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Effect of Humic Acid on Geochemistry Properties of Kaolin

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Abstract. Organic soil is always known as problematic soil because of its engineering properties are inferior from other soft soils and/or because its behaviour may deviate from traditional rules of soil behaviour which makes it difficult to predict and design. Considerable research has been carried out over the years on organic soils, particularly peat soil which consists of various components of organic matter but the effect of particular organic matter is less reported. Hence, this study is carried out to determine the effect of humic acid (a kind of humified organic matter) on kaolin (which is widely studied). This paper addresses the influence of humic acid (30% and 50% of dry mass) on kaolin's geochemistry properties namely Atterberg limits, compaction, specific gravity and Loss on Ignition (LOI). The findings of the study showed that the contents of humic acid had altered the behaviour of kaolin. The loss on ignition increased linearly with the increment of humic acid. However, the specific gravity, maximum dry density and Atterberg limits decreased with addition of humic acid. Atterberg limits decreased as the humic acid increased is believed to be due to the nature of humic acid which precipitated under acidic environment.

Introduction

Kaolins are important materials having major geological and industrial significance. The kaolin minerals kaolinite, halloysite, dickite and nacrite are essentially of similar chemical composition but they have important structural and stacking differences. The most common kaolin mineral is kaolinite [$Al_2Si_2O_5(OH)_4$]. The mode of formation of the kaolins depends on the mineralogy, chemistry and morphology of the kaolin minerals, which may affect their physical and chemical characteristics and their ultimate industrial applications [1].

Organic clay is defined as clay with sufficient organic content to influence the soil properties [2]. Organic clays are normally characterized by high plasticity, high water content, high compressibility, low permeability and low shear strength. These characteristics make organic clays unsuitable for engineering construction unless a suitable improvement method is applied. The amount of soil organic matter significantly affects the index properties, physico-chemical and engineering properties of soils, including specific gravity, water content, liquid limit, plastic limit, density, cation exchange capacity, hydraulic conductivity, compressibility and strength [3]. There are two main fractions of humified organic matter present in organic soils, namely humic acid and fulvic acid. Based on several studies carried out by previous researchers, it was agreed that humic acid is the main constituent of organic matter affecting the properties of soil [4].

This paper addresses the results of experimental study carried out on artificial organic clay in which commercial kaolin (grade FM) was mixed with different humic acid contents to simulate organic clay. The effects of humic acid on geochemistry properties of kaolin are investigated and summarized.

Description of Experimental Program

A series of tests is conducted in order to examine the effect of humic acid on geochemistry properties of kaolin. This includes the effect of humic acid on the specific gravity, Atterberg limit, compaction and Loss on Ignition (LOI) of kaolin grade FM. The water soluble humic acid is obtained from a local fertilizer shop which was imported from China. The loss on ignition of humic acid at 440°C is found to be as high as 60% and its total organic carbon versus total carbon is greater than 99% [5]. Whereas, the kaolin grade FM is marketed by Kaolin (M) Sdn. Bhd. which is dominant silt sized [6].

Soil samples were remolded by mixing kaolin with different percentage of humic acid ranging from 0% to 50% of the total dry mass, thus, the samples are considered as artificial organic soil. In this study, three (3) types of soil were used namely:

- Soil 1 - ratio of kaolin and humic acid (10:0)
- Soil 2 - ratio of kaolin and humic acid (7:3)
- Soil 3 - ratio of kaolin and humic acid (5:5)

Results and Discussion

Specific Gravity Based on Table 1, specific gravity of the samples were in the range of 1.97 to 2.44. Soil 1 was found to have highest specific gravity of 2.44 while the lowest specific gravity was 1.97 for soil 3. According to the results obtained the specific gravity for samples decreased slightly with increments of humic acid content. The specific gravity of soil sample mixed with humic acid varied from 1.97 to 2.12 with different percentages of humic acid added. It was reported that specific gravity of organic soil is quite variable and may fall below 2 [7]. These specific gravity values are low when compared to the soils without humic acid. These low values are attributed to the amount of lightweight humic acid content present in the soils.

Table 1 Specific gravity of soil sample

Specimen Reference	Specific Gravity
Soil 1	2.44
Soil 2	2.12
Soil 3	1.97

Effect on Compaction Characteristics A series of test is conducted to study the effect of humic acid content on the compaction characteristics of soil specimens. These samples were compacted in accordance to the British Standard 1377: Part 4: 1990 whereby the samples were compacted in three layers with a 2.5 kg rammer that delivers 25 blows to each layer. The results obtained are shown in Figure 1.

As shown, the addition of humic acid has significantly reduced the maximum dry unit weight of soil specimens. The reduction of dry unit weight is attributed to the low unit weight of organic matter- humic acid in it. However, the optimum moisture content was not affected by increment of humic acid. These findings are different from previous study which indicated that the optimum moisture contents increased with increment of humic acid contents [9]. This could be due to the low percentage of humic acid added in the previous study which only up to 3%. Hence, it is believed that the behaviour of the soil with low humic acid contents will follow the classical soil mechanics in which the optimum moisture content tends to increase with decreasing of maximum dry density.

Loss on Ignition (LOI) From Figure 2, it is shown that the Loss on ignition of soil ranged from 2.457% to 50.403%, Soil 3 was found to have the highest Loss on ignition among the other samples which was 50.403%. Soil 1 with no humic acid content, was found to have the lowest Loss on ignition among the other samples which was 2.457%, and loss on ignition of soil 2 was 27.492%.

