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Effect of Heating Borehole Spacing on Plasticity of Expansive Soil

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K E Y W O R D S

Expansive soil, Plasticity, Heating and Borehole spacing.

A B S T R A C T

This paper presents the effect of spacing between boreholes heating on plasticity of expansive soils. The expansive soils used were prepared artificially by mixing Kut clay with different percentages of bentonite. Nine laboratory models of expansive soils having dry unit weight of 17.8 kN/m3 with 6% initial water content were prepared inside a steel box of (300 mm × 300 mm × 400 mm height). A special heating system generates 400 Co for six hours was designed and manufactured for this purpose using 12 mm diameter electric heaters inserted through boreholes. Square pattern boreholes of 170 mm length with spacing (4.16d, 6.25d and 8.33d) were used. A representative sample were taken after heating from the center of the square pattern for measuring the plasticity of the soils. The results showed that the plasticity index remarkedly decreases compared with that before heating and increases with increasing bentonite and the spacing. It is also indicated that an expansive soil could be changed from high to low plasticity

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1. Introduction

Plasticity is considered the most beneficial characteristic property of clay soils. This property is the size and nature of the clay mineral particles together with nature of the adsorbed layers. Whenever the average specific surface becomes high, then the plasticity may be extremely high and the soil is extremely compressible [1].

"The moisture content range between the plastic limit and liquid limit is known as the plasticity index and is a measure of the plasticity of the clay. [2]

Unsaturated clayey soil generally possesses high plasticity and will be very sensitive to change in water content and undergoing excessive volume changes. Such soils are categorized as expansive soils. [3]

The clayey soil is classified as highly expansive when the plasticity index is greater than 35% [4]. Many improvement techniques for this soil are existed and heat treatment is one of them. Choosing this method is due to the low cost, short improvement time and a high decrease in plasticity. The effectiveness of heat treatment has been investigated by numerous researchers under laboratory

conditions on the expansive soil samples after being burnt at different temperatures, that is from 50o C to 700oC to study it is effect on physical properties. [5, 6 and 7].
The effect of temperature on Atterberg limits of soil Indicated that any reduction of liquid limit and plastic limit “will cause increasing temperature” [8].
Wang et. al. stated that the bentonite’s bigger particles are existed when they are heated to 600°C. In addition, at 600°C, the clay first becomes non-plastic and non-expansive and then undergoes a moderate strength gain. [9]
The temperature does not have any sufficient effect on the Atterberg limits by doing experimental tests on kaolinite (in the range of temperatures from 20 to 400oC) [10].
The insert the references for these previous studies showed that the plasticity index for expansive soil decreases with increasing heating temperature for investigated samples after exposing to different range of temperature by using furnaces without talking about the presence of heat inside a soil layer
The goal of this paper is to examine the effectiveness of heating borehole spacing on the plasticity of expansive soil models to simulate as close as possible the field condition and it concentrated on the effect of spacing section.

2. Soil Used

In this study, the used soils were prepared in the laboratory by mixing natural soil with three different percentages of bentonite (20, 40 and 60%) by weight.
The natural soil was obtained from a construction site in Kut area from a depth of about 1.5 m below natural ground surface. The bentonite was obtained commercially.

Table: The physical properties of the soils used

Type of soil property	Natural soil	Soil A	Soil B	Soil C
%liquid limit	38	51	65	96
% plastic limit	18	22	25	30
% plasticity index	20	29	40	66
% shrinkage limit	15	14	13	12
specific gravity	2.77	2.78	2.79	2.8
% passing #200	90	92	93.5	95.5
%clay content <0.002	46	36	40	46.5
%colloid content <0.001	14	33	33.5	42
Activity	0.44	0.81	1.00	1.42
Max. dry unit weight (modified) kN/m3	17.75	16.56	15.7	14.8
OMC %	13.5	15.7	17.9	19.1

3. Preparation of Soil Bed and Boreholes Procedure

A 6% water content was added to the required amount of the soil and mixed thoroughly to distribute the water evenly and to prevent the development of clay lumps. In order to allow the distribution of moisture throughout the mass of the soils, the mixture was kept in closed plastic bags for two days. Any required amount of soil corresponding to one third of final thickness of the bed of soil was placed inside the box (300*300*400mm height) and compacted using electric compacter with a square base (15 cm length) manufactured for this purpose. The Compaction was performed in three layers and the final of compaction was controlled by the final thickness of each layer. The final thickness of the bed of clay at the end of compaction was (20 cm) corresponding to (17.8) kN/m3 dry unit weight. As show in Figure 1.
After the bed preparation, boreholes 13.5 mm diameter (d) with square pattern and different spacing (4.16d, 6.25d and 8.33d) according to testing program were drilled to the required depth (170mm) as shown in Figure 2.

