A convection oven (Memmert) with a constant temperature 105 ºC for a period of 24 hours, microwave oven (Prestige GS25 with output power 900 Watts), accuracy balance (0.01), Casagrande device for liquid limit determination and special porcelain containers for microwave oven.

The collected samples were tested as follows:

- For determining moisture content: from each sample have been taken two equal specimens of about 150-200 g., for drying in Convection and Microwave Ovens. For Convection Oven the specimen was placed in a normal metal container, while for Microwave Oven, the specimen was placed in a porcelain container to avoid introduction of spark between metal containers and microwaves inside Microwave Oven.
- For determining the liquid limits: the samples were tested according to ASTM method and from the paste prepared for liquid limit, were taken two equal

TABLE I

RESULTS OF COMPARATIVE MOISTURE CONTENT BETWEEN CONVECTION OVEN (CO) AND MICROWAVE OVEN (MWO)

Locations of samples	Borehole No.	Sample's depth (m)	Test's No.	Soil's type	Moisture Content (%) by CO	Moisture Content (%) by MWO	Difference in Moisture Content (%)
Sulaimani-Chwarchira	1	2	1	Brown clay	19.12	18.02	1.10
		3	2	Brown clay	11.22	10.54	0.68
		4	3	Brown clay	7.70	8.38	-0.68
	2	2	4	Brown clay	13.98	13.93	0.04
		3	5	Brown clay	15.70	14.52	1.18
		4	6	Brown clay	19.34	18.84	0.49
	3	1	7	Gravely clay	8.56	7.40	1.17
		2	8	Brown clay	15.70	16.06	-0.37
		3	9	Brown clay	21.86	21.19	0.67
		5	10	Brown clay	21.01	20.19	0.82
	4	1	11	Brown clay	14.62	15.16	-0.55
		2	12	Brown clay	18.49	18.70	-0.21
		3	13	Brown clay	17.76	17.73	0.04
		4	14	Brown clay	8.86	8.50	0.36
	5	2	15	Light brown clay	9.10	9.35	-0.26
		3	16	Brown clay	12.68	11.81	0.87
Chamchamal	1	1	17	Brown clay	13.52	14.57	-1.05
		2	18	Brown clay	16.54	17.49	-0.95
		3	19	Brown clay	18.60	19.23	-0.63
		4	20	Brown clay	18.79	17.59	1.20
	2	1	21	Brown clay	14.29	14.22	0.07
		2	22	Brown clay	15.16	14.68	0.48
		3	23	Brown clay	16.34	16.73	-0.39
	3	1.2	24	Brown clay	14.30	14.56	-0.25
		2	25	Brown clay	15.30	15.09	0.21
		3	26	Brown clay	16.56	16.84	-0.28

