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Factors Affecting Properties of Cellular Lightweight Clay Improved with Fly Ash Geopolymer and Cement

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Abstract

This research investigated the unit weight and unconfined compressive strength (UCS) of cellular lightweight high-calcium fly ash geopolymer and cement-stabilized soft Bangkok clay (CLFAG-OPC stabilized SC) as potential lightweight embankments and backfill materials. The investigated parameters included the soft clay:fly ash (SC:FA) ratio (50:50 to 90:10), ordinary Portland cement (OPC) content (0%-3%), water content (1.5LL-3.0LL), liquid alkaline content (L) (0.6FA to 1.5FA), NS:NH ratio (0.5-3), NH concentration (8 M), air foam content (Ac) (0%-150% by SC volume), and curing time (7-90 days). The results indicated that the SC:FA ratio, OPC content, water content, NS:NH ratio, L content, and Ac significantly influenced both the unit weight and UCS of samples. Increasing water content, L content, and Ac generally reduced unit weight, except when influenced by FA content, OPC content, and the NS:NH ratio. The optimal composition for maximum UCS was achieved with an SC:FA ratio of 50:50, OPC content of 3%, water content of 2.0LL, NS:NH ratio of 1, L content of 0.6FA, and 0% Ac. A predictive equation for unit weight was proposed using phase diagrams. Additionally, mix design charts were shown to be valuable tools for calculating the unit weight and UCS, demonstrating their effectiveness for lightweight embankment and backfill applications.

Keywords: Lightweight Cellular; Unit Weight; Unconfined Compressive Strength; Lightweight Embankment Materials.

1. Introduction

Civil engineering and infrastructure development, including airport runways, buildings, bridges, and roads, has been rapidly advancing to promote economic and social growth [1]. In Thailand, particularly in the Bangkok region, the soil structure consisted mainly of soft Bangkok clay (SC), which had a high water content, high liquid limit, low shear strength, and low bearing capacity [2, 3]. This resulted in significant deformation or settlement during and after construction. In order to address these issues, ground improvement techniques, such as mechanical and chemical methods, have been widely employed [4-6]. The use of lightweight materials (unit weights ranging from 8 to 12 kN/m³) as a backfill material was an efficient alternative method to reduce the load on SC. Generally, cellular lightweight cemented clay, one of the lightweight materials, involves mixing SC, ordinary Portland cement (OPC), and air foam. Many researchers have conducted research on lightweight embankment materials [7-9]. Horpibulsuk et al. [4] investigated the unit weight and unconfined compressive strength (UCS) of cellular lightweight cemented soft Bangkok clay (CLC-SC) and reported that both the unit weight and UCS of the CLC-SC samples decreased as the air form content

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increased. Furthermore, Teerawattanasuk et al. [7] reported that the unit weight of CLC-SC samples for each pavement material layer could be estimated using mixed design charts. Recently, Chaiyaput et al. [3] studied the settlement of CLC-SC material as a lightweight embankment constructed on SC. They reported that the measured settlement of CLC-SC material was up to 80% lower than that of a traditional embankment. Also, Wu et al. [8] used OPC and air foam to produce CLC-stabilized marine clay for deep mixing columns application and concluded that the 90-day UCS and density of samples with OPC more than 30% were approximately 600–800 kPa and 1100–1200 kg/m^3, respectively. OPC was widely used to improve the strength of SC [10]. Nevertheless, the manufacture of OPC had a significant impact on the environment, which included the consumption of natural resources and the release of carbon dioxide. Every tonne of OPC manufactured resulted in the emission of an equal quantity of carbon dioxide into the environment [11]. Environmental problems have prompted the exploration of alternative binders with reduced carbon emissions.

Geopolymer is a binder material that has gained widespread popularity and is continually being developed as a substitute and alternative to cement in construction operations, with the aim of minimizing its usage. Geopolymers derived from silica (SiO_2) and alumina (Al_2O_3)-rich materials, such as fly ash (FA) [12, 13], bottom ash [14], rice husk ash [15] and activated using an alkaline solution containing sodium hydroxide (NH) and sodium silicate (NS). Several researchers have used geopolymer to stabilize soft clay [16-21]. Following this, Arulrajah et al. [16] studied the use of FA and slag (S) geopolymer to improve soft marine clay and indicated that the optimum binder content and FA:S ratio were found at 20% and 25:75, respectively. Also, the optimum ratio of NH:NS was found at 30:70, which offered maximum UCS, investigated by Yaghoubi et al. [17]. The UCS of SC stabilized with FA and OPC geopolymer was studied by Suksiripattanapong et al. [19], who reported that the optimum ingredient of the sample was an initial water content of 1.5LL, 70 FA:30 OPC ratio, and 50 NS:50 NH ratio, which gave the maximum 28-day UCS. Recently, the strength characteristics of SC with FA geopolymer and zinc sludge were investigated by Phojan et al. [20], who concluded that the maximum zinc sludge of 30% offered UCS, meeting the USEPA requirement. Nonetheless, limited research has been conducted on the engineering properties of cellular lightweight high calcium fly ash and OPC geopolymer (CLFAG-OPC) stabilized SC and the limited reporting of mix design charts for CLFAG stabilized SC, further research is needed in this area.

This study aimed to investigate the feasibility of using CLFAG and OPC to improve the engineering properties of SC as a lightweight embankment and backfill material. The effects of various control variables, including initial water content, SC:FA ratios, OPC content, liquid alkaline activator content, NS:NH ratios, air foam content, and curing time, were examined on the unit weight and UCS of CLFAG-OPC stabilized SC. The results of this study were presented in equation and mixed design charts to estimate the unit weight and UCS of the sample for efficient lightweight embankments and backfill materials. This article is structured as follows: the introduction is covered in Section 1, followed by a description of the materials and methods in Section 2. Section 3 presents and discusses the findings, and Section 4 provides the conclusions of the study.

2. Materials and Methods

2.1. Materials

Soft Bangkok clay (SC) was obtained from the city of Bangkok. The SC's specific gravity (*Gs*) was observed to be 2.67 [22]. The liquid limit (LL) of 62.77%, the plastic limit (PL) of 24.89%, and the plasticity index of 37.88%, respectively, were tested per ASTM D4318 [23]. The SC was categorized by the Unified Soil Classification System (USCS) as a high plasticity clay (CH) [24].

Fly ash (FA) was acquired from the Mae Moh power station located in Thailand. The FA had *Gs* [25] of 2.33. The chemical composition of FA was determined using the X-ray fluorescence Spectrometer (XRF) technique, as reported in Table 1. By weight, the combined fraction of SiO_2, Al_2O_3, and Fe_2O_3 was 75.41%. The calcium oxide concentration was 18.75%. The FA may be categorized as class C based on the ASTM C618 [26] standard.

Table 1. Chemical composition of FA and OPC

Chemical Composition (%)	FA	OPC
SiO_2	42.4	21.15
Al_2O_3	19.11	4.31
Fe_2O_3	13.9	3.66
CaO	18.75	63.68
MgO	N.D.	2.9
SO_3	3.20	2.58
Na_2O	0.58	0.59
K_2O	1.05	0.28
LOI	1.01	0.85

N.D. = Non-Detective

Ordinary Portland cement Type 1 (OPC) has a specific gravity (*Gs*) of 3.15. Table 1 illustrates the chemical composition of the OPC. The main chemical component of the OPC was calcium oxide (CaO), with a content of 63.68%. A liquid alkaline activator (L) was synthesized using NS and NH. In this study, NS:NH ratios of 0.5, 1, 2, and 3 and 8 molar NH concentrations were employed. Sika Poro 40 is an air foaming agent Sika (Thailand) Company Limited produces. The ratio of air foaming agent to water was 1:40.

2.2. Specimen Preparation and Testing

The CLFAG-OPC stabilized SC sample preparation consists of SC, FA, OPC, NS, NH, and air foam content (Ac). The initial water contents of SC of 1.5LL, 2.0LL, 2.5LL, and 3.0LL, SC:FA ratios of 90:10, 80:20, 70:30, 60:40, and 50:50, and OPC contents of 0, 1, 2 and 3% were used. The L contents of 0.6FA, 0.9FA, 1.2FA, and 1.5FA, NS:NH ratios of 0.5, 1, 2, and 3, and Ac of 0, 50, 100, and 150% by volume of SC were investigated in this study.

First, the SC samples, adjusting the water content to 1.5LL, 2.0LL, 2.5LL, and 3.0LL, were stored for 24 hrs. Second, SC, FA, OPC, NS, and NH were mixed for 5 minutes. The Ac was then added into SC, FA, OPC, NS, and NH samples and mixed for 5 mins. The CLFAG-OPC stabilized SC mixture was placed into PVC molds with diameters of 36 mm and heights of 72 mm and cured at room temperature for 24 hours. After curing, the CLFAG-OPC stabilized SC samples were removed from the molds and wrapped in plastic to prevent moisture loss as shown in Figure 1. The samples were stored at room temperature for 7 days before the unit weight and UCS, following ASTM D7263 [27] and ASTM D2166 [28] standards, were evaluated. The UCS development of CLFAG-OPC stabilized SC samples at a curing time of 7, 14, 28, 60, and 90 days was investigated. Additionally, mixed design charts of CLFAG-SC samples at a curing time of 7 days were presented in this study.