Figure 1: Show the bed of soil

Figure 2: The borehole preparation

4. Heating System

The electric power was used as a source of heating instead of gas because the use of gas needed 35 mm as the minimum diameter of heating borehole [11]. This means large dimensions of box is required.

Electrical heaters were used in the experimental work with different number of heaters at any model according to the spacing used. A cartridge heater is a sturdy (electric resistance) industrial heating element (Joule) employed in the process of heating industry, often custom-made for particular watt density, based on its intended application. Being highly compacted, they reach a surface watt density of up to 30 w/ cm^2. “Cartridge heaters seem structurally tubular heaters, but tend to have higher watt densities.” A well-known application for these types of heaters is the plastic pellets that are melted to create molded plastic parts. This type was used for this study after it covered with a thin steel pipe to avoid the damage which may be happened when direct used in contact with soil. The length and diameter of heaters are 170 mm and 12.5 mm respectively as shown in Figures 3 and 4.

Figure 3: Heaters before covering

Figure 4: Heaters after covering

5. Model set up and test

After the drilling of boreholes, the electric heaters of the same diameter and length were installed inside the boreholes as shown in Figure 5 and the electric power is switched on for six hours heating. The temperature inside the soil and at the center of pattern was measured by a thermo cable linked to the heat controls board that maintain the temperature at 400o C After completing the treatment, the heating system is extinguished and the soil model is left to cool for 24 hours, then samples were extracted and tested for determining the plasticity index.

Figure 5: Electric heaters instillation

6. Determination of Atterberg Limits

I.Liquid Limit (LL)

liquid limit of a soil is the water content at which the soil behaves practically like a liquid, but has small shear strength". It flows to close the groove in just 25 blows in Casagrande's liquid limit device. As it is difficult to get exactly 25 blows in a test, 3 to 4 tests are conducted and the number of blows (N) required in each test is determined. A semi-log plot is then drawn between log N and the water content (w). "The liquid limit is the water content corresponding to N=25, as obtained from the plot".

II.Plastic Limit (PL)

The test was carried out using the paste from the liquid limit test, to establish the lowest moisture content at which the soil is plastic. A sample was dried partially on a glass rolling plate and rolled between the plate and the finger. The plastic limit was determined as the moisture content at which a 3 mm diameter thread sheared longitudinally and transversely.

III. Plasticity Index (PI)

"This was determined as the difference between the liquid limit and the plastic limit" (PI = LL-PL).

7. Presentation and Discussion of Test Results

The experimental study results are presented in this section. The presentation attention on the effect of heating on plasticity of expansive soil.

I. Effect of Bentonite percentage on Atterberge's limit

Plasticity index is the difference between the "liquid limit" and "plastic limit" of the soil. It shows "volume of range of moisture content" at which the soil remains in plastic condition Figure 6 shows the variation of liquid limit, plastic limit and plasticity index with variation of percentage of bentonite before and after heat treatment. The values of liquid limit before heat treatment varies from 51% at 20% bentonite to 96% at 60% bentonite while it varies from 30% to 56% after heating. This means that the values of liquid limit increased with the increasing the amount of the bentonite and the heating greatly effect on the liquid limit values. During the heating process, the moisture content decreases (drying process), fine particles move towards "the menisci", the ionic concentration in the pore fluid increases, the thickness of "double layers" shrinks and (van der Waals) attraction prevails over "double layer repulsion" resulting in the strengthening of fabric and then reduce in liquid limit [12]. This decrement may be attributed to the change in the surface area of the clay particle which decreases with increasing heating temperature due to the distribution of the clay mineral structure and form large particles, resulting the percentage of clay decreases and the amount of water adsorption into soil particles is very low compared with that before heating. Comparable with researchers [13, 14, 15 and 16].

