Compressive Strength of Marginal Lateritic Soil Stabilized with Bottom Ash Geopolymer as a Pavement Material

Cherdsak Suksiripattanapong, Niti Tuntawoot, Jaksada Thumrongvut, Nattiya Wonglakorn, Suppharutchaya Chongutsah, and Wisitsak Tabyang

Abstract—**This research investigated compressive strength and microstructure of marginal lateritic soil stabilized with bottom ash geopolymer as a pavement material. The marginal lateritic soil (MLS) was obtained from a borrow pit in Chaiyaphum Province. Bottom ash (BA) was obtained from the Mae Moh power plant of the Electricity Generating Authority of Lampang Province. This research used the MLS:BA ratios of 70:30, 50:50 and 30:70 and Na_2SiO_3:NaOH ratios were 0:100, 10:90, 30:70, 50:50, 70:30 and 80:20. The test results showed that the Na_2SiO_3:NaOH ratios do not affect the unit weight of marginal lateritic soil stabilized with bottom ash geopolymer. The 7-day compressive strength of marginal lateritic soil stabilized with bottom ash geopolymer increases with the increase in Na_2SiO_3:NaOH ratio (higher Na_2SiO_3 content) because silica from Na_2SiO_3 reacts with silica and alumina from bottom ash resulting in geopolymer gel or sodium aluminosilicate hydrate (N-A-S-H). All 7-day UCS values are greater than the minimum strength requirement for UCS of 689 kPa specified by the Department of Highways, Thailand.**

Index Terms—**Compressive strength, microstructure marginal lateritic soil, bottom ash, geopolymer.**

I. Introduction

Transportation is significant for development of country. Roadways and Highways are one major mode of transportation. Generally, roadways are constructed in four layers which composed of subgrade, subbase, base and surface layer. An available material at the road construction site is used for road construction. However, some of available material does not typically meet the standard requirement as subbase/base materials. Marginal available materials can be effectively improved by chemical stabilizing agents with an additive, such as Portland Cement (PC) [1], lime and bitumen. However, the production of 1 ton of OPC releases about 1 ton of carbon dioxide, resulting in a significant amount of greenhouse gas into the atmosphere [2]-[4].

Geopolymerization is a process that creates cementitious compounds by the dissolution of aluminosilicate compounds by highly alkaline liquids. The geopolymerization of aluminosilicate-rich materials results in strong cementitious compounds [5]-[9]. Bottom ash (BA) is a aluminosilicate-rich materials which is a by-product from electrical manufacturing factory, Mae Moh, Thailand. Chemical compositions of bottom ash is essentially the same as the fly ash which is the main aluminosilicate-rich material used in the geopolymer materials. However, the compressive strength of BA was lower than that of fly ash geopolymer because of larger particle size [10].

This research investigates the improvement of marginal lateritic soil (MLS) as a green pavement materials using a bottom ash geopolymer. Na_2SiO_3:NaOH ratio was used as an liquid alkaline activator. The influential factors studied include marginal lateritic soil/BA ratios, liquid alkaline activator contents, Na_2SiO_3:NaOH ratio. Unconfined compressive strength (UCS) of MLS-BA geopolymer was investigated and compared the results with the standard of the Department of Rural Roads, Thailand. The microstructural analyses of BA geopolymer stabilized MLS via scanning electron microscopy (SEM) were carried out to enlighten the role of influence factors. This research is useful for using bottom ash as a green base/subbase materials.

II. Materials and Sample Preparation

A. Materials

The Marginal Lateritic Soil (MLC) was collected from Nakhon Ratchasima province, Thailand at a depth of 5 m (Fig. 1). Fig. 2 shows the grain size distribution of the MLC. The MLC is classified as SP in accordance with the Unified Soil Classification System.

Bottom ash (BA) was collected from Mae Moh power plant in Thailand (Fig. 1). Fig. 2 show the grain size distribution of BA. The grain size of BA was larger than that of MLC.

Liquid alkaline activator (L) composed of sodium silicate (Na_2SiO_3) and sodium hydroxide (NaOH). L content was O.8OLC, OLC and 1.2OLC (OLC = optimum liquid alkaline activator content).