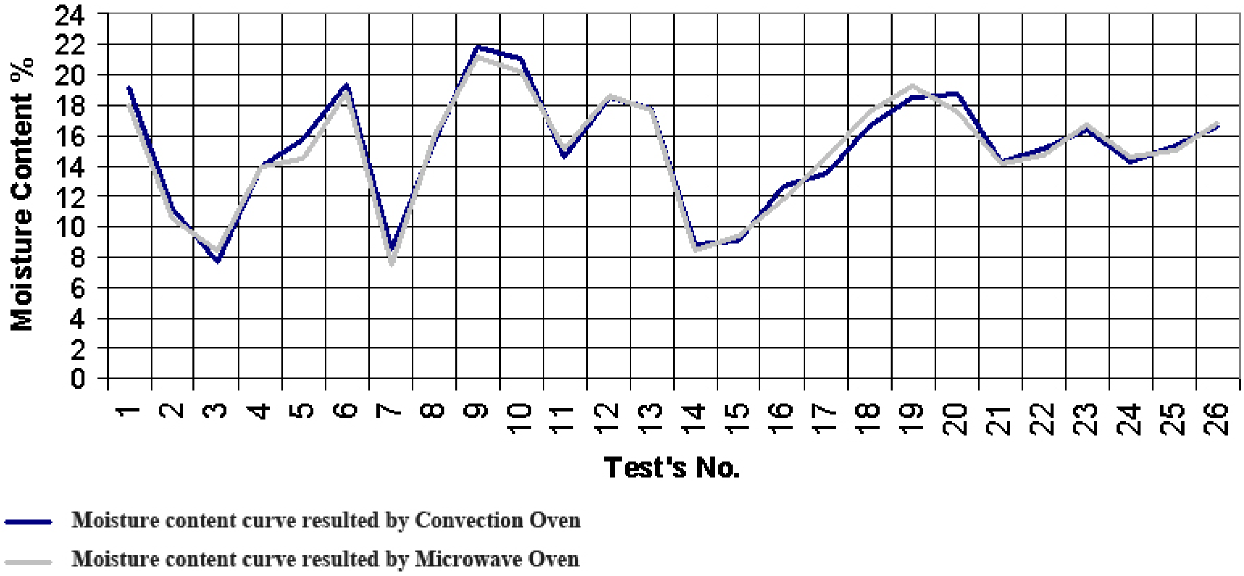

Fig. 1 Moisture content curves

TABLE II
RESULTS OF COMPARATIVE LIQUID LIMIT BETWEEN CONVECTION OVEN (CO) AND MICROWAVE OVEN (MWO)

Locations of samples	Borehole No.	Sample's depth (m)	Test's No.	Soil's type	Liquid Limit (%) by CO	Liquid Limit (%) by MWO	Difference in L.L. Results (%)
Sulaimani-Qirga	1	5	1	Light brown clay	43.53	44.68	-1.14
	2	5.5-6	2	Light brown clay	35.86	36.22	-0.37
	3	2.3	3	Light brown clay	40.65	39.10	1.56
		3.5-4	4	Light brown clay	37.67	36.87	0.80
		4-5.5	5	Light brown clay	30.32	29.12	1.20
		6-7.5	6	Light brown clay	39.52	40.55	-1.03
		7.5-8	7	Light brown clay	49.17	50.78	-1.60
Sulaimani-Zerinok	2	3.4	8	Brown clay	35.58	34.91	0.67
Rania	1	1	9	Brown clay	49.73	50.15	-0.42
	2	1	10	Brown clay	51.40	51.52	-0.12
	3	1	11	Brown clay	51.23	50.51	0.72
	4	1	12	Brown clay	55.04	54.69	0.35
	5	1.1	13	Brown clay	55.24	55.24	0.00
Sulaimani-Zargata	1	1	14	Brown clay	51.74	52.15	-0.41
		2	15	Brown clay	47.95	47.05	0.90
	2	2	16	Brown clay	43.78	42.82	0.96
Sulaimani-Zanko Camping	1	4	17	Brown clay	46.48	46.53	-0.05
		5.5	18	Brown clay	48.14	47.52	0.61
	2	4.5	19	Brown clay	62.17	61.78	0.39
Kalar-1	2	3	20	Brown clay	35.23	34.87	0.36
		4	21	Brown clay	33.27	33.14	0.13
	3	2.5	22	Brown clay	30.14	29.50	0.64
		4	23	Brown clay	27.93	27.63	0.29
	4	2.5	24	Brown clay	36.41	36.43	-0.02
		4	25	Brown clay	35.08	35.04	0.04
	5	5	26	Brown clay	41.53	41.31	0.22