In general, no more change in plastic limit during heating process due to that the plastic limit depends on the chemical composition of soil. While, the heating process is a physical treatment doesn't cause any change in chemical properties, thus it can enplane that by this fact.

The decrease of liquid limit and plasticity index is caused by the increase of temperature. This is related to the process of increasing the temperature which in turn causes the particles of clay soil to paste to each other and becomes bigger [15]. It is noticed that the liberated Aluminum and Iron are quickly oxidized during heating and are also precipitated around clay particles and cement clay particles together to create larger aggregates [17]. Such findings and results are in accordance with the findings or results that have been reported by [18].

Resulting the plasticity index increases with the increase of the spacing between borehole and the rate of increase about (0.65) because it depends on the liquid limit and the plastic limit results

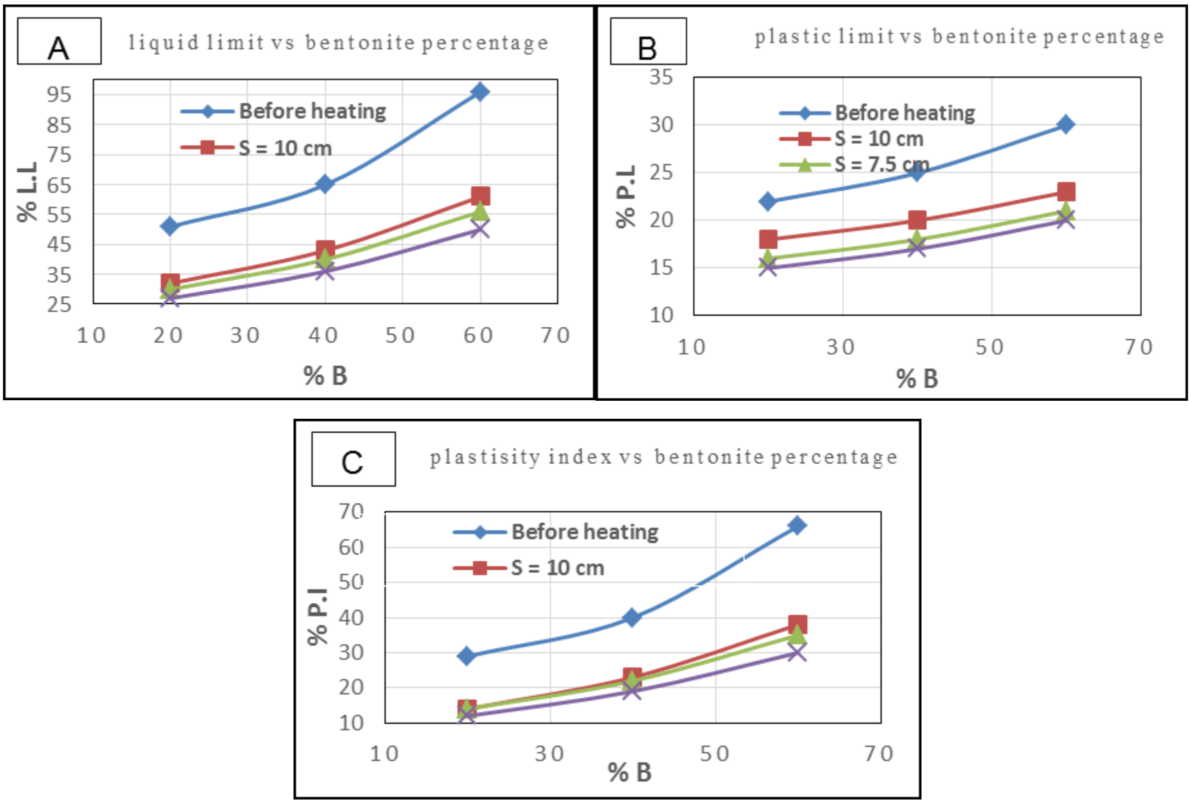

Figure 6: Relationship between liquid limit, plastic limit and plasticity index with bentonite percentages.