Generally, the results showed in Figure 2 indicated that the loss on ignition increased with the increase of humic acid content on soil sample. Loss on ignition was measured as a reference guide on the organic contents of soils. The Malaysian Soil Classification system defines the soil with organic content from 3 to 20% as slightly organic clay and soil with 20 to 75% is considered as organic soil [8]. Based on the results obtained, both Soil 2 and Soil 3 can be categorized as organic soil that falls into the range of organic soil.

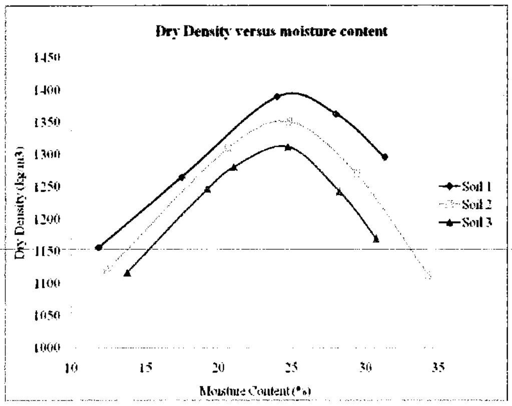

Figure 1 Compaction curve of kaolin with different humic acid contents

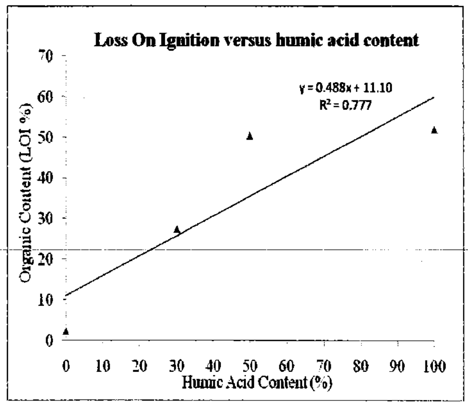

Figure 2 Loss on ignition versus humic acid contents

Atterberg Limit The Atterberg limit is used to describe how the consistency of the soil changes with the water content. Figure 3 shows the effect of humic acid content on the liquid limit, plastic limit and plasticity index of soil specimen. As shown in Figure 3, liquid limit of the soil decreased significantly with the increase of humic acid. However, the plastic limit was only slighlty decreased with the increase of humic acid. Liquid limit of the soils were obtained in the range of 50% to 80%, in which the lowest value was recorded as 50.4% for Soil 3 while the highest was 75.475% for Soil 1. In addition the plastic limit was found to be in the range of 30% to 40%, with the lowest value 30.914% for Soil 3 and the highest value 37.697% for Soil 1. As for plasticity index, it was found that the highest and lowest was soil 1 and soil 3, respectively.

The other researcher [9] also found that the liquid limit decreased with the increase of humic acid. However, this study [9] concentrated only on the humic acid contents up to 10% and found that the plastic limit increased slightly with the increase of humic acid. However, the findings on the plasticity index decreased with the increased of humic acid was in agreement with this researcher [9].

Figure 4 was plotted to determine the relationship of liquid limit with organic content obtained from Loss On Ignition test. It is shown that the liquid limit tends to decrease with increasing of organic content. Likewise, Eq. 1 present liquid limit-organic content based on Loss on Ignition for the soil sample with a correlation coefficient of 0.914.

$$LL = -0.629LOI\ (\%) + 76.28 \quad (1)$$

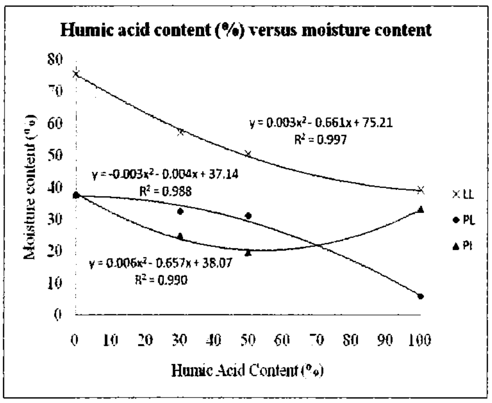

Figure 3 Atterbeg limits of soil versus humic acid contents

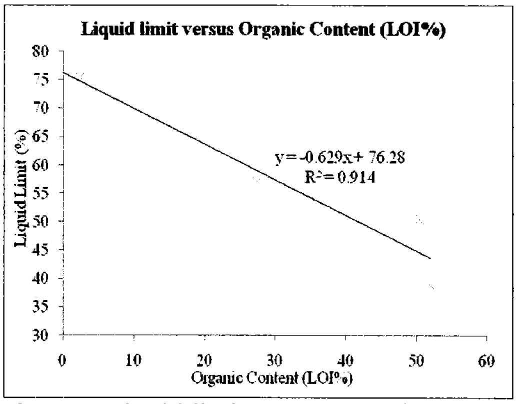

Figure 4 Liquid limit versus organic content (LOI)

Conclusion

From the result of this study it can be concluded that the addition of the humic acid on the soil can affect the properties of the soil.

- The dry unit weight of the soil decreases with an increase in humic acid content. This decrease is due to the fact that the increase in organic material (humic acid) decreases the soil unit weight.
- The specific gravity of soils varied from 1.97 to 2.44. These specific gravity values are low when compared to the inorganic soils. These low values are attributed to the amount of lightweight organic content present in the soils.
- The Loss On Ignition (LOI) of soil samples varied from 2.457 percent to 50.403 percent. The results indicated that soil 1 is not considered as an organic soil while soil 2 and soil 3 are considered as an organic soil.
- The plasticity index of the soil samples varied from 19.486 to 37.778. The plasticity index of the soil is exponential with an increase in the humic acid content. The soil liquid limit found to decrease with increase in the humic acid content in the soil.

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