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THE EFFECT OF BOTTOM ASH AND KAOLIN ON THE STRENGTH OF POOR SUBBASE

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ABSTRACT: The lateritic soil in this study represented weak subbase for road construction. This induced low compressive strength and poor durability of subbase. This research investigated the use of bottom ash and kaolin to improve the strength and durability of lateritic soil. The unconfined compressive test conducted on the soil samples mixed with cement at 1-1.5%, kaolin at 0.5-1% and bottom ash at 2-8% by weight of soil. The samples were cured in a plastic bag at 3, 7 and 14 days then soaked in the water at 2 hours before the test. The results shown the unconfined compressive strength of the soil improvement tends to increase with an increase in the amount of bottom ash. The soil mixed with cement at 1.5%, kaolin at 0.5%, and bottom ash at 6-8% can be developed the strength near the soil mixed with cement at 3% in 7 days. Moreover, the soil samples mixed with bottom ash at 6%, kaolin at 0.5% and cement at 1.5% can be increased the compressive strength 87% of the samples without bottom ash and kaolin. The strength requirement of subbase improvement is 689 kPa at the curing time 7 days. The results demonstrated the strength of soil mixed with cement at 1.5%, kaolin at 0.5% and bottom ash at 4-8% was higher than the requirement. In conclusion, bottom ash and kaolin can develop the strength of poor subbase and reduced the utilized amount of cement to improve the strength of soil.

Keywords: Lateritic soil, Bottom ash, Compressive strength, Kaolin, Subbase

1. INTRODUCTION

The lateritic soil has been used in road construction of Thailand and developing in the rural area. The subbase of road constructions was constructed by lateritic soil. However, it's become the realize problem of lateritic soil. This is because the poor lateritic soil is low compressive strength and poor durability. Therefore, the bearing capacity of poor subbase was lower than the minimum requirement for road construction. Subsequently, the rain infiltration or the water inundates the subbase can be causing the road damage. In general, three important effects in the lateritic soil mineral consist of the initial material is enriched with aluminum and iron oxide and hydroxide, the mineral component of clay is mainly composed of kaolinite and the silica content is highly reduced [1]. This problem represents to emphasis for improvement in engineering properties of lateritic soil such as compressive strength, durability, and permeability [2].

The most commonly used additive for soil stabilization is ordinary Portland cement. To build a subbase with cement stabilized ash alone is not yet common, but this is one of the high volume ash application being promoted by ash producers [3]. The use of ash or the pozzolanic materials combined with cement to improve the strength of soil can be reduced the cost of soil stabilization. Therefore, this study investigated the use of bottom ash, which is the by-product from Mae Moh power plant and kaolin to improve the strength of poor subbase.

Ash removed from the base of the furnace is termed bottom ash [3]. Bottom ash (BA) is a solid waste available in Mae Moh power plant in the north of Thailand is about 0.8 million tons and is disposed of a landfill near the power plant [4]. It is coarser than fly ash, ranging in size from fine sand to gravel [3]. Bottom ash is larger in size and very irregular, containing pores and cavities [5]. Ground to a proper fineness, bottom ash can be used as a pozzolan that produces relative strength [6]. The chemical compositions of bottom ash were 39.3% SiO_2, 21.3% Al_2O_3, Fe_2O_3, 2.1% K_2O, 16.5% CaO, 1.0% Na_2O and 1.4% loss on ignition. The bottom ash has increased pozzolanic activity and used to partially replace Portland cement. The utilization of bottom ash as a cementitious a partial replacement of cement is possible [4].

Bottom ash serves well as structural fill and construction [3]. A variety of research on the mobilization of coal bottom ash for use as the cementitious material has been utilized. The bottom ash has increased the pozzolanic activity [7, 8]. Therefore, many types of research have been used the bottom ash as fine aggregate in concrete [9], asphaltic [10]. On the other hand, the bottom ash can involve clay minerals and increases the value of supporting the capacity of the clay and increasing the compressive strength value [11].

Kaolin is widely spread in Lampang, North of Thailand. It is suitable to use in ceramic industries. However, this material has the potential to use in other applications, such as alumina production [12] and pozzolanic material [13]. In this study, kaolin having a significant content of impurities, such as calcite and alumina. Kaolin is a mineral of soil, which some of these noncement additives. In chemical terms, kaolin has many cementing materials consists of SiO_2, Al_2O_3, and Fe_2O_3. These elements can improvement bonding, durability and stabilization of soil [14].

