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EFFECT OF DRYING TEMPERATURE ON THE PHYSICAL PROPERTIES OF SOIL

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Abstract

According to ASTM, in soil tests, the soil sample must be dried either by air or in the oven to save time, assuming that the results of the different drying methods are identical. The effect of three different degrees of drying, air drying (25 °C), oven drying (60°C, 110°C), on the physical properties of a soil sample was investigated in this study. in addition to atterberg limits, this research looks at the effect of temperature on standard compaction tests, specific weight, and granular analysis. The results show that, higher degrees of drying may result in the loss of all free water and the majority of attached water, resulting in soil restructure and a reduction in soil plasticity, especially if there is an organic content. The clay content decreases after drying due to aggregation, while the silt content increases. Drying causes a decrease in maximum dry density and an increase in optimum water content, but has no significant effect on specific gravity tests.

الملخص

وفقًا لـ **ASTM**، في اختبارات التربة، يجب تجفيف عينة التربة المختبرة إما عن طريق الهواء أو فرنيا لتوفير الوقت، على افتراض أن نتائج طرق التجفيف المختلفة متطابقة. تمت دراسة تأثير ثلاث درجات مختلفة من التجفيف، التجفيف بالهواء (25 درجة مئوية) والتجفيف بالفرن (60 درجة مئوية، 110 درجة مئوية) على الخصائص الفيزيائية لعينة التربة في هذه الدراسة. بالإضافة إلى حدود أتيربيرج، تبحث هذا الدراسة تأثير درجة الحرارة على اختبار الدمك القياسي، والوزن النوعي، والتحليل الحبيبي. النتائج بينت ان قد تؤدي درجات التجفيف العالية إلى فقدان كل المياه الحرة ومعظم المياه المرفقة، مما يؤدي إلى إعادة هيكلة التربة وتقليل لدونة التربة، خاصةً إذا كان بها محتوى عضوي. ينخفض محتوى الطين بعد التجفيف بسبب التراكم، بينما يزداد محتوى الطمي. يتسبب التجفيف في انخفاض الكثافة الجافة القصوى وزيادة محتوى الماء الأمثل، ولكن ليس له تأثير كبير على اختبارات الجاذبية النوعية..

Keywords: drying temperature, Atterberg limits, compaction, specific gravity, organic soil.

INTRODUCTION

Because the soil is the most important component in any structure and can be the primary cause of its failure, the properties of the soil on which the structure will be built must be precisely calculated. Soils are mineral particle aggregates that form a three-phase system with air and/or water (in a void system). So, the main structure of the soil is: solid particles and voids filled with air, water, or both; any change in this structure can cause stresses in the soil mass, acting on the civil structure that comes into contact with it. Terzagi [1] states that soil consolidation is the process of losing water without replacing it with air, which is commonly caused by applying external load to saturated soil. Understanding water dissipation is critical to understanding the consolidation process. Similarly, losing water by drying can consolidate the soil through internal stresses known as suction stress, which is fully defined by Lu and Likos [2] as "the effective stress due to changes in soil water content.". So, in laboratory tests, soil samples were dried using either air or oven drying, which causes loss of free water as well as attached water that combined with soil and considered a part of its structure, causing restructure of soil and consequently affecting its properties.

Whether the soil is used as supporting materials under foundations or as construction materials. the structures built on it must be designed to be stable and durable, so understanding its behaviour and any changes that may occur is essential. Because soil is a very complex engineering material, studying its properties is essential. Atterberg limits are the most important properties used to describe the behaviour of fine-grained soil since they represent physical and mechanical properties of soil. According to ASTM D4138, there are two methods for determining these limits: wet method at the natural moisture of the soil and dry method where the soil must be drying even in air or in an oven at a temperature not exceeding 60°C. The effect of drying temperature is an important point that has been studied in the past; many studies in the literature show that drying results in a significant change in plasticity limit, particularly for soil containing organic matter, halloysite or allophane minerals [3], [4], [5], [6], [7], [8]. Earlier, Casagrande [3] studied the change of Atterberg limits for samples with two drying methods, one prepared at natural moisture content and the other dried in oven; this soil had an organic content of 2.6%, he discovered that LL and PI decreased from 84%, 34% to 51%, 9% after drying, respectively. As a result, the drying process can cause significant changes in soil properties, with some physical properties changing permanently.

