

Evaluation of Physical Properties of Clays Mixed with Silica Sand

(Penilaian Ciri-ciri Fizikal Tanah Liat Dicampur Pasir Silika)

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ABSTRACT

This study examined the effects of heat treatment on two types of clays mixed with silica sand under laboratory conditions. Soils were subjected to three varied temperatures, i.e. 100, 250 and 500°C. The soil properties studied were Atterberg's limits, optimum water content and unconfined compressive strength. Experimental results showed that the temperature greater than 100°C resulted in a reduction in Atterberg's limits, optimum water content and unconfined compressive strength. For illite and silica mixture heating the soils at 500°C, liquid limit, plastic limit, optimum water content and unconfined compressive strength were reduced to 12%, 0%, 40% and 0%, and for kaolinite and silica mixture the above characteristics reduced to 18%, 0%, 50% and 0% respectively when matched to soil specimen's properties at ambient temperature. Whereas maximum dry density for illite and kaolinite increased by 5% and 8% respectively for the two clays.

Keywords: Clay; heat treatment; Atterberg limits; optimum water content; unconfined compressive strength

ABSTRAK

Kajian ini mengkaji rawatan kesan dari rawatan haba ke atas dua jenis tanah liat dicampur dengan pasir silika di bawah keadaan makmal. Tanah melalui tiga suhu berbeza, iaitu 100, 250 dan 500°C. Sifat tanah yang dikaji ialah had Atterberg, kandungan air optimum dan kekuatan mampatan bebas. Hasil eksperimen menunjukkan bahawa suhu melebihi 100°C mengakibatkan satu penurunan di dalam had Atterberg, kandungan air optimum dan kekuatan mampatan bebas. Untuk campuran ilit dan silika, memanaskan tanah pada suhu 500°C menyebabkan had cecair, had plastik, kandungan air optimum dan kekuatan mampatan bebas dikurangkan kepada 12%, 0%, 40% dan 0%, dan untuk campuran kaolinit dan silika, ciri-ciri di atas mengurang kepada 18%, 0%, 50% dan 0% masing-masing apabila dipadankan dengan ciri-ciri spesimen tanah di suhu ambien. Manakala ketumpatan kering maksimum untuk ilit dan kaolinit dinaikkan sebanyak 5% dan 8% masing-masing untuk dua tanah liat ini.

Kata kunci: Tanah liat; rawatan haba; Had Atterberg; kandungan air optimum; kekuatan mampatan bebas

INTRODUCTION

Temperature modifies the physical and mechanical properties of clays. When the clayey soils are treated with heat, some of the changes in properties are permanent. The huge fires in the forests across the world have brought the thought to measure the effect of heat on clayey soils (Alcocer 1993 and William 1997). Many researchers have investigated the effect of heat treatment on the clayey soils. Mitchell (1969) showed that the heat treatment changed the physical properties of the clayey soils such as angle of friction, cohesion and strength. Joshi et al. (1994) investigated the effect of the heat treatment on the strength of clayey bricks at temperatures ranging from 300 to 700°C. And it was found that an increase in strength was accompanied with the increase in temperature. Yang and Farouk (1995), Akinmusuru (1994), and Ma and Hueckel (1992) investigated the effect of heat on the thermal conductivity of clayey bricks. Tanaka et al. (1997) evaluated the stress-strain behaviors of the remodeled illite clay at different temperatures. It was found that the peak undrained strength was increased due to the development of reduced pore water pressure during testing.

Michot et al. (2008) found strong relation between the thermal conductivity of kaolin and the temperature of heat treatment. Heat treatment temperature less than 1050°C yielded thermal conductivity of less than 0.3 W m⁻¹ K⁻¹. Whereas the temperature of heat treatment greater than 1050°C produced thermal conductivity of up to 3 W m⁻¹ K⁻¹. C. Vizcayno et al. (2009) compared the results between pozzolanic activity of metakaolin (MK) obtained by thermal treatment at 700°C for 1 hour and amorphous kaolin produced by mechanochemical treatment in a Herzog oscillating mill for 15-120 minutes. It was found that the pozzolanic index and the mechanical resistances acquired by grinding were alike to the thermal treatment.