There are many of additive that has been tested the effect to develop the engineering properties of lateritic soil. In order to reduce costs by replacing some cementations stabilizers with non-cementations additives [15, 16, 17]. Therefore, this paper investigated the use of bottom ash and kaolin to improve the strength and durability of soils.

The objective of this paper is investigating in the utilization of bottom ash and kaolin to improve the strength and develop durability of lateritic soil. The strength of the soil improvement should be higher than 689 kPa. This is the strength requirement recommended by the Thailand Department of highways.

2. MATERIALS PREPARATION AND MIXTURE OF SOIL IMPROVEMENT

The lateritic soil, which has poor quality was used in this experiment. The strength of the soil samples was less than the requirement of Thailand department of highways. The soil samples were conducted on Atterberg limits test and sieve analysis test to determine the properties and classification of the samples. Portland cement type 1, kaolin and bottom ash were mixed with the soil samples to improve the strength. Kaolin obtained from Lampang province of Thailand. Bottom ash obtained from Mae Moh power plant in Lampang province of Thailand as shown in Fig. 1.

The maximum particle size of bottom ash mixed with the soil samples was 4.75 mm. All admixture stored in plastic bags to maintain their dry condition. The soil samples were mixed with cement, kaolin and bottom ash in the ratio according to Table 1. The mixture code in group A represented the soil samples mixed with cement 1.5-3% by weight of the soil samples. The mixture code in group B represented the soil samples mixed with cement 1%, kaolin 1% and bottom ash 2-8% by weight of soil. The mixture code in group C represented the soil samples mixed with cement 1.5%, kaolin 0.5% and bottom ash 2-8% by weight of soil.

The difference between the mixture in group B and C is the percentage of Portland cement and kaolin. The combination of cement and kaolin in the mixture B and C was 2% by weight of the soil samples. However, the amount of cement in the mixture of group B was less than the mixture of group C at 0.5%.

Fig.1 Bottom ash obtained from Mae Moh power plant.

The soil samples mixed with cement, kaolin and bottom ash, according to Table 1 were conducted on modified compaction tests and unconfined compression tests.

Table 1 The mixture ratio of admixture mixed with the soil samples

Mixture code	Cement (%)	Kaolin (%)	Bottom Ash (%)
A1	1.5	-	-
A2	2	-	-
A3	3	-	-
B1	1	1	2
B2	1	1	4
B3	1	1	6
B4	1	1	8
C1	1.5	0.5	2
C2	1.5	0.5	4
C3	1.5	0.5	6
C4	1.5	0.5	8

Note: The amount of cement, kaolin and bottom ash mixed with soil is percent by weight of soil.

The modified proctor compaction tests on the samples for each mixture were conducted in accordance with AASHTO T180. This test is intended to be used to determine the maximum dry density and optimum moisture content of the samples for each mixture. The samples were manually compacted in five equal layers using the modified compaction effort.

Unconfined compression tests are intended to be used to determine the compressive strength of the samples. Unconfined compression tests were conducted in accordance with AASHTO T 208. The soil samples mixed with cement, kaolin and bottom ash in the ratio according to Table 1 were used in this test. The samples mixed with water at the optimum moisture content (OMC) for each mixture which obtained from the results of modified compaction tests. The samples were compacted in five equal layers using modified compaction effort. After completing the compaction process, each sample was extruded from the compaction mold and then cured in the plastic bag until tested. The specimens were cured in the plastic bag for 3, 7 and 14 days. Following the curing process, the samples were soaked in water for 2 hours and then compressed the samples by the compression machine. The results represented by the effect of bottom ash and kaolin on the strength of soil improvement. However, the Thailand Department of highways suggested that the unconfined compressive strength of subbase improvement should be more than 689 kPa at the curing time 7 days. Therefore, the optimum bottom ash content to improve the strength of the soil can be defined by the test results.

3. RESULTS AND DISCUSSIONS

3.1 Engineering Properties of Lateritic Soil

The soil samples were conducted on Atterberg limits test, sieve analysis test, and modified compaction test to determine the engineering properties of the soil samples. Liquid limit, plastic limit, and plasticity index of the soil samples were 27%, 17%, and 10%, respectively. Fig. 2 shows the particle size distribution of the soil samples in this study. According to the AASHTO classification system, the soil samples were in A-2-4. The gradation of soil samples is excellent to good for subgrade materials when considered on the general subgrade rating of AASHTO. Moreover, the results of modified compaction tests demonstrated the maximum dry density of the soil samples was approximately 1940 kg/m^3 and optimum moisture content was 9.9%.