Basma et al. [4] conducted an experimental study to examine the effect of drying method on Atterberg limit, as well as other basic physical properties of soil (grain size distribution, swelling, and compressibility characteristic) on five samples of soil dried at 25°C (air drying), 60°C, and 110°C. They discovered that drying in an oven caused soil aggregation, which resulted in a significant decrease in the liquid limit LL and plasticity index PLAlthough the soil classification did not change, it exhibited less plasticity. The swell and consolidation tests revealed that drying temperature reduced both swell parameters while increasing the compression index. Terzaghi et al [5] investigated the loss of water in soils containing organic matter, stating that this type of soil loses water irreversibly due to the oxidation process, causing clay particles to aggregate and lose their plasticity. They also stated that where a soil was classified as high plasticity silt or organic silt MH-OH in natural moisture, it was classified as silty sand SM after drying.
Yoon et al [9] investigated the effect of drying temperature and time on clay soil index parameters and discovered a significant decrease in both liquid limit and plastic index of up to 16% and 13%, respectively, with increasing drying time and temperature. Uyeturk et al [10] conducted an experimental study on 18 samples of soil with organic content ranging from 4.3% to 12.1%, and the plasticity limits were determined at moisture content, after drying at 60°C, and after drying at 110°C. They discovered that after drying, Atterberg limits decreased at different rates depending on the amount of organic matter and the minerology of the soil due to irreversible dehydration. The majority of previous research focused on the effect of drying on soil plasticity limits because it affects soil classification, but it was discovered that the effect of temperature on other physical characteristics could lead to incorrect conclusions and a lack of understanding of soil behaviour. Sunil and Deepa [11] look at how drying affects three soil properties. Temperature had a long-term effect on the limits of plasticity, compaction characteristics, and strength as measured by CBR.

Despite the fact that this research and its aspects have been studied in the past, it remains an important topic. The purpose of this study is to see how drying temperature affects soil Atterberg limits, granular analysis, compaction parameters, and specific gravity. Under certain conditions, the behaviour of these soils is problematic.

MATERIALS AND METHODOLOGY

In this study, the used soil was collected from Shahat located in the eastern part of Libya. The soil was classified as loam soil and its color was dark grey to green. Table 1 presents the soil sample details and Figure 1 shows the physical appearance of the soil as presented in the site.

The soil sample was dried at room temperature for a month (air dried 25°C±5), then divided into four portions, the first without any additional drying, the second and third in an oven at 60°C±5 and 110°C±5, respectively, for 48 hours. To investigate the effect of drying period on soil plasticity, the remaining soil was dried for three months at room temperature before the two oven drying processes were repeated.

The testing programme that will be used in this study is shown in Figure 2.