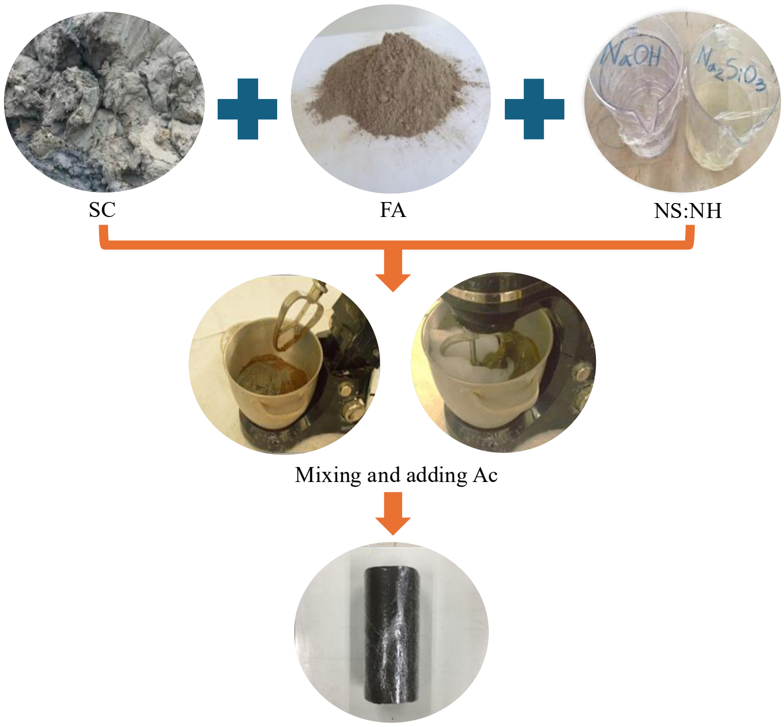

Figure 1. The preparation scheme of the CLFAG-OPC stabilized SC samples

3. Results and Discussions

3.1. Unit Weight of CLFAG-OPC Stabilized SC

The influence of water content on the 7-day unit weight of CLFAG-OPC stabilized SC samples at an SC:FA ratio of 70:30, water contents of 1.5LL, 2.0LL, 2.5LL, and 3.0LL, NS:NH ratio of 1, NH concentration of 8 molar, L content of 0.6FA, OPC contents of 0, 1, 2, and 3% by weight of SC and FA, and Ac of 0, 50, 100, and 150% by volume of SC, is shown in Figure 2. The 7-day unit weight of CLFAG-OPC stabilized SC samples noticeably decreased as the water content increased for all cement contents. However, for water content less than 1.5LL, the SC becomes highly viscous, preventing air voids from being able to infiltrate the gaps between the soil particles [4, 7]. The minimum 7-day unit weight of CLFAG-OPC stabilized SC samples was observed at a water content of 3.0LL, Ac of 150%, and OPC contents of 0, 1, 2, and 3%, which were 8.09, 8.11, 8.25, and 8.41 kN/m^3, respectively. The reduction in unit weight is due to the increased air void content, which can infiltrate the gaps between the soil particles.

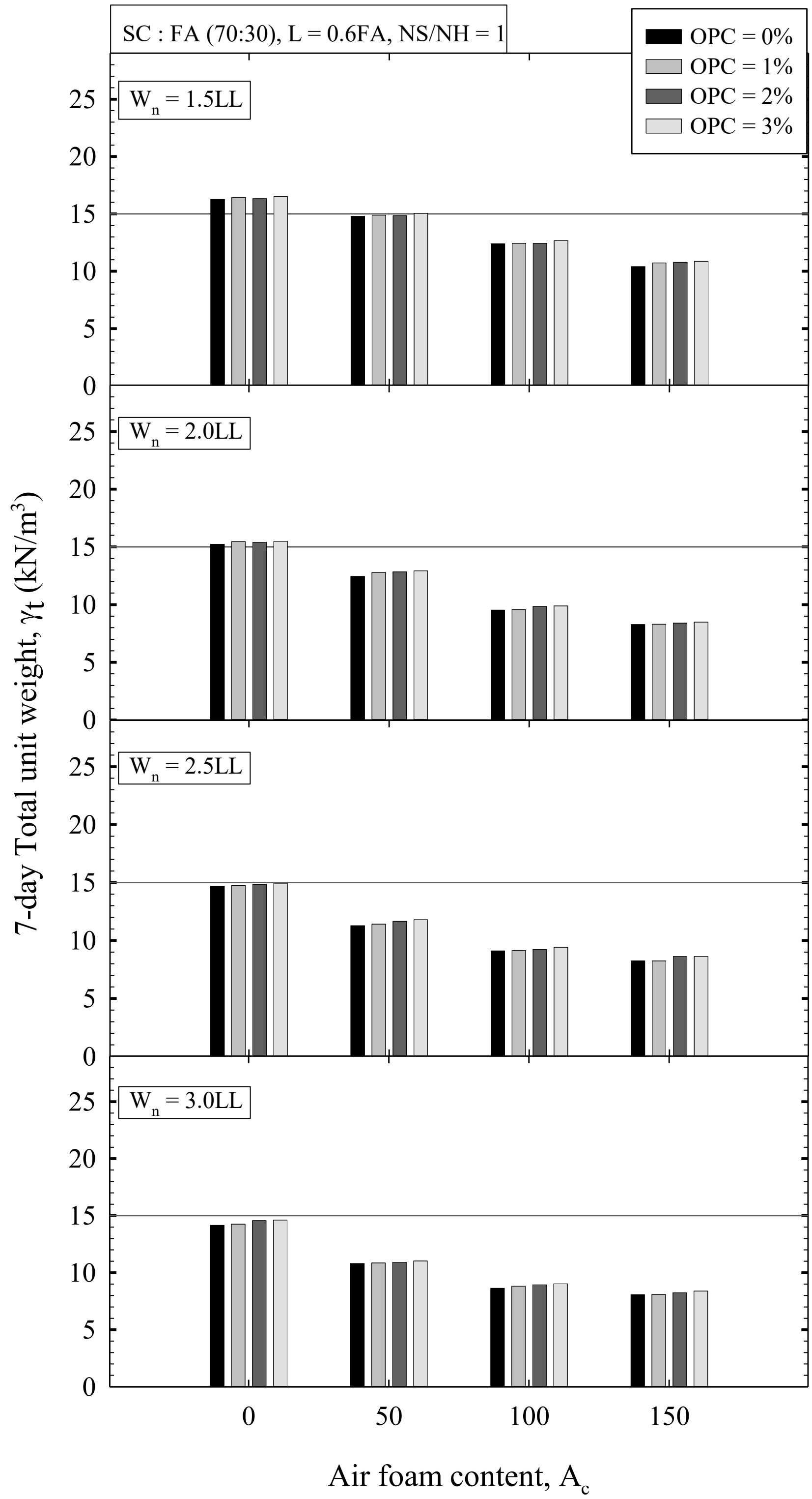

Figure 2. Unit weight and UCS of CLFAG-OPC stabilized SC samples with different initial water contents

Figure 3 presents the influence of SC:FA ratio on the unit weight of CLFAG-OPC stabilized SC samples at water contents of 2.0LL, NS:NH ratio of 1, NH concentration of 8 molar, L content of 0.6FA, SC:FA ratios of 90:10, 80:20, 70:30, 60:40, and 50:50, OPC contents of 0, 1, 2, and 3% by weight of SC and FA, and Ac of 0, 50, 100, and 150%. The unit weight of CLFAG-OPC stabilized SC samples tended to increase with higher FA replacement, as FA had a sharp sphere, which could fill in SC particles. The lowest unit weight of the CLFAG-OPC stabilized SC sample was found at an FA replacement ratio of 70:30, an Ac content of 150%, and OPC contents of 3%, which was 8.24 kN/m³. Meanwhile, the unit weight of CLFAG-OPC stabilized SC samples with SC:FA ratios of 90:10 and 80:20 and OPC contents of 0%, 1%, and 2% could not be tested because the FA content was insufficient to bond the SC particles, resulting in sample damage.