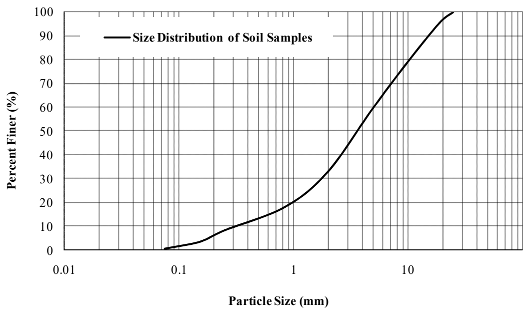

Fig.2 Particle size distribution of the soil samples used in the test.

3.2 Maximum Dry Density and Optimum Moisture Content

The modified compaction tests were conducted on soil samples mixed with cement, kaolin and bottom ash in a ratio according to Table 1. The results of compacted soil samples mixed with cement 1.5%-3% shown in Fig. 3. The results showed the dry density of the samples mixed with cement was slightly different from the samples without cement. The maximum dry density of the samples A1, A2, and A3 was 1957 kg/m^3, 1959 kg/m^3, and 1946 kg/m^3 respectively. The optimum moisture content of the samples A1, A2 and A3 were 9.7%, 9.8%, and 10.2%, respectively.

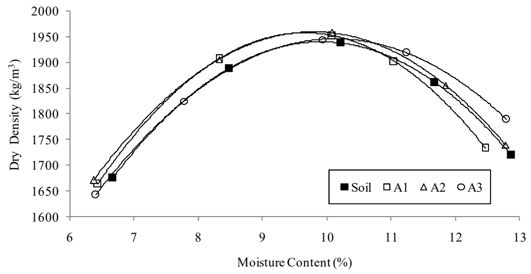

Fig.3 The relationship of dry density and moisture content of the soil improvement by cement.

The results of soil samples mixed with cement, kaolin and bottom ash shown in Fig. 4 and Fig. 5. The results in Fig. 4 illustrates dry density and moisture content of the samples in group B. The maximum dry density of the samples B1, B2, B3, and B4 was 1945 kg/m^3, 1961 kg/m^3, 1954 kg/m^3 and 1966 kg/m^3, respectively. The optimum moisture content of the samples B1, B2, B3, and B4 was 9.8%, 9.9%, 9.9%, and 11.1%, respectively.

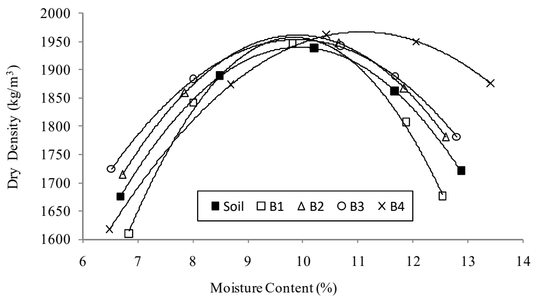

Fig.4 The relationship of dry density and moisture content of the soil improvement in group B.

Dry density and moisture content of the samples in group C illustrated in Fig. 5. The maximum dry density of the samples C1, C2, C3, and C4 was 1960 kg/m^3, 1942 kg/m^3, 1938 kg/m^3 and 1940 kg/m^3, respectively. The optimum moisture content of the samples C1, C2, C3, and C4 was 9.8%, 10.4%, 10.0%, and 10.0%, respectively.

The results demonstrated a slight difference of maximum dry density and optimum moisture content of the samples for each mixture. The maximum dry density of the samples for each mixture was between 1940-1960 kg/m^3. Therefore, bottom ash and kaolin adding in the soil samples is less effect on the maximum dry density of soil.

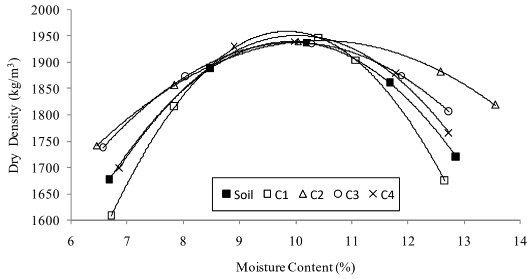

Fig.5 The relationship of dry density and moisture content of the soil improvement in group C.