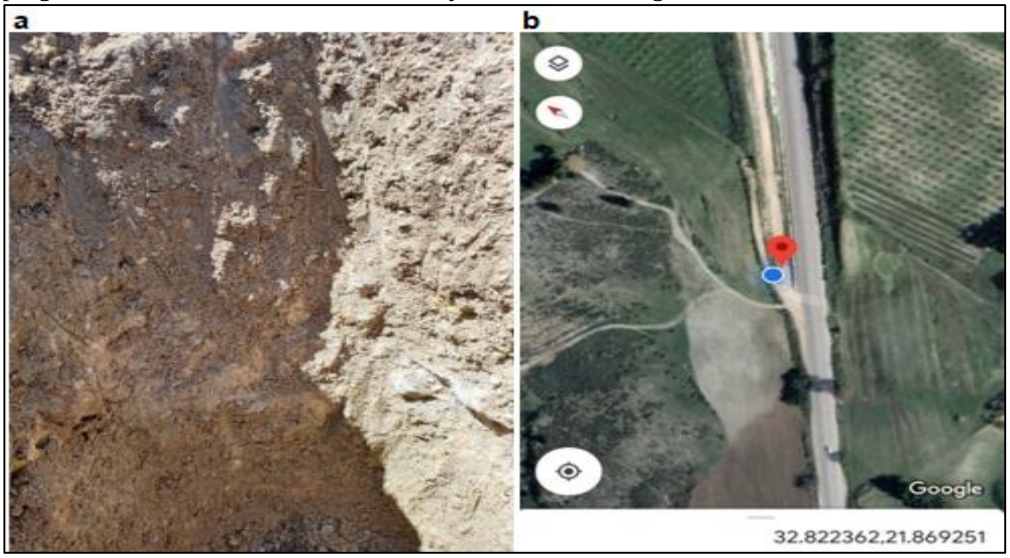

Fig. 1 soil sample used for testing, (a): physical appearance, (b): soil location**.**

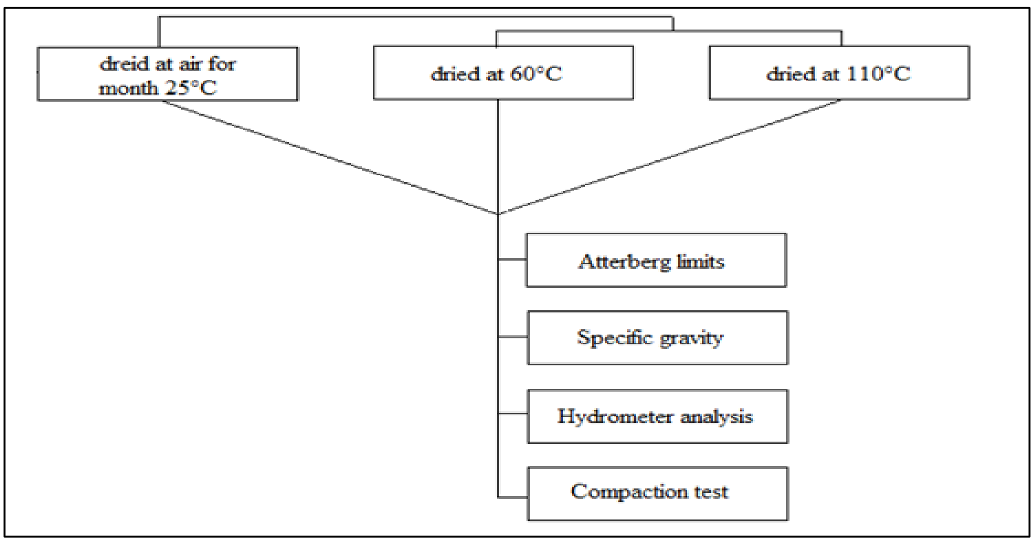

Fig. 2 Experimental program.

RESULTS AND DISCUSSIONS

Table 2 displays the selected physical properties that were tested on the soil drying at three different temperatures (air drying 255 °C, 60 °C, and 110 °C). Each of the soil properties is discussed in detail in the following sections.

Consistency Limits

Raw 2 of Table 2 show the obtained values from the Atterberg limits test of soil, despite the fact that there are various factors effecting these soil indexes that give different results, such as the mass of used sample, relative humidity in the laboratory, testing device, and how much the test is reliable because the accuracy LL from the Casagrande device is 2 [12]. However, because this comparison was conducted

Table 1: details of soil sample used for testing.

Sample marking		Soil sample
Location		Shahat- Libya
coordinates	Latitude	32.822362
	Longitude	21.869251
Water content w (%)		15.17
Sample condition		Disturbed
Depth of soil collected		0.7 m
Field density		1.792 g/cm^3

Table 2: results of properties for tested soil subject to different temperatures.