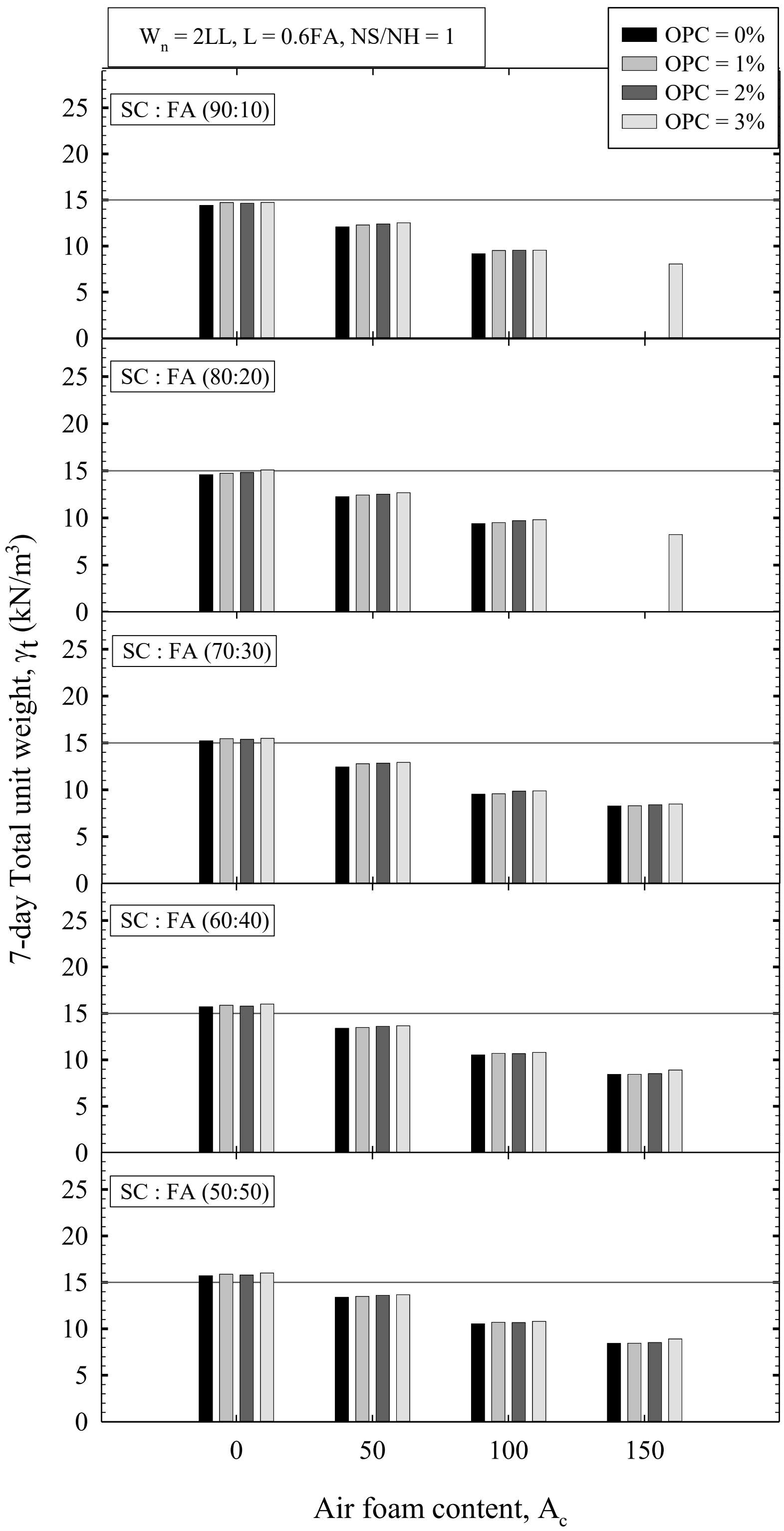

Figure 3. Unit weight and UCS of CLFAG-OPC stabilized SC samples with different SC:FA ratio

The influence of the NS:NH ratio on the unit weight of CLFAG-OPC stabilized SC samples at SC:FA ratios of 70:30, water contents of 2.0LL, NH concentration of 8 molar, L content of 0.6FA, NS:NH ratio of 0.5, 1, 2, and 3, OPC content of 0%, 1%, 2%, and 3%, and Ac of 0, 50, 100, and 150%, is shown in Figure 4. It can be seen that the unit weight of CLFAG-OPC stabilized SC samples slightly increased when the NS:NH ratio increased. This is because NS had a higher density than NH [29], and an increase in the amount of NS made the sample more viscous, reducing the ability of air foam to infiltrate. Therefore, an NS:NH ratio of 0.5 provided the lowest unit weight of CLFAG-OPC stabilized SC samples for all air foam contents.

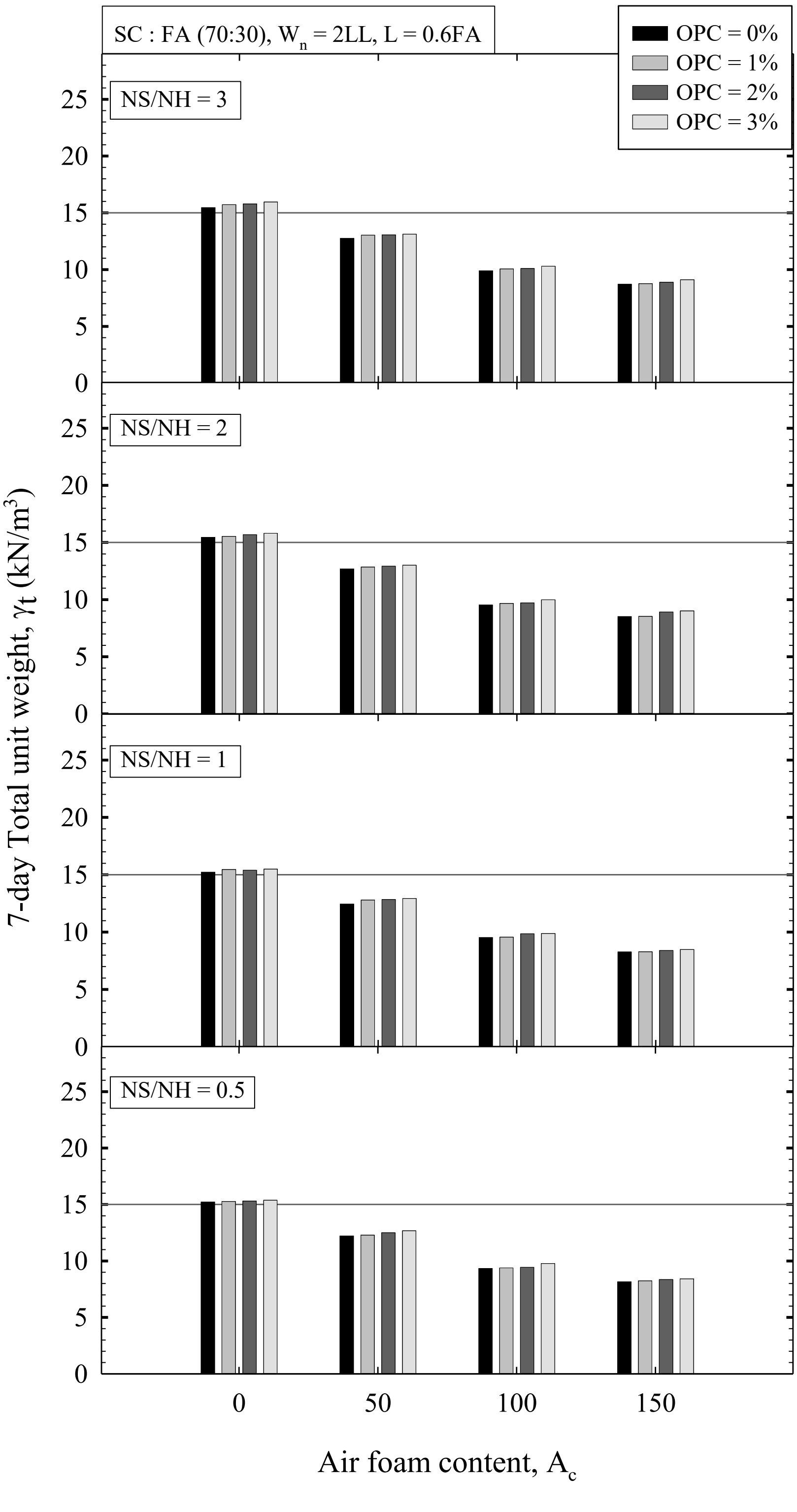

Figure 4. Unit weight and UCS of CLFAG-OPC stabilized SC samples with different NS:NH ratios

The influence of L content on the unit weight of CLFAG-OPC stabilized SC samples at SC:FA ratios of 70:30, water contents of 2.0LL, NS:NH ratio of 1, NH concentration of 8 molar, L content of 0.6FA, 0.9FA, 1.2FA, and 1.5FA, OPC content of 0%, 1%, 2%, and 3%, and Ac of 0, 50, 100, and 150%, is shown in Figure 5. It was found that the unit weight of the CLFAG-OPC stabilized SC samples decreased with an increase in the L content for all air foam contents. The lowest unit weight was observed at the CLFAG-OPC stabilized SC samples, with an L content of 1.5FA and air foam content of 150%, which gave the lowest unit weight. This is because increasing the L content in the sample behaved similarly to improving the water content; as the liquid was lost, more pores developed in the sample. Also, the excessive L content allowed air foam to infiltrate more easily between SC particles. This finding is consistent with the research of Suksiripattanapong et al. [14] and Posi et al. [29].