B. Sample Preparation

The composition of MLS-BA geopolymer sample was MLS, BA and liquid alkaline activator (Na_2SiO_3 and NaOH). The MLS:BA ratios were varied by 70/30, 50/50 and 30/70. The Na_2SiO_3:NaOH ratios were 0/100, 10/90, 30/70, 50/50 70/30 and 80/20. The MLS and BA were mixed until an observable consistency in coloration was observed for 2 minutes. The Na_2SiO_3:NaOH was added and 5 minutes mixed. Under modified Proctor energies in preventing liquid

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evaporation and hardening of the geopolymer, compaction was continued immediately thereafter. The L content of 5 to 20% by total weight was added into the mix to obtain the optimum L content of all mix proportions according to ASTM D1557-12. The mixture was then compacted in a standard mould of 101.6 mm in diameter and 116.4 mm in height. The Unconfined Compressive strength (UCS) specimens (Fig. 3) were wrapped in clear vinyl, after that cured at room temperature for 7 days.

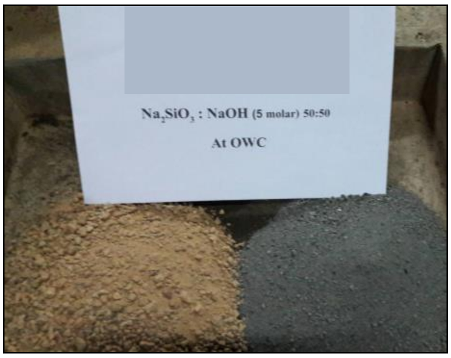

Fig. 1. Characteristic of MLS and BA.

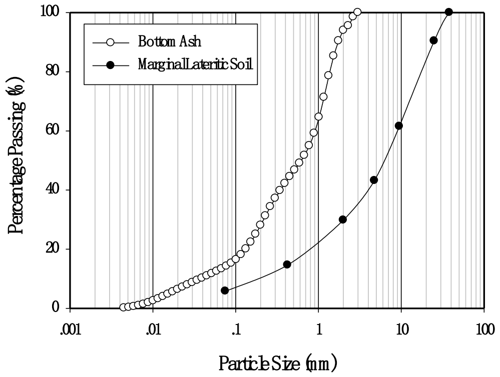

Fig. 2. Grain size distribution of MLS and BA.

Fig. 3. MLS-BA geopolymer specimens.

III. Results and Discussion

A. Compaction Curve of MLS-BA Geopolymer

Fig. 4 shows the relationships between dry unit weight and alkaline content of the MLS-BA geopolymers at various MLS/BA ratios of 70/30, 50/50 and 30/70 and Na_2SiO_3:NaOH ratios of 0:100, 10:90, 30:70, 50:50, 70:30 and 80:20. The test results show that the Na_2SiO_3:NaOH ratios do not affect the unit weight of marginal lateritic soil stabilized with bottom ash geopolymer. The maximum dry unit weight (γ_{dmax}) values of samples decreased with an increase in BA content for all Na_2SiO_3:NaOH ratios, due to the specific gravity of MLS being higher than that of BA. The MLS:BA ratio of 70:30 and Na_2SiO_3:NaOH ratios of 0/100 gave the highest γ_{dmax}. The optimum L contents increased as the BA content increased for all Na_2SiO_3:NaOH ratios; i.e., the L values of MLS-BA geopolymer samples of 70:30, 50:50 and 30:70 were about 10, 11 and 14%. This increase in L was due to BA, which has high surface particles [11] resulting in a high water absorption.

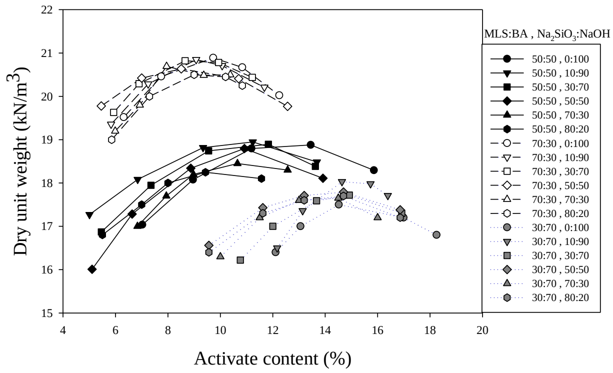

Fig. 4. Compaction curves of MLS-BA geopolymer with various Na_2SiO_3:NaOH.