Soil properties			25±5°C	60°C	110 °C
Consistency limits	**1 m**	**LL (%)**	32.947	34.055	31.173
		PL (%)	19.036	17.933	17.847
		PI (%)	13.911	16.122	14.325
	4 m	**LL (%)**	32.286	31.605	30.608
		PL (%)	18.062	17.059	16.068
		PI (%)	14.225	14.546	14.539
Specific Gravity Gs			2.553	2.635	2.678
Compaction	**Max. dry density Υ_d (g/cm^3)**		1.825	1.768	1.775
	O.W.C (%)		14.831	15.897	16.274
Hydrometer analysis	**Clay (%)**		29.52	16.81	12.84
	Silt (%)		77.263	73.75	60.81

on a single soil, these factors were ignored and it was assumed that the differences were solely due to temperature differences.

Figure 3 depicts the temperature-related variation in soil index. Table 2 and Figure 3 clearly show that different temperatures affect the plasticity limits in different proportions, with the liquid limit being the most affected. The liquid limits decrease as the temperature rises. This can be explained by the fact that as the temperature rises, more soil particles aggregate due to the loss of free water and a portion, if not all, of attached water. These losses produce an irreversible change, which produces interparticle stresses (suction stress). Through this stress, the contact between the particles is facilitated by strong bonds that cannot be easily separated. This aggregation reduces the specific surface of the soil that interacts with water, lowering the limits of plasticity. The redistribution of grains, as well as changes in water content and voids in the soil, cause restructuring and, in extreme cases, a change in classification.

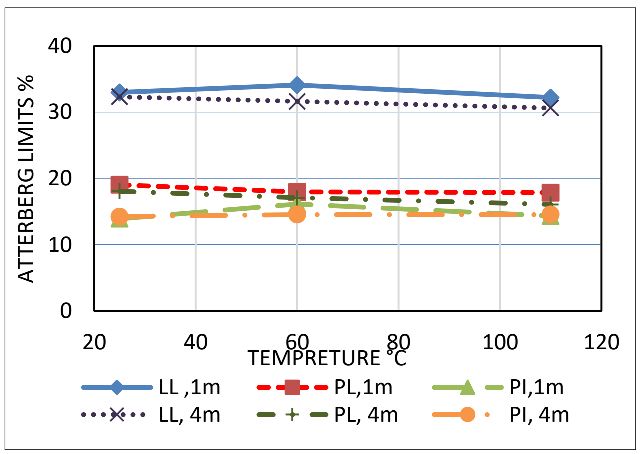

Fig. 3 variation of consistency limits with different temperature drying.

According to yong et al [13], the composition of soil (interaction of soil, water, and air phases) defines its nature, so any change in this structure will affect soil properties. Changing the Atterberg limits in this soil could result in ambiguous results, but this change was not significant enough to change the classification of the soil; Figure 4 shows that the soil in different pre-drying conditions is classified as CL according to USCS.

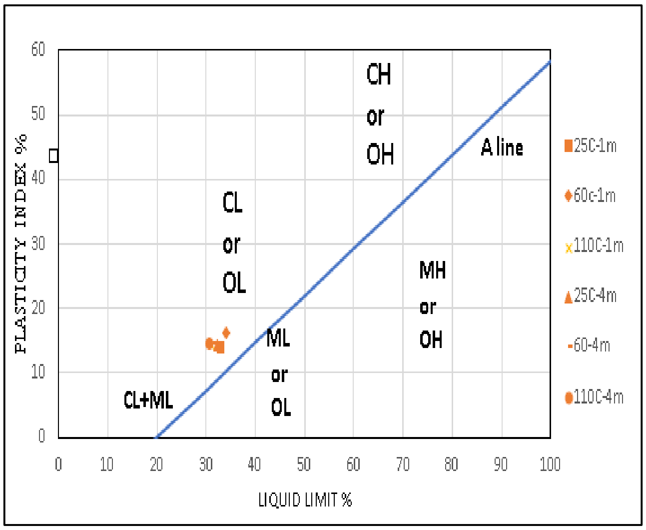

Fig. 4 effect the drying temperature on the classification of soil.