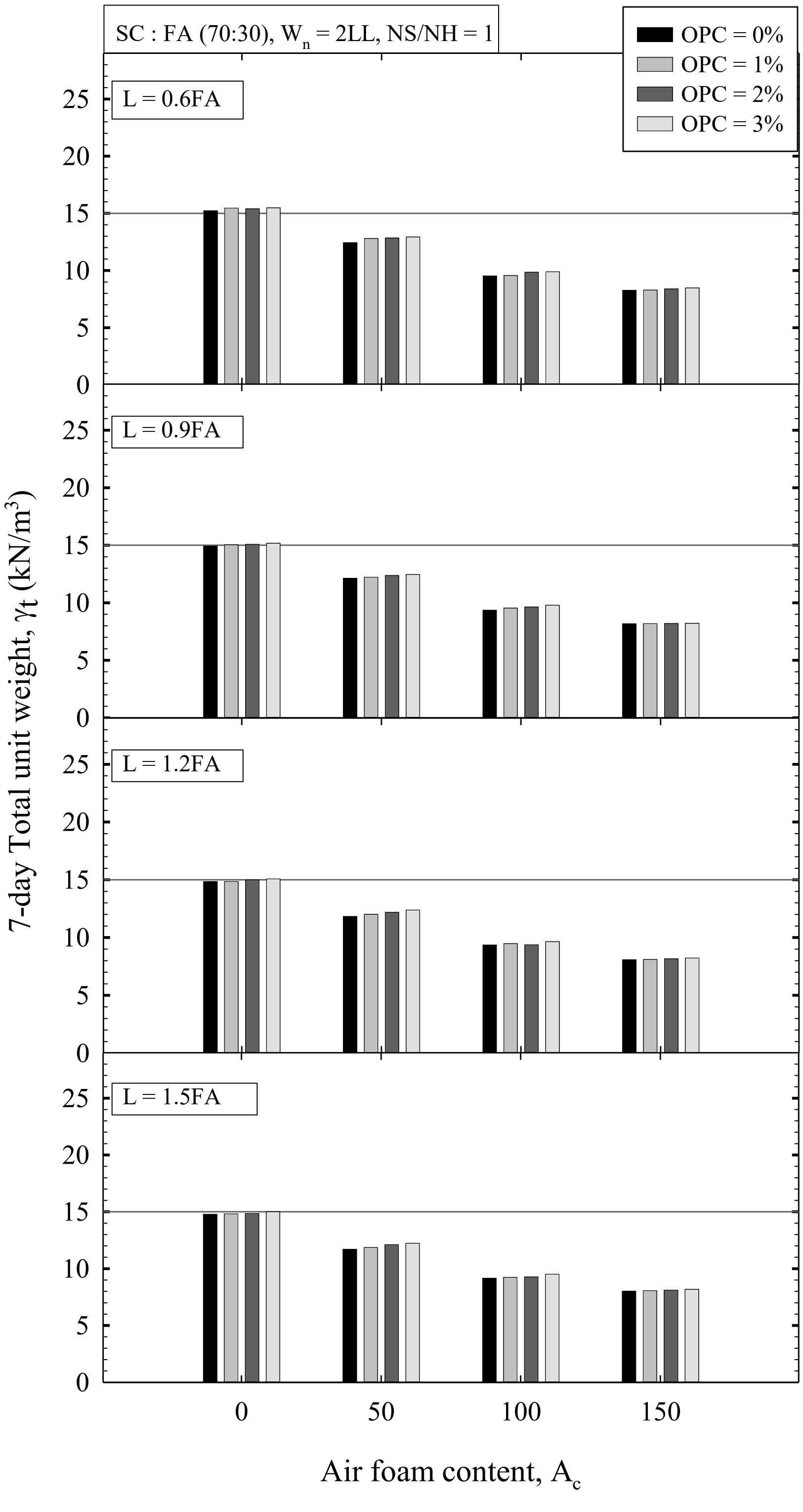

Figure 5. Unit weight and UCS of CLFAG-OPC stabilized SC samples with different L content

Figure 6 shows the phase diagram of CLFAG-OPC stabilized SC samples which consisted of 7 phase diagrams. The unit weight (in kN/m^3) was determined by the following Equation:

$$\gamma = \frac{1+OPC+FA(1+OPC+a)}{\frac{(1+A_C)(1+wG_S)}{\gamma_w G_S(1+w)}+\frac{FA}{\gamma_w G_{SFA}}+\frac{OPC(1+FA)}{\gamma_w G_{SOPC}}+a\cdot FA\left(\frac{NS}{\gamma_{NS}}+\frac{NH}{\gamma_{NH}}\right)} \tag{1}$$

where A_c was air foam content (0%<A_c<150%); a was constant values $L=a*FA$ (0.6<a<1.5); w was initial water contents (90%<w<180%); OPC was cement content (0%<OPC<3%); FA was fly ash contents (11.11%<FA<100%); NH and NH were sodium hydroxide (25%<NH<66.67%) and sodium silicate (33.33%<NS<75%); G_S, G_{SFA}, and G_{SOPC} were the specific gravity of soil, FA, and OPC, respectively. γ_w, γ_{NH}, and γ_{NS} were unit weight of water, NH, and NS, respectively.

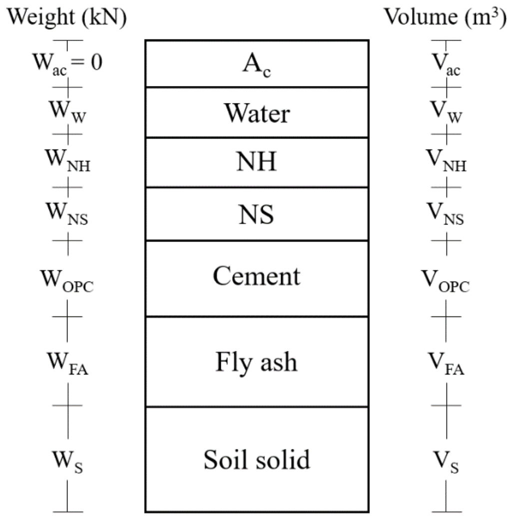

Figure 6. The phase diagram of CLFAG-OPC stabilized SC samples

Figure 7 shows the comparison between measured and predicted unit weight of CLFAG-OPC stabilized SC samples with SC:FA ratios of 70:30, moisture contents of 1.5LL, 2LL, 2.5LL, and 3LL, a liquid-to-fly ash ratio (L) of 0.6FA, a sodium silicate to sodium hydroxide ratio (NS:NH) of 1, OPC contents of 0%, 1%, 2%, and 3%, and air void contents of 0%, 50%, 100%, and 150%. The predicted unit weight equation assumes that air voids can fully penetrate the soil particles. It was found that the predicted unit weights from Equation 1 and the measured one were in good agreement for all OPC contents, all Ac, and water contents of 2LL, 2.5LL, and 3LL. However, for water contents of 1.5LL, CLFAG-OPC stabilized SC samples with Ac of 50%, 100%, and 150% for all OPC contents, the predicted unit weight was approximately 0.8 times the measured unit weight. This is because the SC with a low water content (LL = 1.5) had high viscosity, preventing Ac from penetrating between the soil particles [21, 30].

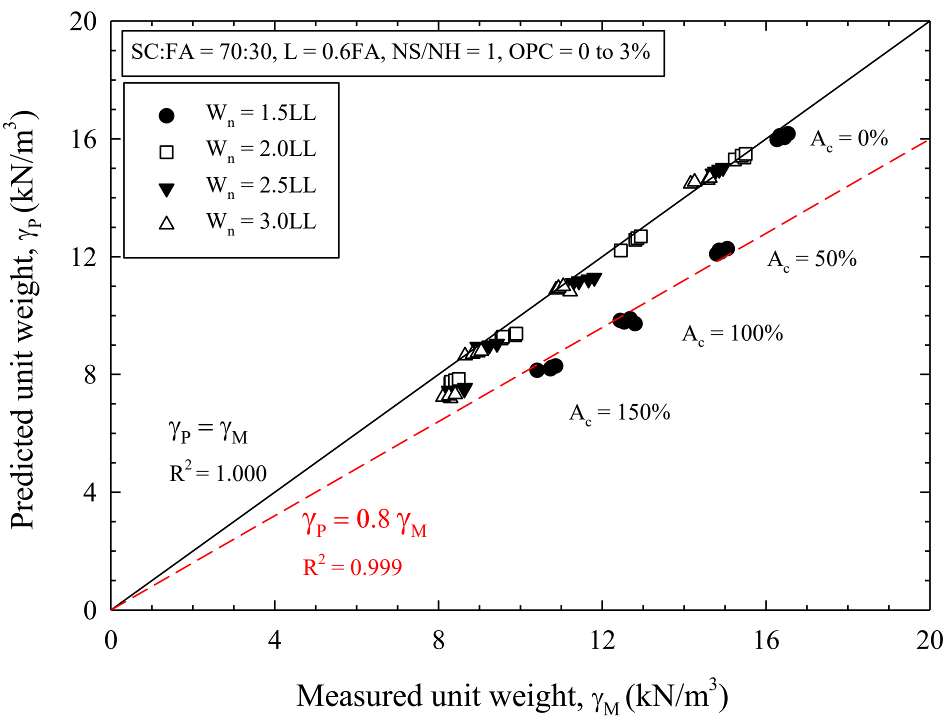

Figure 7. The comparison between measured and predicted unit weight of CLFAG-OPC stabilized SC samples

3.2. UCS of CLFAG-OPC Stabilized SC

The influence of water content on the 7-day UCS of CLFAG-OPC stabilized SC samples at an SC:FA ratio of 70:30, water contents of 1.5LL, 2.0LL, 2.5LL, and 3.0LL, NS:NH ratio of 1, NH concentration of 8 molar, L content of 0.6FA, OPC contents of 0, 1, 2, and 3% by weight of SC and FA, and Ac of 0, 50, 100, and 150% by volume of SC, is shown in Figure 8. It can be seen that the UCS of CLFAG-OPC stabilized SC samples decreased with increasing water content and Ac. This is because high water content caused porosity when the water content was lost, hindering the geopolymerization reaction, and higher air void content allowed for more infiltration between soil particles and pores, resulting in a reduction in UCS. This finding aligns with the research by Horpibulsuk et al. [4] and Teerawatthanasuk et al. [7]. Also, the UCS of CLFAG-OPC stabilized SC samples increased with the increase in OPC content. This is because the higher calcium content from the OPC enhanced the reaction between calcium, silica, and alumina from the FA, forming calcium aluminosilicate hydrate (C-A-S-H). Additionally, calcium hydroxide from the hydration reaction reacts with silica and alumina from the FA and SC to form calcium silicate hydrate (C-S-H), resulting in increased UCS, which is consistent with the findings of Suksiripattanapong et al. [14]. The Department of Highways' embankment soil material stated that the CBR value must be greater than 4%, or the UCS must be 294.20 kPa [7]. When considering that the UCS meets the standard criteria, it was found that for all water content and Ac not exceeding 50%, the UCS was higher than 294.20 kPa.