Bayram et al. (2010) evaluated the effect of heat treatment on bentonite (CaB). Bentonite was heated for two hours for temperatures ranging from 100 to 1100°C. It is evident that Bentonite lost adsorbed and hydration water at 300°C, dehydroxylation took place between the temperature of 300 to 750°C and water was completely removed at 900°C.

The research has been mainly focused on illite or kaolinite, where as in this study mixtures of these soils with

silica sand were evaluated. Acknowledging that in the natural form the soils are rarely pure clay minerals. The main objective of this study was to investigate the effect of temperature on physical properties of clayey soils. The parameters investigated in this study include Atterberg limits, optimum water content and unconfined compressive strength.

EXPERIMENTAL PROCEDURE

The clay minerals used in this study were kaolinite and illite. Silt which was mixed with clay minerals in the present

study was silica sand with fine grained particles (45 μm). Kaolinite and illite clay minerals were obtained from Kaolin (Malaysia) factory under the trade name of "S-300" and "KM800" respectively. Table 1 & 2 present the properties of kaolinite and illite, which were determined during this study by performing a series of geotechnical laboratory experiments using procedures recommended by relevant ASTM standards. In Figure 1, Figure 2 and Figure 3, scanning electronic microscope (SEM) images are given which show the kaolinite, illite and silica sand layers.

TABLE 1. Physical property of materials

Kaolinite		Illite	
Moisture content	Below 1.5%	Moisture content	Below 2.0%
pH	4.0	pH	4.5
100 mesh residue	Below 10%	325 mesh residue	Below 3.0%
60 mesh residue	Below 0.5%	Average particle size	2.5-5.0 μm
Specific gravity (Gs) ASTM D854	2.723	Specific gravity (Gs) ASTM D854	2.701

TABLE 2. Chemical compositions of clay minerals and silica sand

Kaolinite		Illite		Silica Sand	
Formula	Concentration (%)	Formula	Concentration (%)	Formula	Concentration (%)
SiO ₂	85.76	SiO ₂	29.43	SiO ₂	97.29
Al ₂ O ₃	9.11	Al ₂ O ₃	52.37	Al ₂ O ₃	2.71
Fe ₂ O ₃	0.38	Fe ₂ O ₃	1.85	-	-
K ₂ O	1.34	K ₂ O	8.21	-	-
Heat loss	3.41	MgO	1.76	-	-
-	-	TiO ₂	1.36	-	-
-	-	Heat loss	5.02	-	-