Table 2 shows that the soil at 60°C after 1m has a higher liquid limit. This is because, according to Basma et al [4], drying at 60°C requires at least 10 days to remove all free water. Additionally, this soil is left in the air after the air drying test, which may cause humidity, so it requires more than 24 hours to dry. In the case of 4m, the drying period was extended to three days rather than one, and the results were consistent with previous research.

Although drying at 60°C is mentioned in the specification, it frequently produces unsatisfactory results and requires more precision than drying in air. It is also important to conduct tests at the same time when determining the plasticity limits, because leaving the sample after drying in air causes a change in the moisture which explains the difference in results between samples at 1 and 4 months.

A simple experiment was carried out to demonstrate soil particle aggregation caused by water loss. A 99mm inner diameter and 26mm height ring was filled with saturated soil that had passed through a 4.75mm sieve. Three samples were prepared, and each ring was dried under different conditions: air drying at 25°C, oven drying at 60°C, and oven drying at 110°C. After about a week, the volume change for each soil sample was calculated, as shown in table 3, where it was discovered that the highest change occurred when drying at a temperature of 110, and the lowest when drying with air, which is consistent with the previous results. Figure (5) shows aggregated particles in the upper part of a soil specimen that has been directly exposed to heat, which is most visible for dried soil at 110°C.

Another explanation for the variation in plasticity limits with temperature is that, as stated by Murthy [14], drying causes an invariable change in the colloidal characteristics of organic matter in a soil, which reduces the liquid limit and has a lesser effect on reducing the plasticity limit; additionally, ASTM D2487-17 considers the change in liquid limit after drying as an indication of organic soil. If $LL_{oven-dried}$ is less than about o.75 times for $LL_{air-dried}$, the soil is organic. In this soil, the $LL_{oven-dried}$ /$LL_{air-dried\ ratio}$ = 0.976, so the soil is inorganic. Since the current classification may fail to determine if the soil contains organic matter, Huang et al [15] proposed another system: "soil with organic content greater than 3% is classified as mineral soil with organics." This soil is problematic due to its poor strength, high void ratio, and high water content. The organic content was determined using the loss on ignition method according to ASTM D2974- 14, and the sample was placed in a 480°C oven for six hours. The obtained organic content is 4.5%, indicating that this soil is classified as CL-O by Huang.

Compaction Parameters

Table 2 shows the maximum dry density Υ_d max and optimum water content O.W.C of soil after drying at three different temperatures. Figure 6 depicts the variation of these compaction parameters. As the drying temperature rises, the maximum dry density decreases slightly while the optimum water content rises. Because water acts as a lubricant in compaction, allowing soil particles to slide and take their proper positions to achieve the highest density possible, when the soil dries, a large amount of water is lost, which is important for work, and the soil requires more water for compaction. Dry soil is more difficult to compact and requires more compaction energy; as a result, the addition of water and the reduction of compaction energy all contribute to soil with a lower maximum dry density than air-dry soil; the goal of obtaining the maximum density is to increase soil strength, which is consistent with the findings of basma et al [4], which indicated that the higher the drying temperature, the lower the compressive strength.

This result may differ if a soil with different characteristics than this soil is used, as well as depending on the ability of soil to absorb the water required for compaction. If the clay soil cannot absorb the water required to compaction the soil during the test duration, the water content will be reduced.