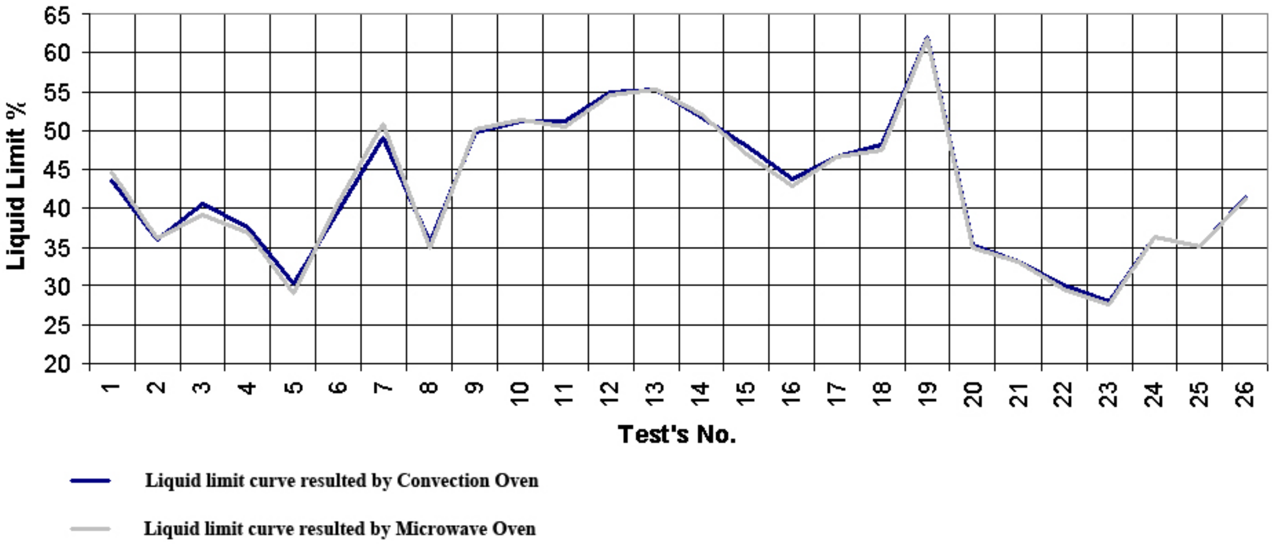

Fig. 2 Liquid limit curves of table II

TABLE III
RESULTS OF COMPARATIVE LIQUID LIMIT BETWEEN CONVECTION OVEN (CO) AND MICROWAVE OVEN (MWO)

Locations of samples	Borehole No.	Sample's depth (m)	Test's No.	Soil's type	Liquid Limit (%) by CO	Liquid Limit (%) by MWO	Difference in L.L. Results (%)
Kalar-2	1	1	1	Brown clay	31.03	30.63	0.40
	2	1	2	Brown clay	30.00	30.67	-0.68
	3	1	3	Brown clay	28.69	28.49	0.20
	4	1.5	4	Brown clay	29.61	29.02	0.59
Chamchamal	1	1	5	Brown clay	44.10	46.47	-2.36
		2	6	Brown clay	43.60	43.77	-0.17
		3	7	Brown clay	48.46	51.07	-2.62
		4	8	Brown clay	44.46	46.26	-1.80
	2	1	9	Brown clay	42.63	43.31	-0.68
		2	10	Brown clay	44.09	44.74	-0.65
		3	11	Brown clay	44.09	45.55	-1.46
	3	1.2	12	Brown clay	40.24	41.61	-1.37
		2	13	Brown clay	47.61	48.83	-1.23
		3	14	Brown clay	54.04	53.36	0.68
	4	1	15	Brown clay	43.67	43.08	0.59
		2	16	Brown clay	46.46	45.63	0.83
		3.5	17	Brown clay	50.67	49.97	0.70
Sulaimani-Raperin	2	3	18	Light brown clay with carbonate	35.3	35.50	-0.20
		4	19	Light brown clay with carbonate	30.5	31.20	-0.70
	3	2.5	20	Light brown clay with carbonate	29.9	30.40	-0.50
		4	21	Light brown clay with carbonate	26.9	26.10	0.80
	4	2.5	22	Light brown clay with carbonate	35.9	35.70	0.20
		4	23	Light brown clay with carbonate	33.2	32.00	1.20
	5	5	24	Light brown clay with carbonate	44.5	43.60	0.90

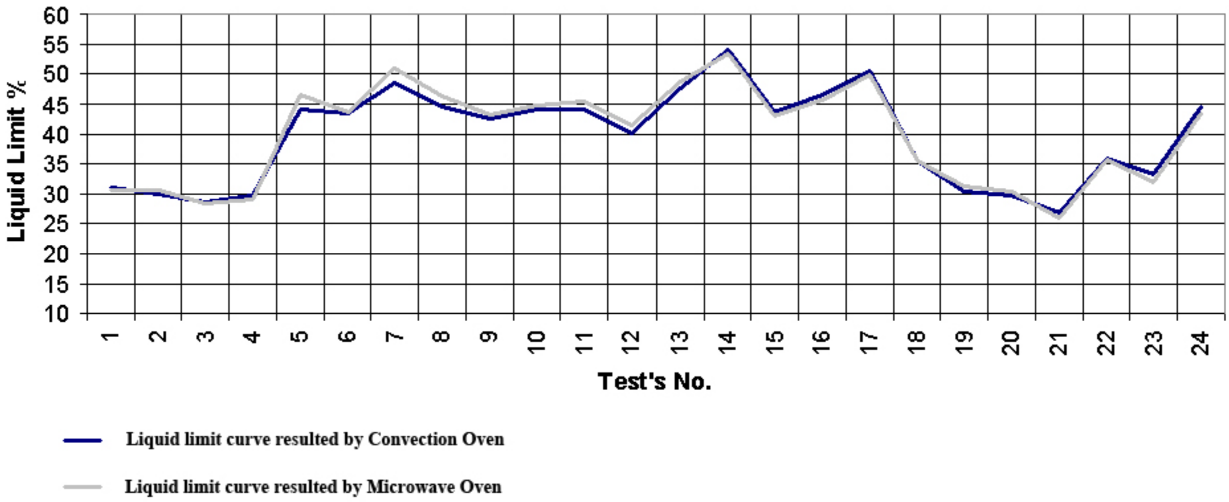

Fig. 3 Liquid limit curves of table 3

TABLE IV
RESULTS OF COMPARATIVE LIQUID LIMIT BETWEEN CONVECTION OVEN (CO) AND MICROWAVE OVEN (MWO)