II.Effect of borehole spacing on Atterberge's limit

Figure 7 illustrates the effect of spacing between “heating boreholes on the plasticity” of the tests soil. The figure shows that the liquid limit increases with increasing the spacing. This behavior is attributed to the effect of heating which decreases with increasing the spacing.
A linear relationship between Atterberge’s limit and spacing was obtained and the rate of increase is about (2). The same behavior was obtained for the effect of spacing on plastic limit and the effect of spacing on plastic limit and the rate of increase is about (0.6).
Resulting the plasticity index increases with increase the spacing between borehole and the rate of increase is about (1.6).

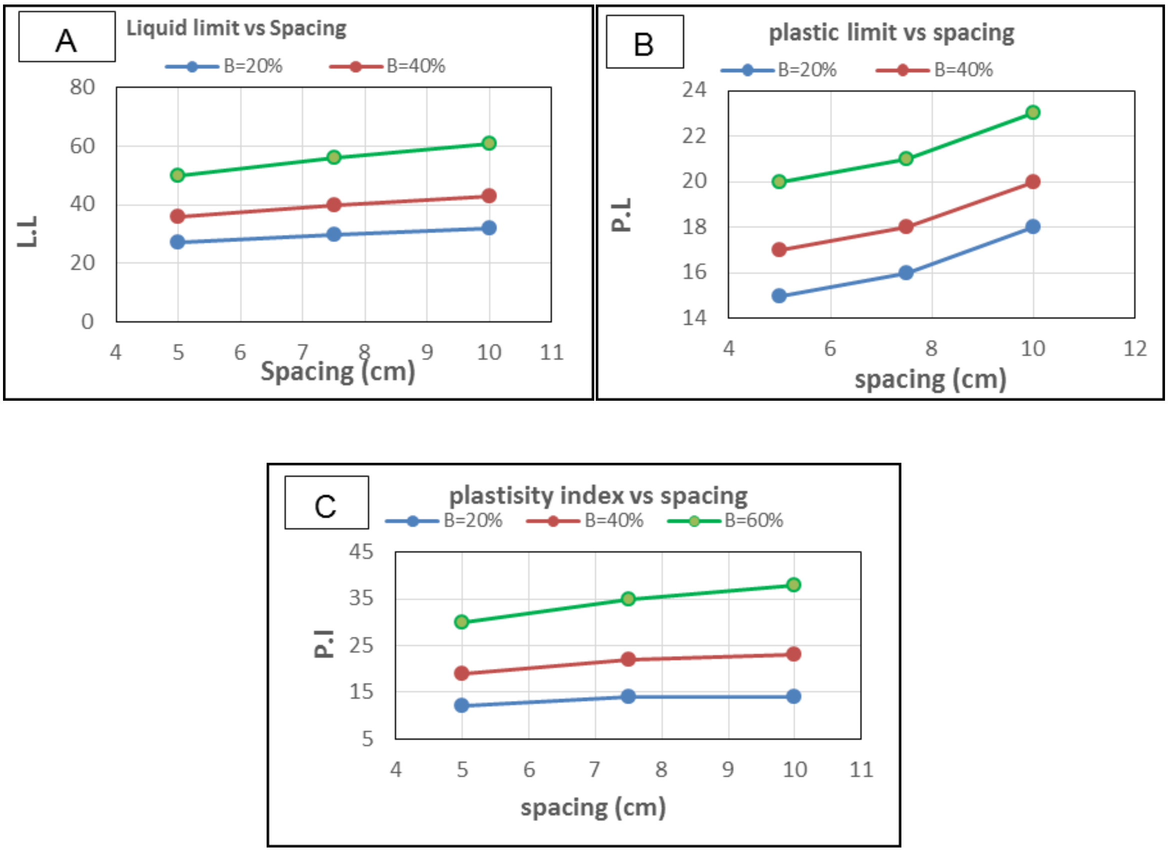

Figure 7: effect of borehole spacing on Atterberge's limit of expansive soil

8. Conclusions

1.Nonlinear relationship of increase in liquid limit, plastic limit and plasticity index with increase of percentage of bentonite.
2.The heating greatly effects on "liquid limit" and "plasticity index" values and the percentage of decrement is about (0.725) and (0.6) respectively and the plastic limit is not changed in the same way as "liquid limit" and "plasticity index".
3.Soils that have high percentage of bentonite need more heat duration to change from high to low plasticity.
4.ncrease in borehole spacing leads to increasing in both the liquid and plastic limits, and plasticity index of soil.

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