Specific Gravity

The specific gravity values for soil at various drying temperatures are shown in table 2, and the variation of these values is shown in figure 7. According to the findings, the higher the temperature, the greater the specific weight of the soil used. For oven dry soils, the difference is smaller. This difference can be explained by the fact that as the soil dries, the stresses formed between the soil particles due to water loss lead to a reduction in soil voids; however, this reasoning

Fig. 5 Saturated soil under various drying conditions, a: changing the volume of the soil cylinder. b: soil particle aggregation as a result of water loss.

has a limited effect because, on the one hand, it increases the weight of the soil while also increasing its volume, as the specific weight represents the relationship between the weight and volume of the soil, as a result, the effect of drying on specific gravity will be minimal, which is consistent with Sunil and Deepa's [11] findings that drying conditions have no effect on specific gravity. The presence of organic content is the most logical explanation in this case, because organic content reduces soil specific gravity, and high temperatures cause organic matters to burn, resulting in a permanent change in the composition of the soil, which leads to an increase in specific weight.

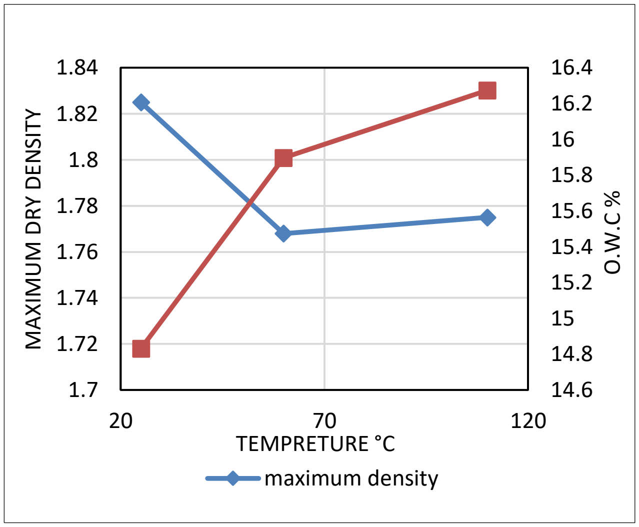

Fig. 6 Variation of compaction parameters upon different drying temperature.

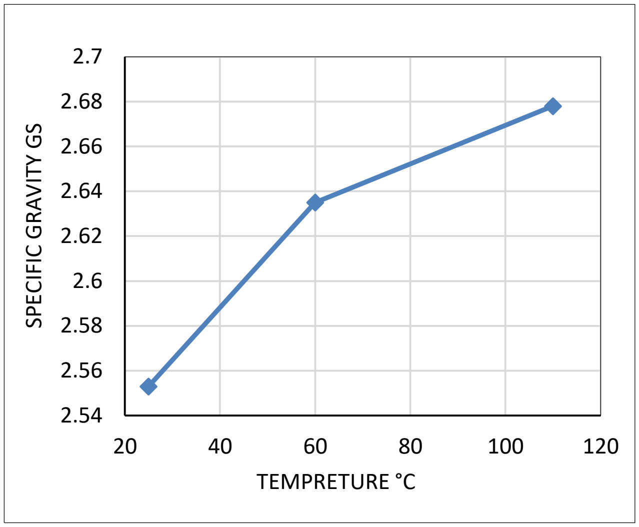

Fig. 7 Variation of specific gravity at different drying temperature.

Hydrometer Analysis

Table 1 shows the percentage of clay and silt from the hydrometer test, while figures 8,9 show the grain-size distribution of fine soil and the variation of clay and silt content at three different drying temperatures. The ASTM D-422 test was performed on soil particles finer than 0.075mm.

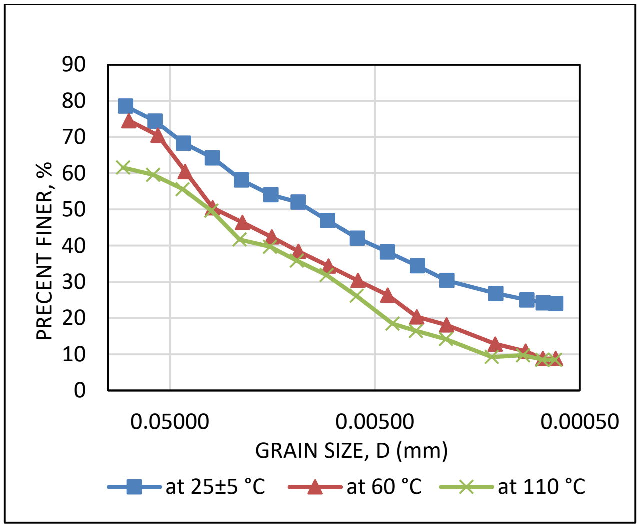

Fig. 8 Grain-size distribution of soil finer than 0.075 mm at different temperature.