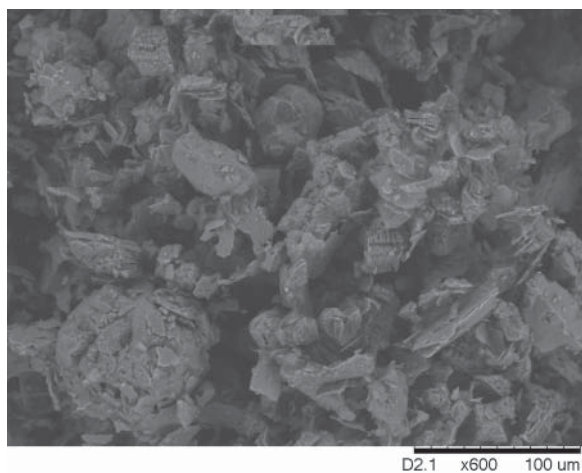


FIGURE 1. Kaolinite particles under SEM

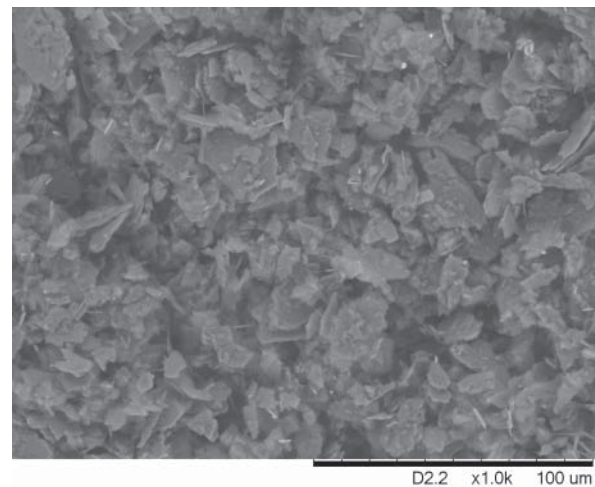


FIGURE 2. Illite particles under SEM

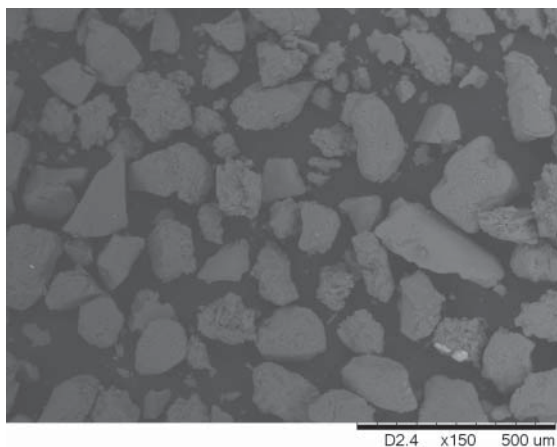


FIGURE 3. Silica Sand particles under SEM

The mix selected for the test was 50% clay (kaolinite/illite) + 50% silica sand. Physical properties including plastic and liquid limits, maximum dry unit weight and optimum water content of untreated and treated specimens were determined by using ASTM standards D4318-10 and D698-12 respectively. For the unconfined compressive strength experiment, soil samples were compacted with standard Proctor test (D698-12: 3 layers, 25 blows per layer) and then tested in accordance with ASTM D2166-06. Soil specimens were compressed until the failure under a strain rate of 1.5 mm/min. and deformations were noted during the whole test.

RESULTS AND DISCUSSION

The effect of temperature on liquid limit and plastic limit for kaolinite and illite are shown in Figure 4 and Figure 5. Liquid and plastic limits progressively decreased with increasing temperature and the plastic limit finally reached a value of zero at 500°C. Liquid limit was decreased by a little up to 100°C, whereas plastic limit remained almost the same for this variation. Between 100°C and 250°C, Atterberg limits

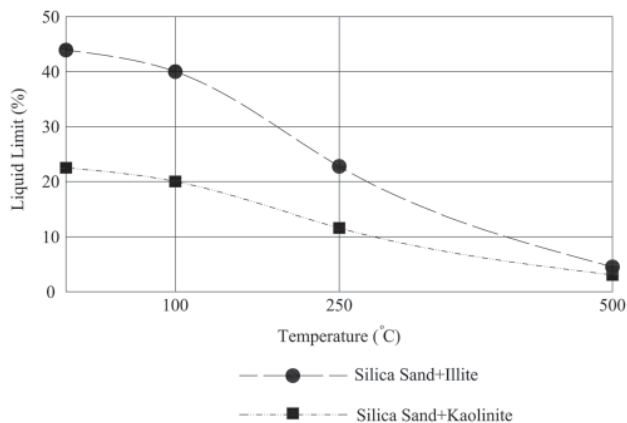


FIGURE 4. Effect of heat treatment on liquid limit

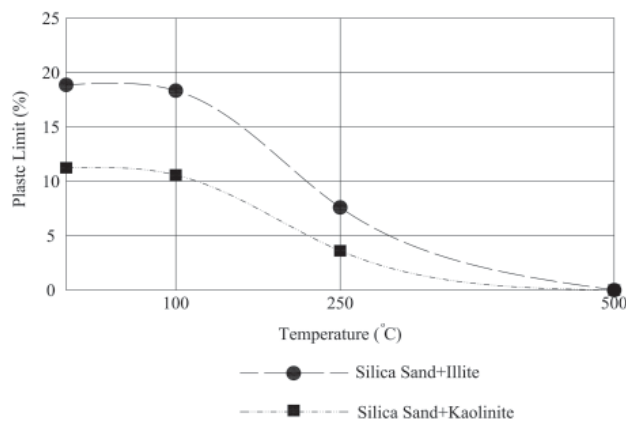


FIGURE 5. Effect of heat treatment on plastic limit

decreased by more than 50% for both samples. Beyond 250°C, liquid limit appeared to get less affected by temperature, rise to reach a value of about 5% for the two specimens.