Locations of samples	Borehole No.	Sample's depth (m)	Test's No.	Soil's type	Liquid Limit (%) by CO	Liquid Limit (%) by MWO	Difference in L.L. Results (%)
Sulaimani-Garden City	1	1.5-2	1	Light brown silty clay	43.70	44.3	-0.60
		6.5-8	2	Light brown silty clay	40.30	40.9	-0.60
		8.5-10	3	Light brown silty clay	44.40	44.6	-0.20
		10.5-12	4	Light brown silty clay	41.90	42.9	-1.00
		12.5-14.5	5	Light brown silty clay	44.40	44.6	-0.20
		14.5-15	6	Light brown silty clay	44.40	45.1	-0.70
	2	0.0-1.0	7	Light brown silty clay	41.00	40.52	0.48
		1.5-2.0	8	Light brown silty clay	42.40	41.50	0.90
		3.0-4.0	9	Light brown silty clay	41.36	40.92	0.44
		5.0-6.5	10	Light brown silty clay	48.01	47.29	0.72
		7.0-8.5	11	Light brown silty clay	46.38	45.34	1.04
	3	1.5-2.5	12	Light brown silty clay	50.10	50.07	0.04
		3-4.5	13	Light brown silty clay	47.80	47.2	0.60
		5-6.5	14	Light brown silty clay	46.60	47.8	-1.20
		7-8.5	15	Light brown silty clay	46.10	46.9	-0.80
		9-10.5	16	Light brown silty clay	44.30	45.3	-1.00
	4	2-2.5	17	Light brown silty clay	35.80	35.4	0.40
		3-4.5	18	Light brown silty clay	47.90	48.5	-0.60
		5-6.5	19	Light brown silty clay	46.00	45.9	0.10
		7-8.5	20	Light brown silty clay	45.90	46.2	-0.30
		9-10.5	21	Light brown silty clay	43.61	43.34	0.28
		10.5-11	22	Light brown silty clay	40.00	40.8	-0.80
		13-13.5	23	Light brown silty clay	50.10	50.7	-0.60
	5	1.5-2.5	24	Light brown silty clay	41.20	41.4	-0.20
		7-8.5	25	Light brown silty clay	40.30	39.8	0.50
		9-10.5	26	Light brown silty clay	42.10	42.9	-0.80

