Effect of Wildfire on Geotechnical Properties of Clayey Soil

Anis Ayesha Noraini[1]

[1]*Faculty of Civil Engineering & Earth Resources, Universiti Malaysia Pahang, Lebuhraya Tun Razak, 26300, Kuantan, Pahang, Malaysia*

Abstract - *This study examines the effects of wildfire on soil exposed to wildfire under laboratory condition collected from Kuantan, Malaysia. Various geotechnical properties such as liquid limit, plastic limit, optimum water content, maximum dry density and specific gravity were studied. According to experimental results, the optimum water content decreased whereas the maximum dry density increased after the soil affected by wildfire. The liquid limit and plastic limit decreased rapidly after heated by fire. The specific gravity decreased as temperature increased during heating. (Size 10 & Italic , cambria font)*

Key Words: **Clay, Wildfire, Atterberg limits, Optimum water content, Maximum dry density, Specific gravity**

1. INTRODUCTION

Global temperature has increased since past three decades (Hansen et al., 2006) [1]. Most computer climate models predict that the globe will warm up by 1.5°C to 4.5°C if the carbon dioxide concentration reaches the predicted level of 600 parts per million by the year 2050 (Masih, 2010; Solomon et al., 2009) [2] [3]. Malaysia shows warming trend in the annual mean temperature with increasing 0.04°C every year (Quadir et al., 2002) [4]. Climate changes are anticipated to increase the frequency, duration and intensity of extreme weather effects and associated droughts and wildfires (Karl et al., 2008) [5]. Many physical, chemical, mineralogical and biological soil properties can be affected by forest fire (DeBano, 1999; Mataix-Solera, 2011) [6] [7]. Temperature had a significant effect on soil physical properties (Abu-Zreig et al., 2001) [8]. Many researchers have investigated the effect of fire on the clayey soil. Liquid limit decrease rapidly between 100°C to 300°C but less affected by temperature rise after 400°C. Plastic limit decreased rapidly up to 300°C and reached non-plastic state (NP) at 400°C (Tan et al., 2004; Abu-Zreig et al., 2001) [9] [8]. As for kaolin, the changes in Atterberg limits with temperature up to 400°C are rather small but it become NP after heated at 500°C. Acccording to Wang et al. (1990) [10], liquid limit decreased with increasing temperature up to 500°C while plastic limit remains constant but is become NP. Heat also causes rapid decrease on specific gravity of clay (Tan et al., 2004) [9]. However, Wang et al. (1990) [10] conclude that the changes in specific gravity are small so that it can be considered insignificant. Abu-Zreig et al. (2001) [8] investigated the optimum water content and maximum dry density of the clayey soils at the temperatures of 100, 200, 300 and 400°C.

2. OBJECTIVE

Literature review on heat treated clay showed that the engineering properties of the heat treated clay were not investigated on-site. For this purpose, on-site study was performed. Therefore, main objective of this study was to determine various engineering properties of clays such as liquid limit, plastic limit, optimum water content, maximum dry density and specific gravity were investigated for the soil exposed to wildfire.

3. MATERIAL AND METHOD

Sample were collected from Kuantan, Malaysia and used for this study. The major clay minerals are montmorillonit. Clays were characterized as CH, according to unified soil classification (USCS). The properties of the clay are shown in Table 1. The clay samples were collected from the surface and were kept in sealed bag prior being tested. In order to determine the maximum dry density, optimum water content, Atterberg limits (i.e liquid limit and plastic limit) and specific gravity of the clay samples, experiments were performed in laboratory condition. The standard compaction tests were performed using ASTM D698 to determine maximum dry density and optimum water content. The tests for Atterberg limits and specific gravity were performed according to BS 1377.

Soil compaction curve were determined by standard proctor test. The test was used to determine the relationship between the dry unit weight and the moisture content using the standard rammer in Proctor method and to determine the maximum dry density and the optimum moisture content of a given soil. About 3 to 4 kg of oven-dry soil was prepared. The soil was pulverized and only the ones passing 4.75mm was used. The first point of the test was conducted at water content of about 5% (by weight) and soil was mixed thoroughly. The compaction mold was weighed including the base plate (i.e, without the collar) and was recorded in data sheet. The volume of mold was checked (volume of standard mold is 1000 cm^3) and was fixed with the collar to the base plate. A quantity of moist soil was applied in the mold such that when compacted it occupies a little over one third of the height of the mold. About 25 free fall blows was applied from 300 mm above the soil by using the rammer. The blows were uniformly distributed over a surface. The procedure above was repeated for the following two layers and make sure there is excess soil on top of the mold. Collar and base plate was detached and the soil was strike out at the top of mold by using the straightedge. The mold was weighed with base plate and soil, and its mass was recorded on data sheet. Soil from mold was extruded by using the extruder. Soil samples were collected and the water content was recorded (2 moisture content determination for each compaction points. 4 compaction points was conducted, i.e., sat at moisture content of about 5, 10, 20 and 30% (by weight of dry soil) or until the weight is decreased.

Liquid limit test followed BS 1377: Part 2: 1990: 4.3. About 250 g oven dried soil passing 0.425mm were left air dried for at least 30 minutes. Distilled water were added to the soil sample to form paste and then transferred to the cylindrical cup of cone penetrometer apparatus, ensuring that no air is trapped in the soil sample. The penetrometer was adjusted that the cone point touches the surface of the soil paste. The vertical clamp was released to penetrate into soil paste under its own weight for 5 seconds. The test was repeated for three times of values of penetration in the range of 13.5 to 27.5mm. The graph of water content versus cone penetration was plotted. The moisture content corresponding to cone penetration of 20mm was taken as liquid limit of the soil. Plastic limit test followed the BS 1377: Part 2: 1990: 5.3. The soil paste was rolled out a thread on a flat surface. The plastic limit is defined as the moisture content where the soil paste begin to break apart at diameter 3.2mm.