Figure 6 and Figure 7 shows the effect of temperature treatment on optimum water content and maximum dry density, respectively. Optimum water content decreased with increasing temperature, though it was less affected by temperature below 100°C. At a temperature of 500°C the optimum water content of illite and kaolinite reduced to 40% and 50% respectively. A rise in maximum dry density was observed for both the clays reaching the increase up to 5% and 8% for illite and kaolinite respectively at 500°C.

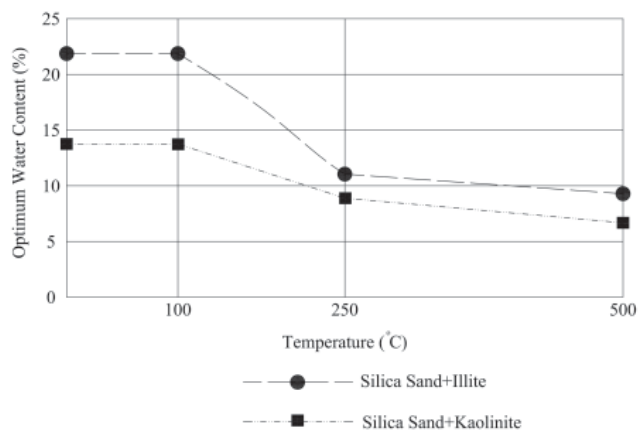


FIGURE 6. Effect of heat treatment on optimum water content

The effect of temperature on the unconfined compressive strength of the two soil samples is shown in Figure 8. Temperature increase beyond 100°C produced excessive decrease in unconfined compressive strength for the two soils and finally it reached to 0% at the temperature of 500°C.

In previous literature, the study of heat treatment has been mainly focused on illite or kaolinite, where as in this study mixtures of these soils with silica sand were evaluated and compared.

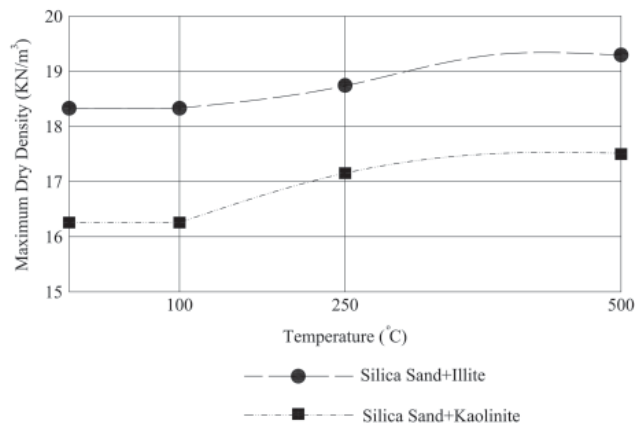


FIGURE 7. Effect of heat treatment on maximum dry density

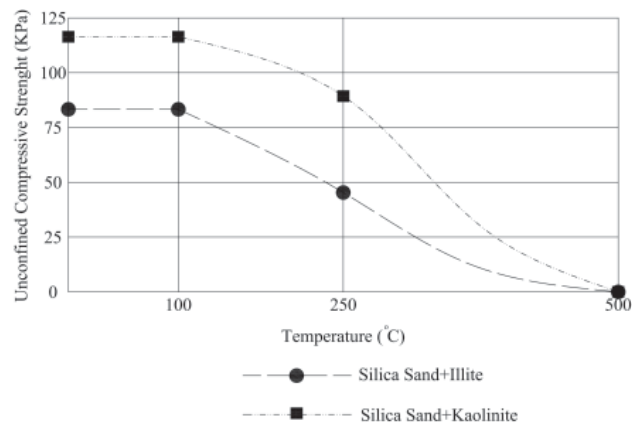


FIGURE 8. Effect of heat treatment on unconfined compressive strength

CONCLUSION

This study shows that the temperature has a significant effect on soil physical properties such as Atterberg limits, optimum water content and unconfined compressive strength. The relative change in these properties was higher when temperature ranged from 100 to 500°C. Soils were normally not affected in great deal by temperature below 100°C. Therefore it can be concluded that a temperature of 500°C brings drastic changes in the mechanical properties of the two soils and transforming them into very weak soils.

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