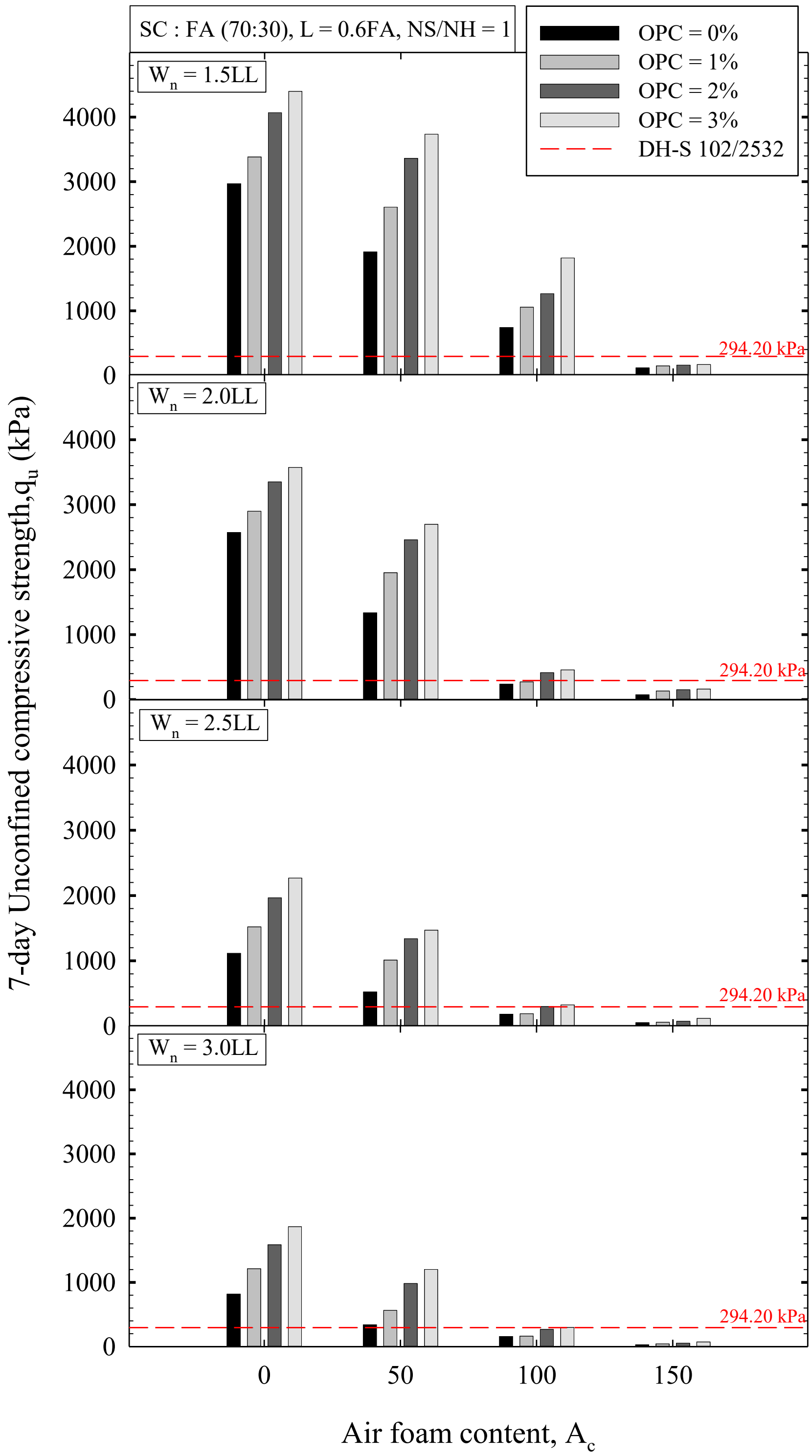

Figure 8. Unit weight and UCS of CLFAG-OPC stabilized SC samples with different initial water contents

Figure 9 shows the influence of the SC:FA ratio on the UCS of CLFAG-OPC stabilized SC samples. It was found that the 7-UCS of CLFAG-OPC stabilized SC samples increased with a higher FA replacement. For example, CLFAG-OPC stabilized SC samples with an SC:FA ratio of 50:50, providing the maximum UCS, which were 7745, 4758, 939, and 481 kPa for Ac of 0, 50, 100, and 150%, respectively. This is because the increased FA replacement resulted in an increase in the SiO_2 and Al_2O_3 content, leading to higher geopolymerization rates [14].

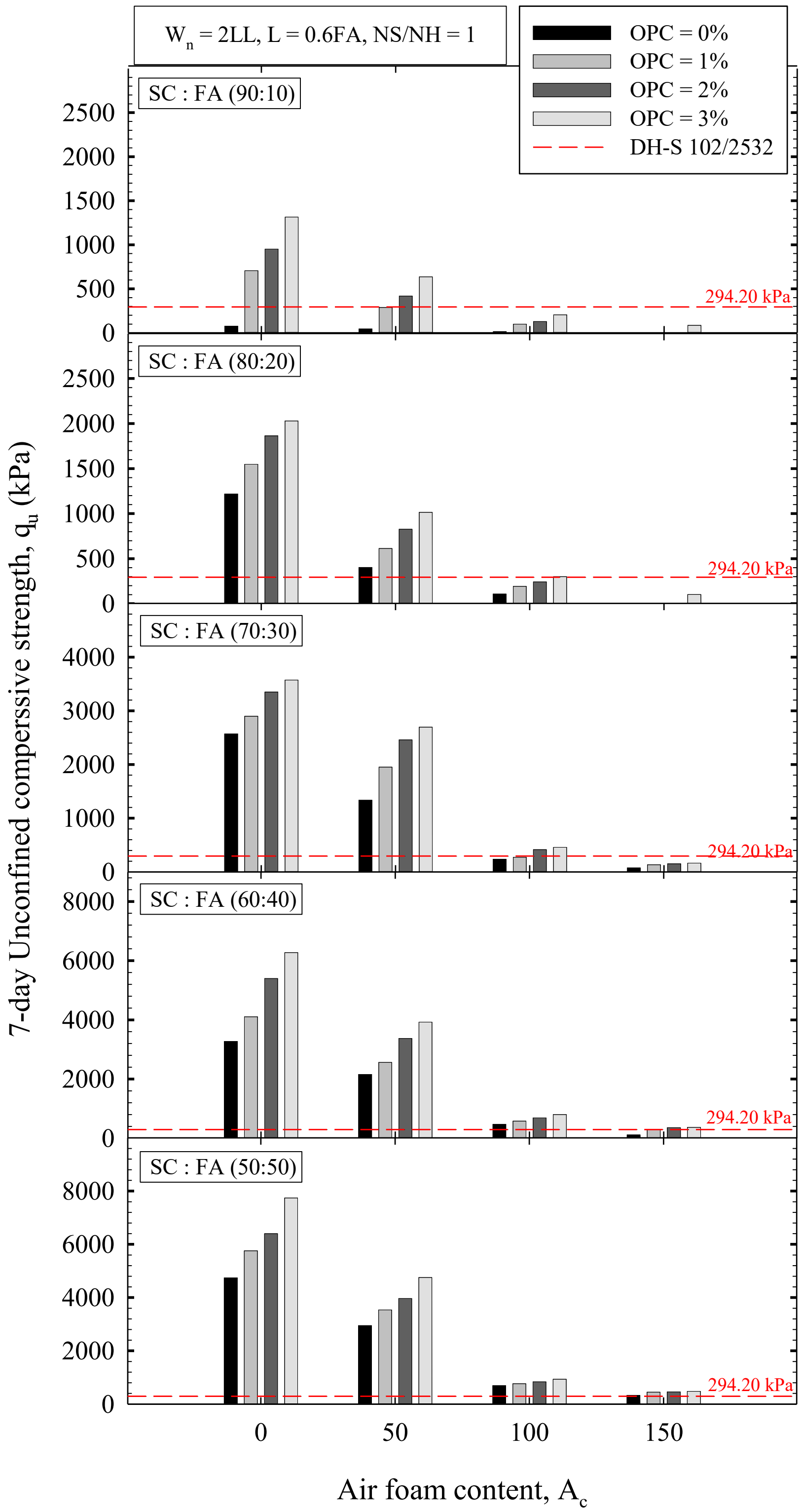

Figure 9. Unit weight and UCS of CLFAG-OPC stabilized SC samples with different SC:FA ratio

The influence of the NS:NH ratio on the UCS of CLFAG-OPC stabilized SC samples is shown in Figure 10. The test results show that CLFAG-OPC stabilized SC samples' UCS increased with the NS:NH ratio up to an NS:NH ratio of 1. This is because the increased amount of NS contributed to a higher SiO_2 content in the system, resulting in enhanced reactions and higher UCS. Beyond this point, the UCS decreased as the NS:NH ratio increased further because an excessively high amount of NS led to an excess of unreacted SiO_2 in the system [14]. Additionally, the reduction in NH content, which served to leach SiO_2 and Al_2O_3 for the geopolymerization reaction, also decreased [31].