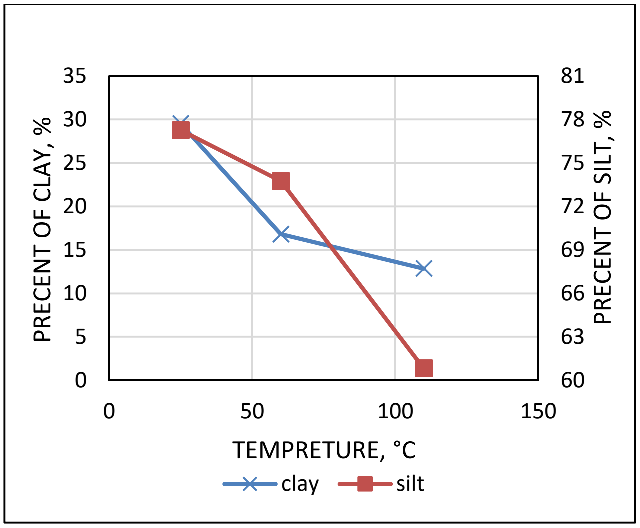

Fig. 9 Variation of clay and silt fractions at different temperature.

The results of this experiment confirm the previously mentioned effect of heat on the soil; as the temperature drying increases, so does the loss of attached water; this process leads to strong particle attraction, as mentioned by Basma et al [4], which increases the capillary stresses that allow the particles to aggregate and develop a strong coulombic bond that cannot be easily changed. As a result, as the drying temperature rises, the particles of silt and clay fraction decrease, as shown in figure 9, and it can be stated that heat caused a portion of the particles to change size to greater than 0.075 mm, implying that the percentage of sand will rise.

CONCLUSION

A soil sample taken from Shahat, Libya at a depth of 0.7m was tested at different temperature drying conditions to study the effect of temperature on the soil plasticity, compaction parameters, specific gravity, and hydrometer analysis. Based on the results and discussion, we conclude that drying of the soil has an effect on the soil properties values, based on the laboratory testing conducted, the following conclusion can be drawn:

1. As the drying temperature rises, the consistency limits fall. This effect is less pronounced for the plastic limit and plasticity index than for the liquid limit, but it is not statistically significant in this soil (from 1% to 1.7%). The variation in results in each case of drying, on the other hand, may lead to a misunderstanding of soil behaviour and a change in classification. The tests and drying time also have an impact on the results; the longer the drying time, the lower the water content. Because drying at 60 produces ambiguous results and drying at 110 causes water loss in the soil, the optimal method is A month of air drying the soil will remove all free water.
2. The organic matter level was 4.5%, indicating that the soil was organic. Organic soils should not be oven dried because it causes irreversible changes in soil properties.
3. Increasing drying reduces maximum dry density while increasing optimum water content, which has a direct impact on soil strength. The additional water will help disperse the soil particles, reducing soil strength and compaction.
4. The drying temperature has little effect on the specific gravity. Temperature has an effect on the specific gravity of an organic-rich soil. The organic matter in the oven will be burned, raising the specific gravity value.
5. As the drying temperature rises, the soil becomes less plastic. Because small particles combine to form larger particles, the proportion of silt and clay decreases while the proportion of sand increases.

Finally, we conclude from this research that soil should be dried outside rather than in an oven. Although drying in the oven saves time, which is always beneficial, drying in the open air preserves the representative features of the soil.

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