3.3 Unconfined Compressive Strength

The average unconfined compressive strength values of the soil improvement for each mixture are plotted in Fig. 6.

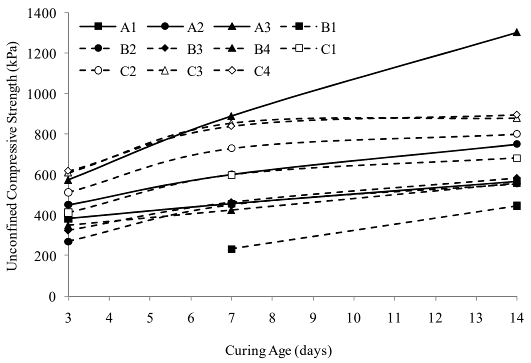

Fig.6 Unconfined compressive strength of the soil improvement for each mixture.

The results demonstrated the soil samples mixed with 3% of cement gave the highest strength in 14 days. The strength of A3 samples was 1302 kPa at curing time 14 days. The strength of C3 and C4 samples at the curing 14 days was lower than A3 approximately 415 kPa. However, the early strength of C3 and C4 samples was near A3 at the curing time 3 and 7 days as shown in Fig.7.

Although, C3 and C4 samples contain Portland cement only 50% of A3. The results suggested that bottom ash mixed with soil can be developed the early compressive strength of soil. This is due to the composition of bottom ash obtained from Mae Moh power plant were 21.3% Al_2O_3 and 13.5% Fe_2O_3 [4]. Al_2O_3 and Fe_2O_3 in the bottom ash can be developed the early strength of the samples. However, the strength of A3 is more than C3 and C4 at the curing time 14 days. This is because the cement content in A3 samples was higher than C3 and C4 and the later strength is controlled mainly by calcium silicate hydrate.

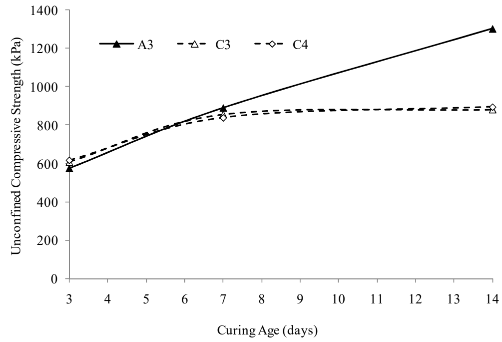

Fig. 7 The unconfined compressive strength of C3, C4, and A3.

Consideration on A1 samples and the samples in group C which contain the same amount of cement in the samples at 1.5% by weight of soil. The results demonstrated the strength of the samples in group C which contained kaolin 0.5% and bottom ash 2-8% was higher than A1 samples as shown in Fig.8. Moreover, the strength of the samples tends to increase with an increase in the amount of bottom ash. The compressive strength of C3 and C4 was near at the curing time 3-14 days. The compressive strength of the samples C3 and C4 increased approximately 87% and 84% of A1 samples at curing time 7 days. However, the strength of C3 and C4 samples at curing time 14 days was higher than A1 approximately 55%.

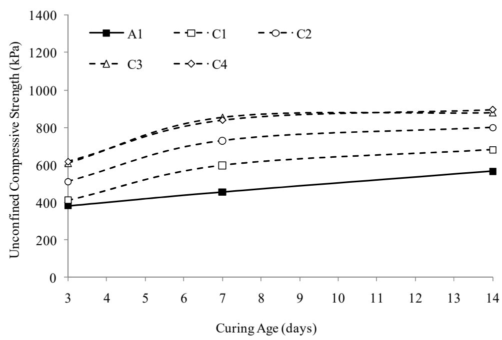

Fig.8 The unconfined compressive strength of A1, C1, C2, C3, and C4.

Moreover, B2, B3, and B4 samples represented the unconfined compressive strength near A1 samples. Although, the samples in group B contain the amount of cementless than the A1 samples at

0.5% by weight of soil. Therefore, this result demonstrated that bottom ash can be reduced the utilized amount of cement to improve the strength of soil. The influence of bottom ash on the compressive strength of soil shown in Fig. 9 and Fig. 10.

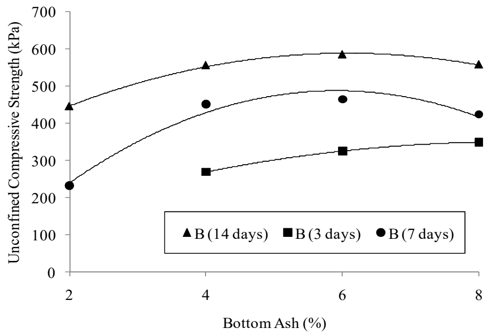

Fig.9 The influence of bottom ash on the compressive strength of soil mixed with the admixture in group B.