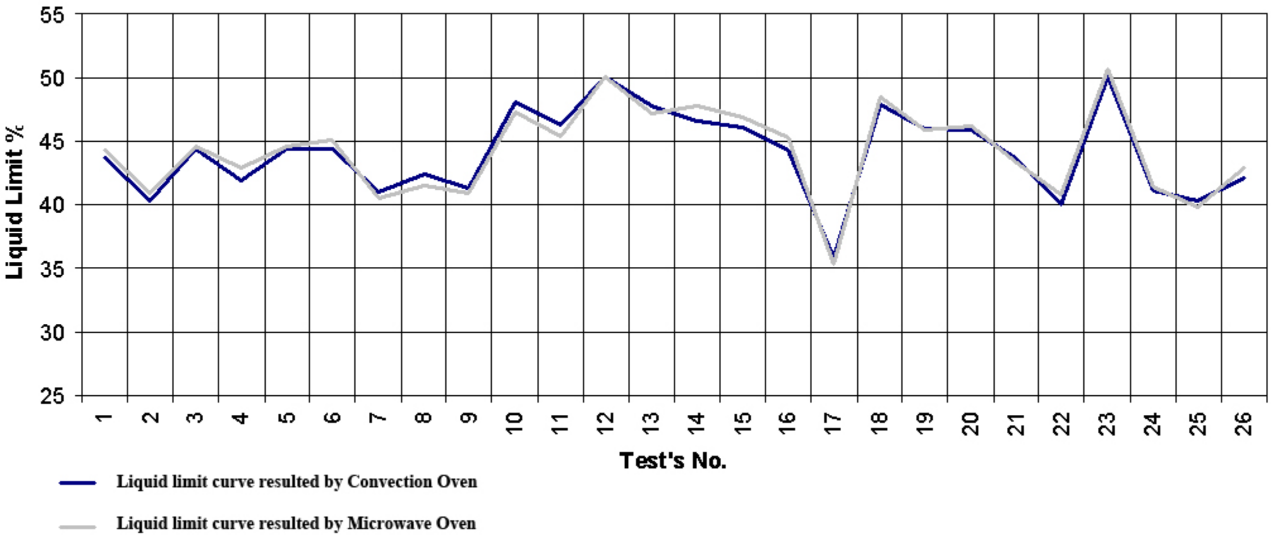

Fig. 4 Liquid limit curves of table 4

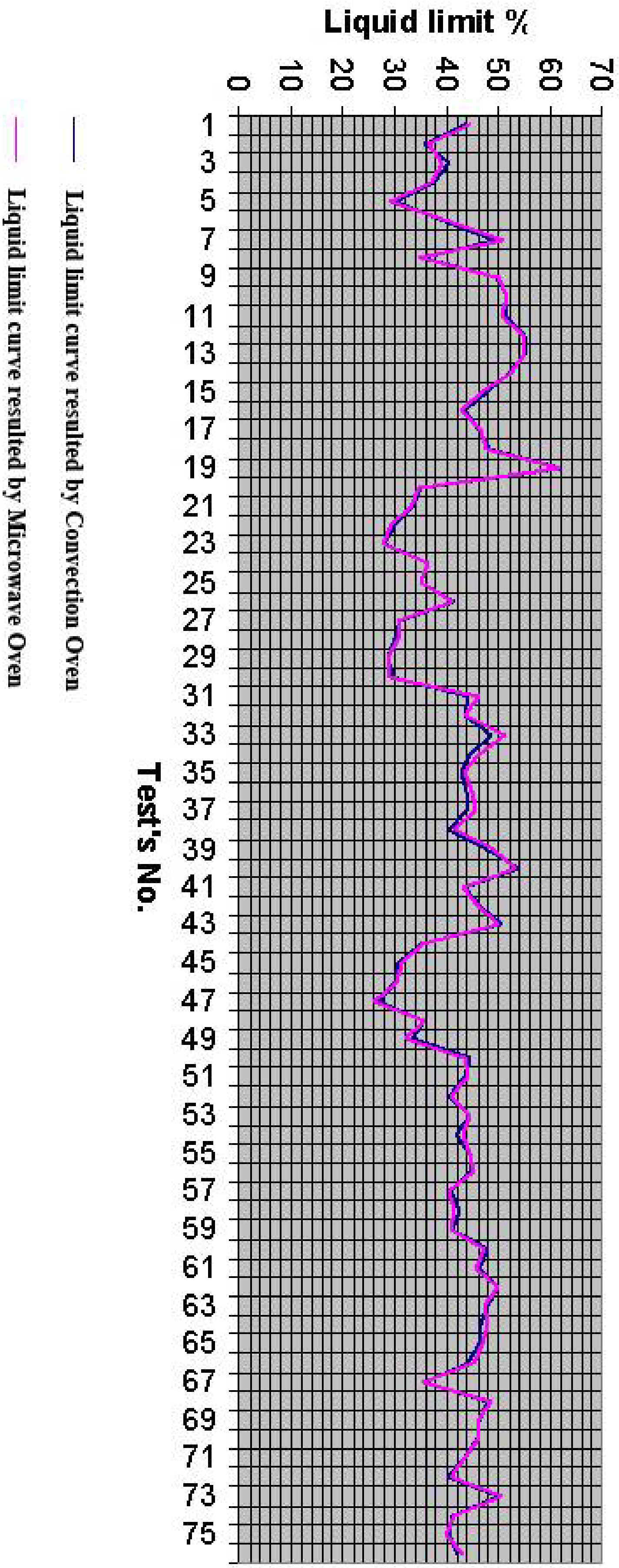

Fig. 5 Liquid limit curves of total tested samples

quantities of about 50-60 g. for drying in the two ovens, as well as the first stage.

- For both determinations, moisture content and liquid limit in the Microwave Oven, the specimens were tested at intervals, 10 minutes, 20 minutes and 30 minutes. The typical drying duration was 30 minutes and the drying time for Convection Oven was 24 hours.