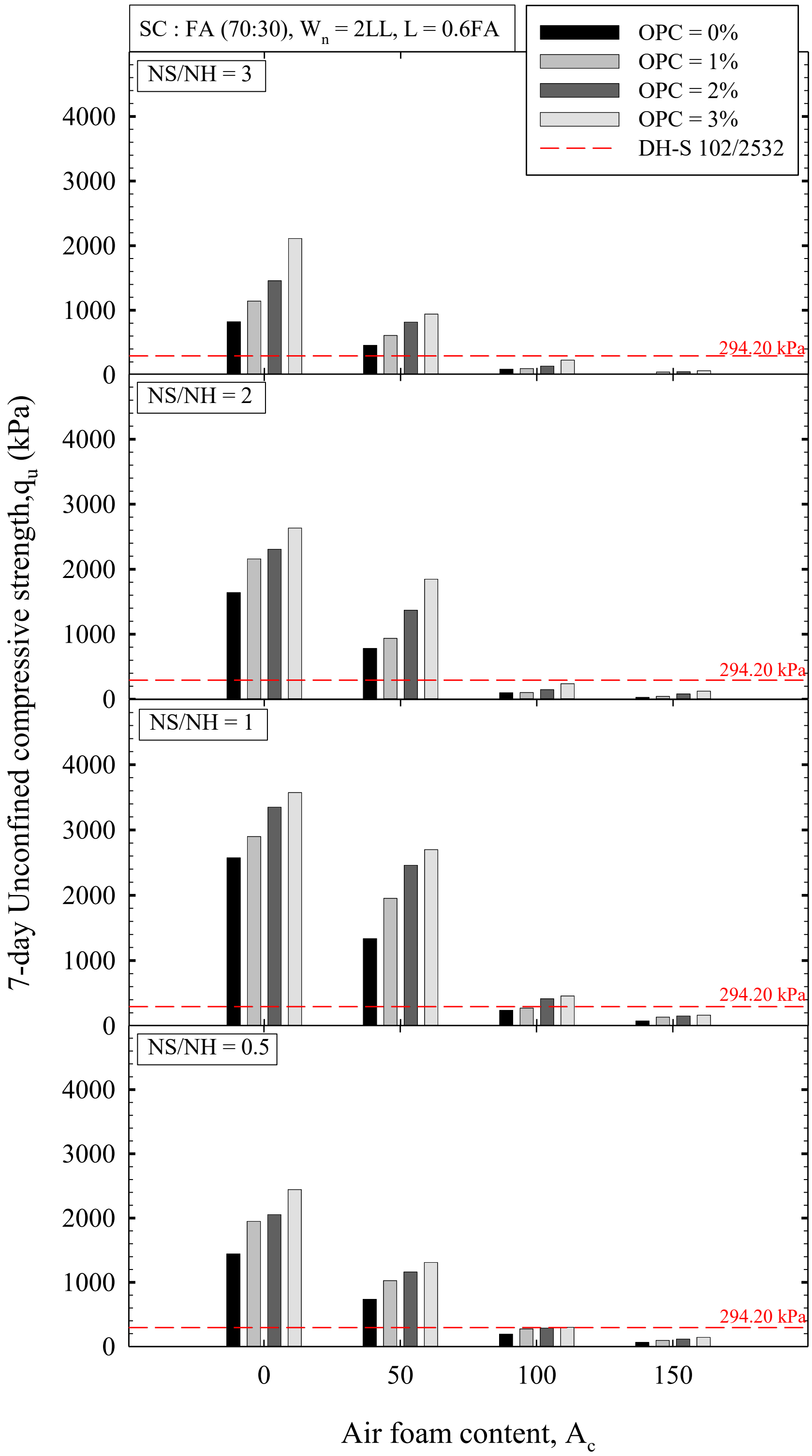

Figure 10. Unit weight and UCS of CLFAG-OPC stabilized SC samples with different NS:NH ratios

The influence of L content on the UCS of CLFAG-OPC stabilized SC samples is shown in Figure 11. It can be seen that the maximum UCS of the CLFAG-SC sample was 3,574 kPa, which was found at an L content of 0.6FA and air foam content of 0%. The UCS of the CLFAG-SC sample decreased with the increase in L content for all air foam content. This is because the increased L content in the system caused the internal SC particles to separate and create voids [30].

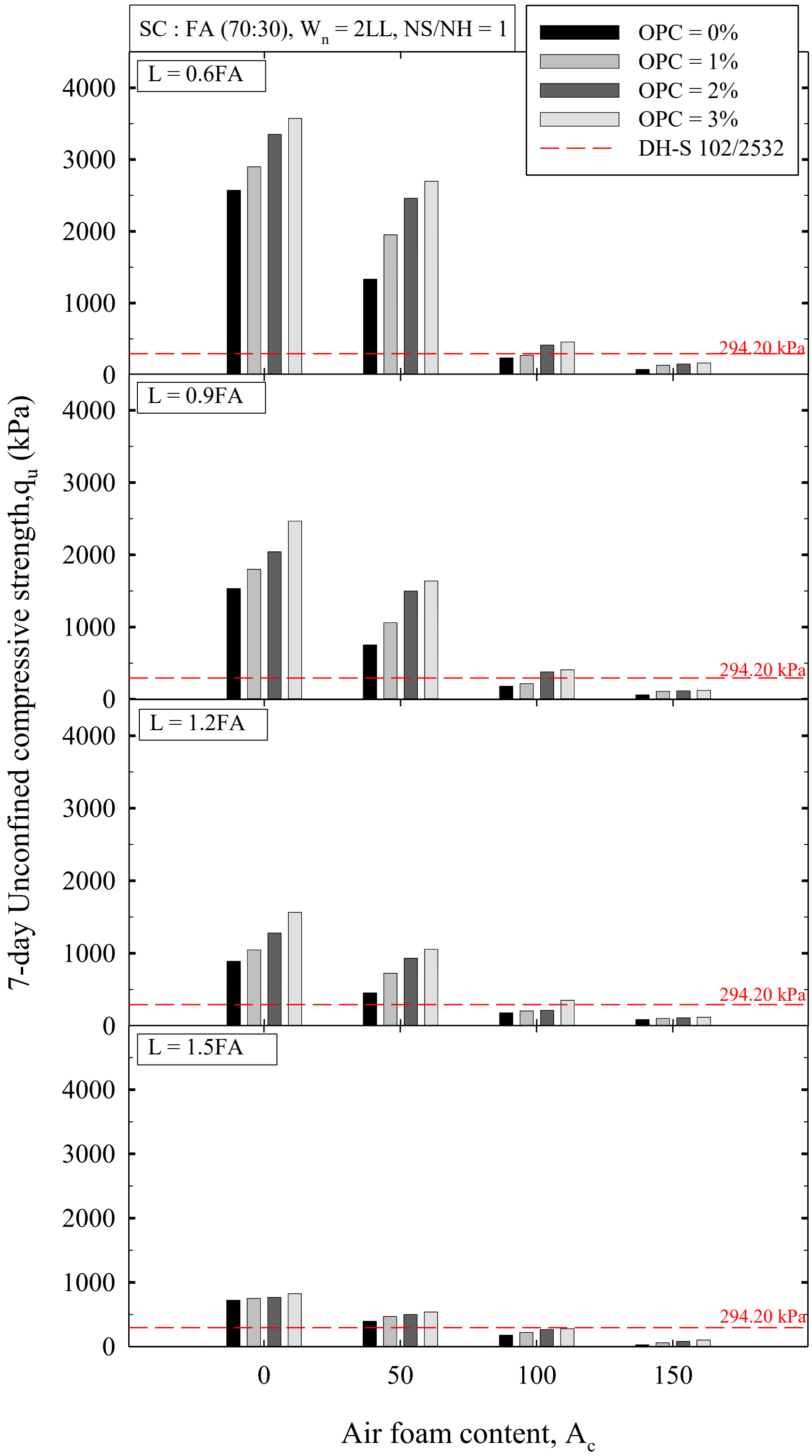

Figure 11. Unit weight and UCS of CLFAG-OPC stabilized SC samples with different L content

Figure 12 shows the influence of curing age on the UCS of CLFAG-OPC stabilized SC samples with an SC:FA ratio of 70:30, water content of 2LL, L content of 0.6FA, NS:NH ratio of 1, OPC content of 0%, 1%, 2%, and 3%, Ac of 0%, 50%, 100%, and 150%, and curing ages of 7, 14, 28, 60, and 90 days. The UCS of the CLFAG-OPC stabilized SC samples was found to increase with longer curing ages. This is attributed to the reaction of CaO from the OPC with SiO_2 and Al_2O_3, as well as the activators, leading to the formation of calcium silicate hydrate (C-S-H) and sodium aluminosilicate hydrate (N-A-S-H) [14]. However, increasing Ac up to 150% influenced UCS development. The UCS of the CLFAG-OPC stabilized SC samples across all OPC contents remained nearly constant because the excessive Ac occupied a larger air volume than the soil matrix and binding materials, resulting in minimal changes to UCS.