B. Compressive Strength of MLS-BA Geopolymer

Fig. 5-7 indicate the 7-day UCS of MLS-BA geopolymer samples at various MLS/BA ratios of 70/30, 50/50 and 30/70, Na_2SiO_3:NaOH ratios of 0:100, 10:90, 30:70, 50:50, 70:30 and 80:20 and L of 0.8OLC, 1.0OLC and 1.2OLC. The 7-day compressive strength of marginal lateritic soil stabilized with bottom ash geopolymer increases with the increase in Na_2SiO_3:NaOH ratio (higher Na_2SiO_3 content) because sodium aluminosilicate hydrate (N-A-S-H) product [12]-[15]. The 7-day UCS of MLS-BA geopolymer samples at L of 1.0OLC give the highest UCS values for all MLS/BA ratios and Na2SiO3:NaOH ratios. Their 7-day UCS values are also greater than the minimum strength requirement for UCS of 689 kPa specified by the Department of Highways, Thailand [16]. The maximum 7-days UCS of MLS-BA geopolymer sample was found at MLS/BA ratio of 70/30, Na_2SiO_3:NaOH ratios of 80/20 and L of 1.0OLC offering 7-day UCS of 2,672 kPa.

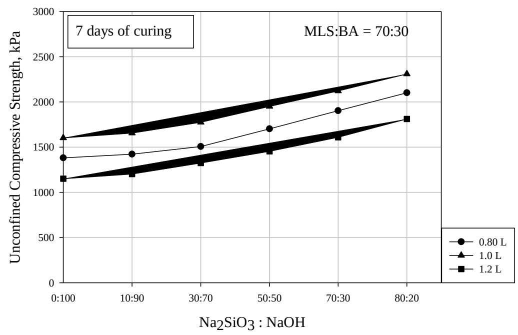

Fig. 5. The 7-day UCS of MLS-BA geopolymer at MLS-BA of 70:30.

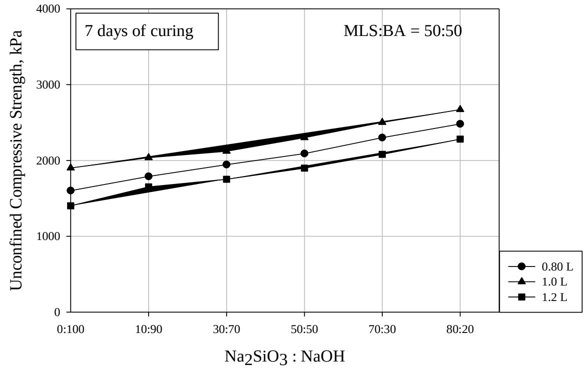

Fig. 6. The 7-day UCS of MLS-BA geopolymer at MLS-BA of 50:50.

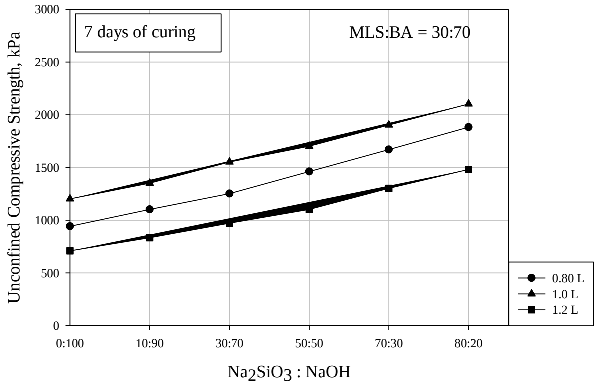

Fig. 7. The 7-day UCS of MLS-BA geopolymer at MLS-BA of 30:70.

IV. Conclusions

The compressive strength and microstructure of marginal lateritic soil stabilized with bottom ash geopolymer as a pavement material is presented in this study. The influential factors studied include marginal lateritic soil/BA ratios, liquid alkaline activator contents, Na_2SiO_3:NaOH ratio. The Na_2SiO_3:NaOH ratios do not affect the unit weight of marginal lateritic soil stabilized with bottom ash geopolymer. The 7-day compressive strength of marginal lateritic soil stabilized with bottom ash geopolymer increases with the increase in Na_2SiO_3:NaOH ratio (higher Na_2SiO_3 content) because silica from Na_2SiO_3 reacts with silica and alumina from bottom ash resulting in geopolymer gel or sodium aluminosilicate hydrate (N-A-S-H). All 7-day UCS values are greater than the minimum strength requirement for UCS of 689 kPa specified by the Department of Highways, Thailand. The maximum 7-days UCS of MLS-BA geopolymer sample was found at MLS/BA ratio of 70/30, Na_2SiO_3:NaOH ratios of 80/20 and L of 1.0OLC offering 7-day UCS of 2,672 kPa.

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