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Research article

Strength of Soft Bangkok Clay improved by Geopolymer from Palm Fuel Ash

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Abstract

This research is to study the strength improvement of soft Bangkok clay by using palm fuel ash as geopolymer. The parameters in this study are initial water content, percentage of Sodium Hydroxide (NaOH), percentage of palm fuel ash. The water content of soft clay varies from 0.8LL, LL and 1.5LL where LL is Liquid Limit of soft Bangkok Clay. The percentage of Sodium Hydroxide (NaOH) varies from 8%, 10% and 12% of dry weight of soft clay. The percentage of palm fuel ash varies from 5%, 10%, 15% and 20% of dry weight of soft clay. The strength is measured by unconfined compression test. The results the initial water content is the main parameter to increase the strength, and also the sodium Hydroxide and palm fuel ash are also affected to the strength.

Keywords: soft Bangkok clay, geopolymer, unconfined compressive strength, palm fuel ash, soil improvement

Introduction

Deep mixing is one of the improvement techniques for soft clay by mixing Portland cement into soil at a certain depth. Mixing methods could be either by rotary mixed or jet mixed; using dry cement or wet cement combined with soil and set as a column pile which can resist a heavier load, resist the soil settlement, and increase the soil stability. Pozzolanic material is an alternative material to compensate Portland cement. Pozzolanic material is the by product from industries and it can be applied mixed with Portland cement to improve the properties of concrete. In geotechnical field, the require strength is not so high so that there is a new idea called as Geopolymer to used instead of cement [1].

Geopolymer is composed of Silicon Trioxide and Aluminium Oxide which has the same composition as Portland cement. It is disintegrated by alkali solution such as Potassium Hydroxide and Sodium Silicate; it requires heat to activate in order to form a polymer chain. According to the geopolymerisation reaction, the main components are Silicon Trioxide and Aluminium Oxide. Soft Bangkok clay has a high proportion of Silica and Alumina. When both Silica and Alumina are mixed with Sodium Hydroxide (NaOH) and pozzolanic material, the effect is similar to cement formation. By focusing on using NaOH and palm fuel ash to compensate Portland, therefore, these materials may be new alternative materials to be used as an essential mixture instead of using cement [2].

The aims of this paper are to study the possibility of using geopolymer from palm fuel ash to improved soft Bangkok clay instead of cement and to study the effect of the concentration of Sodium Hydroxide (NaOH), soil water content and palm fuel ash.

Materials and Method

Soft Bangkok Clay, the sample was collected from approximately three to five metres below the ground surface at Thammasat University, Rangsit campus. It has liquid limit, LL = 67.5% and specific gravity = 2.67. Alkaline powder that is used as activation agent is Sodium Hydroxide. Palm fuel ash used in the experiment was taken from Suksomboon Palm Oil Co., Ltd. at Hangsung sub district, Nongyai district, Chonburi, which is burned at 700 degree Celsius. The grain size distribution of palm fuel ash is shown in Figure 1. It is found that grain size of the Palm fuel ash varies from large (20 mm) to small size (0.075 mm). In this research the Palm fuel ash that passing sieve no.100 (0.15 mm) was used.