III. Discussion of Results

Microwave ovens are a viable means of rapidly drying soils. This study has shown that they are safe, accurate, and efficient. There were no aggregate explosions, fires, or vaporization of organics at the power settings and testing intervals used in this study. This study would enhance the efficiency of the laboratory since moisture contents and Atterberg limits could be obtained within 30 minutes instead of 24 hours. It can be seen that the moisture contents and liquid limits determined by Microwave Oven method agree very well with those obtained from Convection Oven method and they are very close to each other with a very little difference between them. Specimens used with the microwave described should have an initial mass between 150 and 200 g for moisture content and 50-60 g for liquid limits determination. Smaller specimens will not dry as efficiently and will likely yield less accurate water content, especially for highly plastic soils. Larger specimens will result in a longer time required for drying and unnecessary energy expenditure. Containers used in the microwave oven should be able to transmit microwaves and this excludes metal containers. The porcelain containers are recommended.

The tests were conducted and the values of the moisture content and liquid limit along with the duration required to complete testing were recorded. The values were placed in a Microsoft Excel spreadsheet to illustrate the results as well as to calculate the difference values of moisture content and liquid limit between both, microwave and convection ovens.

Moisture content tests were conducted with the Convection Oven (CO) and Microwave Oven (MWO) on the soils listed in table 1 and Fig. 1, and the values of liquid limit are listed in tables 2, 3, 4 and figs. 2, 3, 4 and 5.

The difference between the two moisture contents obtained by two ovens, range between 0.04% and 1.20% (table 1). From the 26 samples were analyzed, only 4 samples had differences 1.0-1.20% (table 1) and others 22 samples had differences less than 1%. The two moisture content curves obtained by CO and MWO, almost overlap, with little difference across samples 5, 17 and 20.

From 76 samples that were analyzed, to determine the liquid limits by both, CO and MWO, the differences between the liquid limits were calculated, and it was found, that the biggest difference reaches 1.80% for majority tested samples, except for two samples which were 2.36% and 2.62%. Only 16 samples had differences between 1% and 2.62% (tables, 2, 3, 4) and others 60 samples had differences less than 1%. The two curves of the liquid limits obtained by CO and MWO are almost overlapping (Figs. 2, 3, 4, 5). Analyzing the data in tables 1-4, figures 1-5 and comparing them with previously published data, it can be concluded that in such soils, the moisture contents and Atterberg limits, can determine using the MWO, shortening the drying time from 24 hours to 30 minutes.

IV. Conclusion

1. Moisture contents and Atterberg limits were obtained within 30 minutes instead of 24 hours;
2. Moisture contents and liquid limits determined by both Convection and Microwave Ovens are very close to each other with maximum difference of 1.2 % in moisture content and of about 1.8 % in liquid limits;
3. The suitable time requested for drying in microwave oven was 30 minutes;
4. The suitable containers used in microwave oven were porcelain containers;
5. The suitable initial mass for moisture content determination is between 150-200 g and 50-60 g for liquid limits determination;
6. The output power recommended for Microwave Oven is 900 Watts.

References

[1] ASTM D 4642-87, “Standard Test Method for Determination of Water Moisture Content of Soil by the Microwave Oven Method”, 1987

[2] Gilbert, P. A., “Evaluation of soil mechanics laboratory equipment, Report 13, feasibility study, microwave oven used for rapid determination of soil water contents”. Misc Paper No. 3-478. U.S. Army Engineer Waterways Experiment Station, Vicksbury, MS, 1974

[3] Hagerty, D. J. *et al.*, “Microwave drying of soils. Geotechnical Testing”. Journal, Vol. 13, No. 2, p. 138-141, 1990

[4] He, X. Y., “Theory and application of microwaves”. Science Monthly, Vol. 292, Science Monthly and King-Taiwan Information Technology Inc., 1994

[5] Lade, P. V. and Nejadi-Babadai H., “Soil drying by microwave oven. Soil specimen preparation for laboratory testing”. ASTM STP 599. ASTM, Philadelphia, p. 320-335, 1975

[6] Miller, R. J. *et al.*, “Soil water content microwave oven method”. Soil Science Society of America Proceedings, Vol. 38, No. 3, p. 535-537, 1974

[7] Philip W. K. Chung and Tony Y. K. Ho, “Study on the determination of moisture content of soils by microwave oven method”. Geo Report no. 221, Geotechnical Engineering Office, Hong Kong, 2008

[8] Ryley, M. D., “The use of a microwave oven for the rapid determination of moisture content of soils”. RLR Report LR280. Road Research Laboratory, Crowthorne, England, 1969