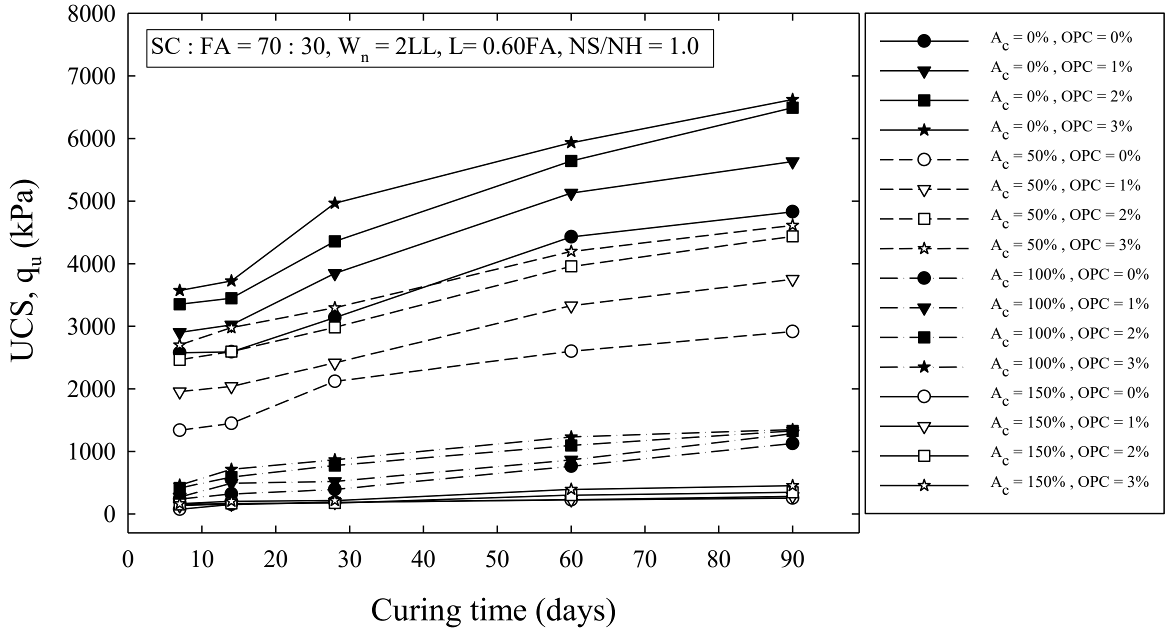

Figure 12. Strength development of CLFAG-OPC stabilized SC samples

3.3. Design Charts for CLFAG Stabilized SC

Figure 13 provides a design chart for CLFAG stabilized SC samples with an SC:FA ratio of 70:30, water content of 2LL, L content of 0.6FA, NS:NH ratio of 1.0, NH concentration of 8 molar, and air foam contents of 0, 50, 100, and 150%. This chart is valuable for the practical design of CLFAG stabilized SC samples. For instance, when designing based on UCS and targeting a UCS of 1,000 kPa, a line is drawn from the Y-axis (UCS) to intersect the UCS curve. From this intersection, a vertical line is extended downward to determine the air foam content, approximately 65%. A horizontal line is drawn from this point to the right along the unit weight curve, yielding a design unit weight of 11.60 kN/m³. Similarly, the air foam content and UCS can be estimated for a desired unit weight.

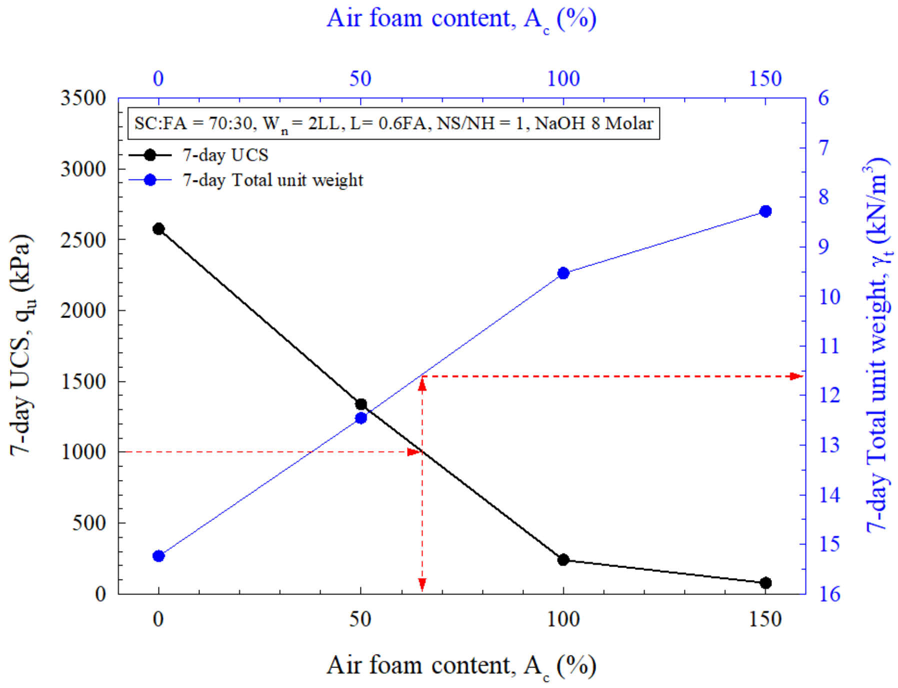

Figure 13. UCS and unit weight of CLFAG-SC at different air form content

Figures 14 to 17 present the design charts for CLFAG stabilized SC samples with water content of 2LL, L content of 0.6FA, NS:NH ratio of 1.0, NH concentration of 8 molar, and SC:FA ratios of 80:20, 70:30, 60:40, and 50:50. UCS for pavement material specified by the Department of Highways, Thailand from Teerawattanasuk et al. [7] was used to developed the mix design charts. It can be seen that CLFAG stabilized SC samples were suitable for all pavement materials. For example, CLFAG stabilized SC samples with SC:FA ratio of 50:50 and air foam content ranging from 0-77%, 0-100%, 0-137%, 0-146%, and 0-150% can be used as a soil-cement base, soil cement subbase, selected material A, selected material B, and subgrade material, respectively.