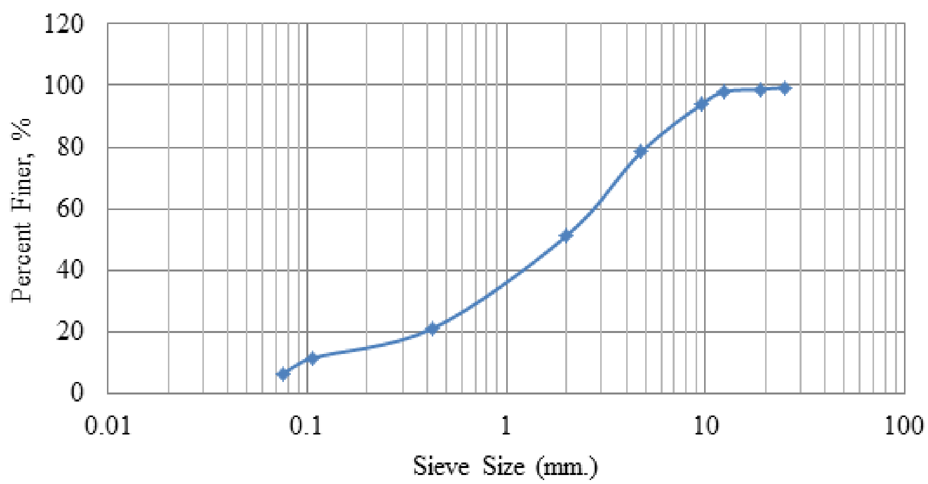

Figure 1: Grain size distribution of palm fuel ash

The samples for unconfined compression test were prepared. Table 1 shows the condition of sample for the unconfined compression test. In each set, three samples were prepared and tested. The size of the sample is approximately 55 mm diameter and 100 mm length. The required water was calculated in order to meet the requirement of water content at 0.8LL (54%), LL (67.5%) and 1.5LL (101.25%). Then the required NaOH and palm fuel ash by dry weight of soft clay were prepared. NaOH need to be dissolved in water for the mixture in the glass bowl to protect from corrosion from NaOH and metal. Palm fuel ash, mixture of NaOH and water are then thoroughly mixed into the prepared soil sample [3]. The mixing time is 45 minutes. The mixture then will be compacted into the PVC pipe and wrapped with plastic wrap. The finished samples activate in a 30 degree Celsius controlled oven for 24 hours and then cure in the water for 7 and 28 days as shown in Figure 2. Unconfined compression tests in accordance with ASTM D2166-85 were carried out on samples cured for 7 and 28 days. The

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rate of loading displacement in unconfined compression test was 1 mm/min. Figure 3 shows the typical failure of the soil sample. The water contents of the samples were determined after the unconfined compression test.

Table 1: Condition for unconfined compression test ASTM D2166-00

Alkaline	%water content of soft Bangkok Clay	% of alkaline by dry soft Bangkok clay's weight	% of palm fuel ash by dry weight of soft Bangkok Clay	Activated Temperature	Curing time (days)	Total samples
NaOH	0.8LL, LL, 1.5LL	8, 10, 12	5, 10, 15, 20	30°C	7, 28	216

Figure 2: Activating and curing of the sample

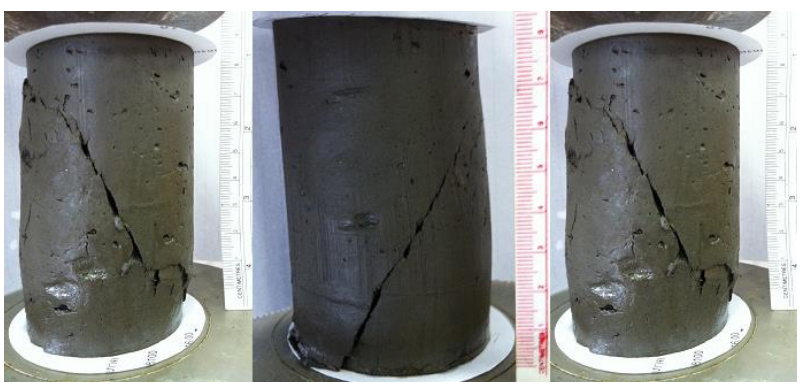

Figure 3: Typical failure of the sample

Results and Discussion

The typical stress-strain curves of the samples with the initial water content 0.8LL from the unconfined compressive strength test at 7 days curing are shown in Figure 4. It can be seen that the stress-strain curves are non-linear like soil behavior. The effect of the percentage of NaOH on unconfined compressive strength can be seen obviously when the percentage of palm fuel ash is 20%. And the same behaviors were found when the initial water contents were LL and 1.5LL. But after 28 days curing, the effect of NaOH on unconfined compressive strength can be seen for all the percentage of palm fuel ash as shown in Figure 5. Table 2 shows the results of average unconfined compressive strength of the samples. From the results, it is shown that the unconfined compressive strength increases with the increasing of NaOH for all initial water content. For the case that initial water content 0.8LL, the unconfined compressive strength increases rapidly when the percentage of NaOH increases from 10% to 12%.