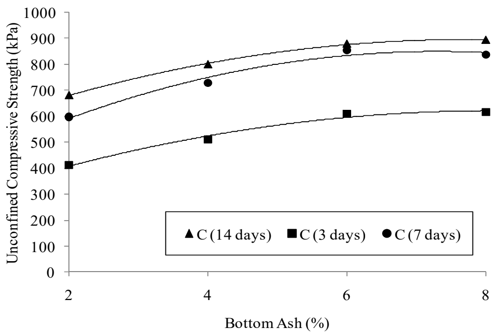

Fig.10 The influence of bottom ash on the compressive strength of soil mixed with the admixture in group C.

The results demonstrated the strength of soil improvement tends to increase with an increase in the amount of bottom ash. The unconfined compressive strength was rapidly increasing when bottom ash contains in the samples was 2% to 6%. However, the samples which contain bottom ash 6% and 8% shown the similar value of the unconfined compressive strength. Therefore, this result can suggest the optimum content of bottom ash used to improve the strength of the soil.

Nevertheless, the soil samples mixed with cement 1%, kaolin 1% and bottom ash 2% at curing time 3 days represented breakdown of the samples after soaked in the water for 2 hours. This is because the amount of cementitious materials is not enough to react. However, the increasing amount of cement, bottom ash, and kaolin in the soil samples can increase the strength and the durability of soil. Moreover, the sample mixed with cement at 1% and bottom ash 4-8% (without kaolin) was breakdown during the samples soaked in the water. The addition of kaolin at 1% in the mixture (Mixture in group B) can maintain the physical characteristics of the sample (not breakdown) after soaked in the water. Therefore, this results demonstrated kaolin can improve the durability of soil.

The required unconfined compressive strength of subbase improvement suggested by the Thailand Department of highways was 689 kPa at the curing time 7 days. Fig.11 demonstrated the unconfined compressive strength of soil mixed with an admixture for each mixture at the curing time 7 days. The samples passed the minimum strength requirement consisted of the samples A3, C2, C3, and C4. The unconfined compressive strength of the samples A3, C2, C3, and C4 was 889 kPa, 729 kPa, 854 kPa, and 838 kPa, respectively. Therefore, the samples mixed with cement at 1.5%, kaolin at 0.5%, and bottom ash at 4-8% can develop the strength of poor subbase higher than the minimum required strength. However, the soil samples mixed with admixture in group B cannot develop the strength higher than the required strength. This is because the amount of cement in the mixture is not enough to increase the strength of soil.

Fig. 11 The unconfined compressive strength of the soil improvement for each mixture at curing time 7 days.

Although the A1 samples have the amount of cement same as C2, C3, and C4, the A1 samples cannot develop the strength of soil higher than the minimum requirement. However, C2, C3, and C4 samples can be developed the strength higher than the minimum requirement. This result can be demonstrated that bottom ash and kaolin can develop the strength of soil. Therefore, bottom ash and kaolin mixed with the soil can be reduced the utilized amount of cement to improve the strength of soil.

4. CONCLUSION

Based on the results obtained from the

experimental in this study, the following conclusion was made:

1. Bottom ash and kaolin can increase the unconfined compressive strength of poor subbase. The optimum content of bottom ash mixed with soil is 6% by weight of soil.

2. Bottom ash and kaolin can develop the early strength of soil. The strength of the samples contains bottom ash and kaolin was higher than the samples without bottom ash and kaolin approximately 84% at curing time 7 days.

3. The strength requirement which suggested by the Thailand Department of highways is 689 kPa at curing time 7 days. The soil samples mixed with cement at 1.5%, kaolin at 0.5%, and bottom ash at 4-8% can be developed the unconfined compressive strength more than the strength requirement.

4. The strength of soil mixed with cement at 1.5%, kaolin at 0.5% and bottom ash at 6-8% is equivalent to the soil mixed with cement 3% at curing time 7 days. The unconfined compressive strength was approximately 850 kPa.

5. Bottom ash and kaolin can improve the strength and durability of poor subbase. Moreover, bottom ash and kaolin can be reduced the utilized amount of cement to improve the strength of soil.

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