For specific gravity, about 10 g oven dried soil sample that passed 2mm sieve was transferred to the density bottle. The distilled water was added about half to three-fourth of the density bottle and was placed in the vacuum desiccator. The soil sample was left in the desiccator for at least one hour until no further loss of air was apparent. The distilled water was added until the density bottle full and was left for an hour in room temperature. Then the soil and water was removed from the bottle. The density bottle was refilled with water until full and was left for an hour. The test was repeated twice for the same soil sample.

Table -1: Some properties of clayey soil used in this study

	Clay 1
Specific gravity, Gs	2.67
Liquid limit, LL (%)	55
Plastic limit, PL (%)	35
Plasticity index, PI (%)	20
Maximum dry density (kN/m3)	15
Optimum water content (%)	29
Sand (1 mm-75μm) (%)	8
Silt (75μm-2μm) (%)	33
Clay (< 2 μm) (%)	59
Activity, A	0.5
Unified classification system	CH

4. RESULT AND DISCUSSION

The geotechnical properties of clay exposed to wildfire were determined for the optimum water content, maximum dry density, liquid limit, plastic limit and specific gravity are given in Table 2.

Table -2: Geotechnical properties of soil exposed to wildfire

Geotechnical properties	Unburned	Burned
Optimum water content (%)	29	19
Maximum dry density (kN/m^3)	15	16
Liquid limit (%)	55	30
Plastic limit (%)	35	14
Specific gravity	2.67	2.59

Effect of fire on the optimum water content and maximum dry density

Table 2 shows the effect of fire on the optimum water content and maximum dry density. There was increment in the optimum water content exposed to fire. The unburned soil has 29% of optimum water content and it drop to 19% after wildfire event. The percentage of decreased was about 34%. The maximum dry density of unburned soil was 15% then increased to 16% after exposed to fire. The percentage of increment was about 7%. The trend is similar to Tan et al. (2004) [9] which conclude that optimum water content decreased and maximum dry density increased after clayey soil were heat treated.

Effect of fire on Atterberg limits

The effect of fire on Atterberg limits are shown in Table 2. As can be seen on Table 2, there is rapid decreased in Atterberg limit after soil exposed to heat. Liquid limit of unburned soil was 55% and then drop to 30% after fire. The percentage of reduction was about 45%. Plastic limit also reduced rapidly from 35% for unburned soil to 14% for burned soil. The percentage of decreased was about 57%. The result is similar to studies conducted by Abu-Zreig et al. (2001) [8] and Wang et al. (1990) [10] which conclude that liquid limit and plastic limit decreased after soil exposed to heat.

Effect of fire on specific gravity

The effect of fire on specific gravity are shown in Table 2. There is reduction in specific gravity after soil exposed to wildfire. The specific gravity of unburned soil was 2.67 and then reduced to 2.59 for burned soil. The percentage of reduction was about 3%. The trend is similar to Abu-Zreig et al. (2001) [8], Tan et al. (2004) [9], and Wang et al. (1990) [10] which conclude that specific gravity reduced as temperature increased.

3. CONCLUSIONS

This study showed that the wildfire had an important effect on the clay properties such as optimum water content, maximum dry density, liquid limit, plastic limit and specific gravity. From the experimental results, it can concluded that:

- The optimum water content decreased and maximum dry density increased after the soil were exposed to wildfire.
- The liquid limit and plastic limit decreased significantly after the soil were affected by fire.
- The specific gravity reduced after the soils were exposed to high temperature wildfire.

REFERENCES

[1] James Hansen, M. S., Reto Ruedy, Ken Lo, David W. Lea, and Martin Medina-Elizade. (2006). Global temperature change.

[2] Masih, J. (2010). Causes and Consequences of Global Climate Change.

[3] Susan Solomon, G.-K. P., Reto Knutti, Pierre Friedlingstein. (2009). Irreversible climate change due to carbon dioxide emissions.

[4] Dewan Abdul Quadir, M. L. S., Tariq Masood Ali Khan, Nazlee Ferdousi, Mizanur Rahman, Abdul Mannan. (2002). Variations of Surface Air Temperature over the Land Areas in and around the Bay of Bengal.

[5] Thomas R. Karl, G. A. M., Christopher D. Miller, Susan J. Hassol, Anne M. Waple, and William L. Murray. (2008). Weather and Climate Extremes in a Changing Climate.

[6] DeBano, L. F. (1999). The role of fire and soil heating on water repellency in wildland environments: a review.

[7] J. Mataix-Solera, A. C., V. Arcenegui, A. Jordán, L.M. Zavala. (2011). Fire effects on soil aggregation: A review.

[8] Abu-Zreig, M.M., Al-Akhras, N.M., & Attom, M.F. (2001). Influence of heat treatment on the behavior of clayey soils. Applied Clay Science, 20(3), 129-135.

[9] Tan, O., Yilmaz, L. & Zaimoglu, A.S. (2004). Variation of some engineering properties of clays with heat treatment. Materials Letters, 58(7), 1176-1179.

[10] Wang, M. C., Benway, J. M. & Arayssi, A. M. (1990). The Effect of Heating on Engineering Properties of Clays. Physico-chemical Aspects of Soil and Related Materials, (1095), 139.