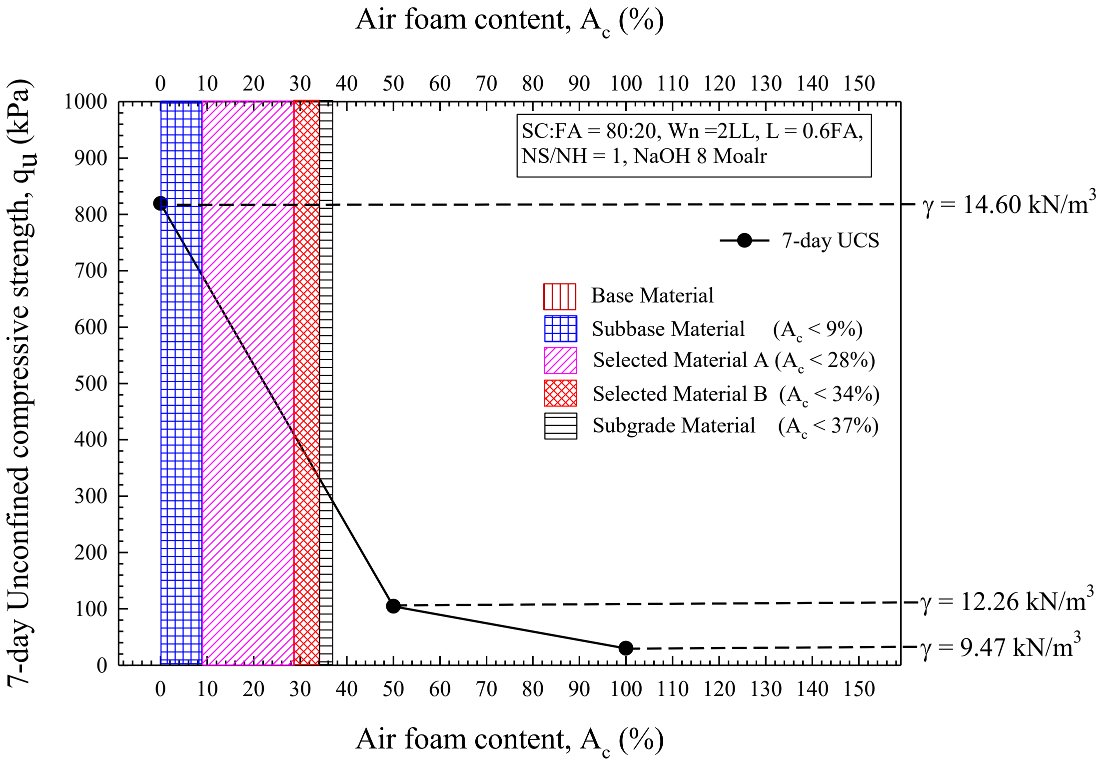

Figure 14. Design charts for CLFAG stabilized SC samples at SC:FA ratio of 80:20

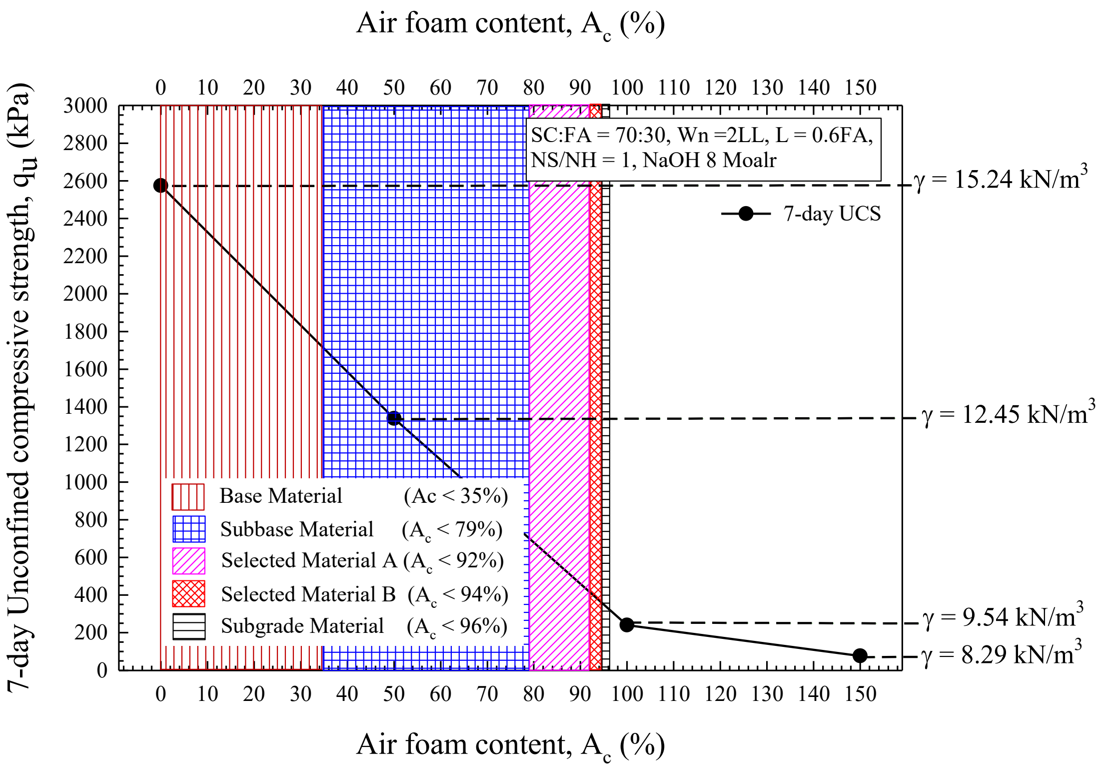

Figure 15. Design charts for CLFAG stabilized SC samples at SC:FA ratio of 70:30

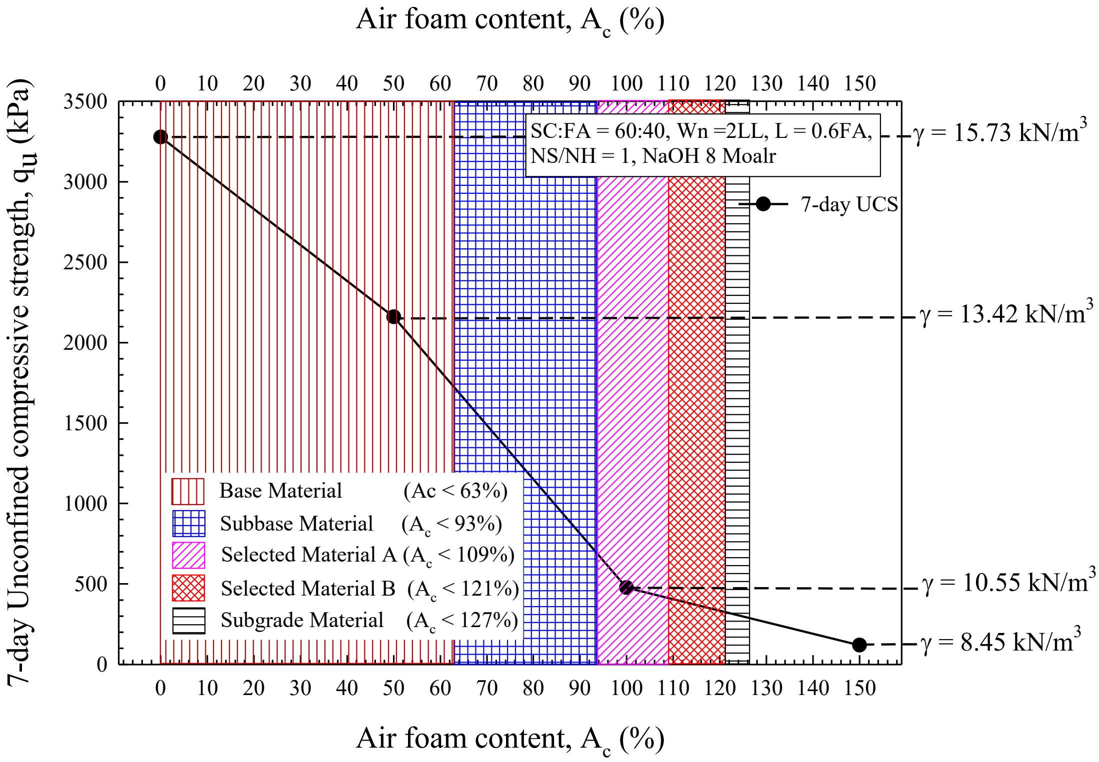

Figure 16. Design charts for CLFAG stabilized SC samples at SC:FA ratio of 60:40

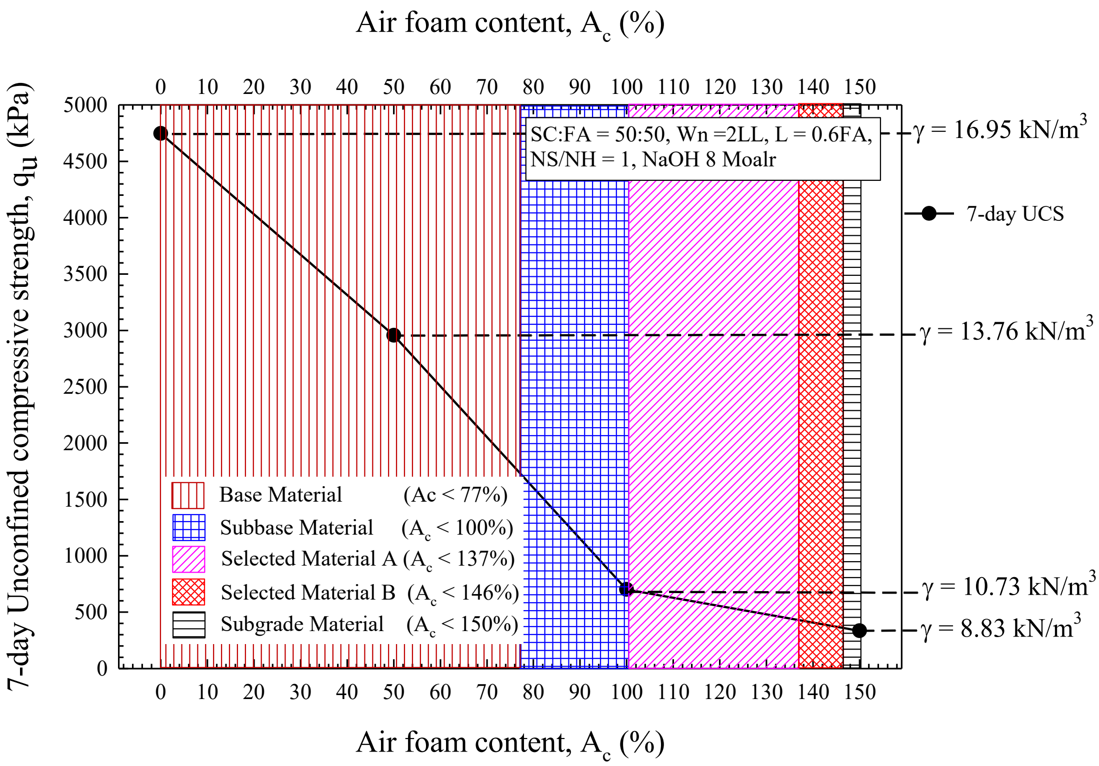

Figure 17. Design charts for CLFAG stabilized SC samples at SC:FA ratio of 50:50

4. Conclusion

This study focused on evaluating the unit weight and UCS of CLFAG-OPC stabilized SC. A series of mix design parameters were investigated, including the SC:fly ash (FA) ratio, OPC content, water content (relative to liquid limit), sodium silicate to sodium hydroxide (NS:NH) ratio, liquid alkaline activator (L) content, and air foam content (Ac). The results indicated that all these factors significantly influenced both unit weight and UCS. Specifically, increased water content, L content, and Ac generally led to a reduction in unit weight, while higher OPC content, FA content, and an optimal NS:NH ratio had the opposite effect. The optimum NS:NH ratio was found to be 1. Ratios lower than 1 (e.g., 0.5) led to insufficient SiO_2 availability for effective geopolymerization, whereas ratios greater than 1 reduced the availability of NH, which is critical for extracting Si and Al from FA, thereby hindering the geopolymerization process.

The maximizing UCS was achieved with a mix comprising an SC:FA ratio of 50:50, OPC content of 3%, water content at 2.0 times the liquid limit, NS:NH ratio of 1, L content at 0.6 times the FA content, and no added air foam. Furthermore, increasing Ac up to 150% influenced UCS development; however, UCS remained nearly constant across all OPC contents due to the excessive Ac occupying a larger air volume than the soil matrix and binding materials. Notably, a predictive model using phase diagrams was proposed to estimate unit weight and UCS, highlighting the suitability of CLFAG-OPC stabilized SC for lightweight geotechnical applications such as embankments and engineered backfills. These findings highlight the promise of CLFAG-OPC stabilized SC in advancing sustainable ground improvement practices. It is recommended that future studies focus on aspects such as long-term durability performance, large-scale field trials, life cycle or embodied carbon assessments, and in-depth microstructural analysis of CLFAG-OPC stabilized soft clay samples.

5. Declarations

5.1. Author Contributions

Conceptualization, N.W. and C.S.; methodology, N.W. and T.A.; investigation, N.W., T.A., and J.T.; resources, T.A. and C.S.; writing—original draft preparation, J.T.; writing—review and editing, J.T., T.A., N.W., W.T., S.T., and C.S.; supervision, C.S.; project administration, C.S.; funding acquisition, C.S. All authors have read and agreed to the published version of the manuscript.

5.2. Data Availability Statement

The data presented in this study are available in the article.

5.3. Funding

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5.4. Conflicts of Interest

The authors declare no conflict of interest.

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