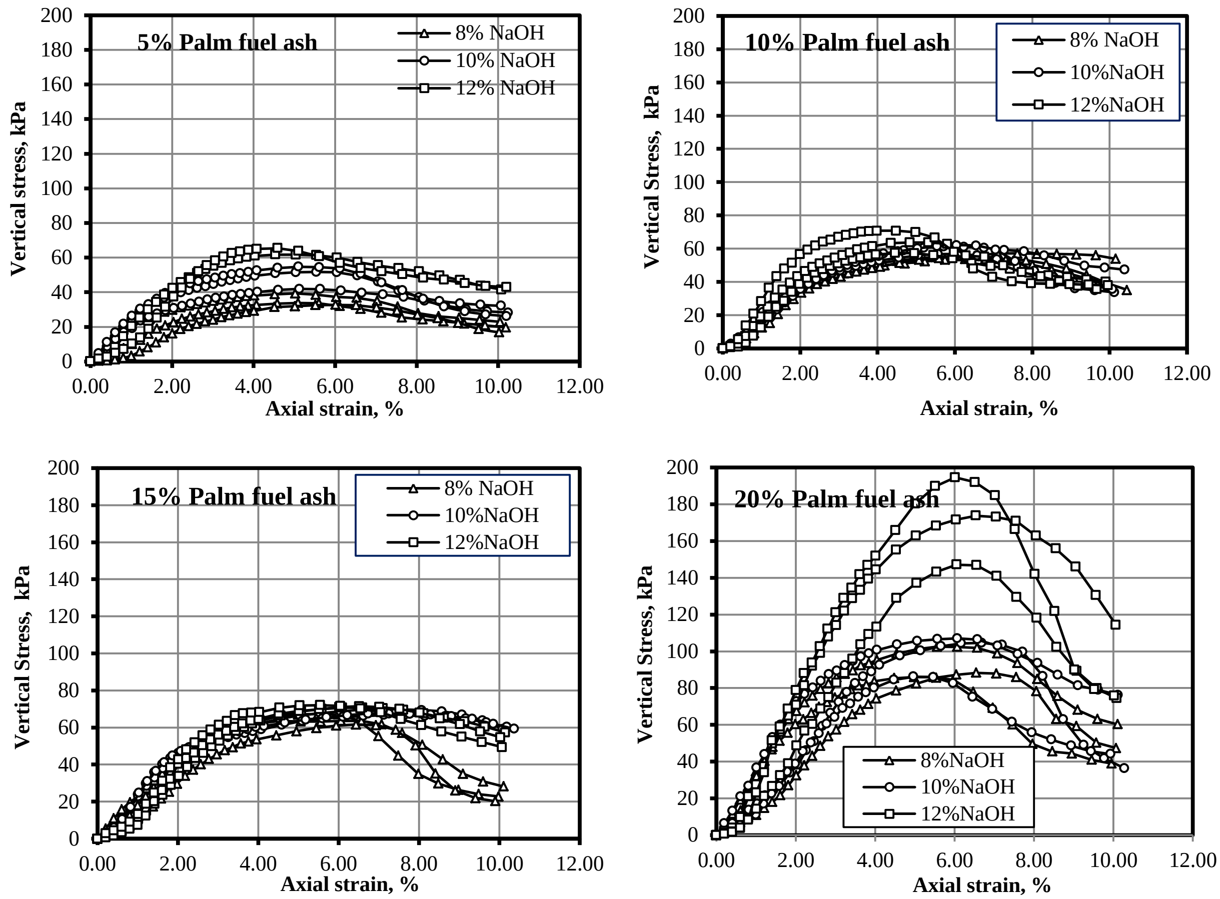

Figure 4: Relationship between vertical stress and axial strain of samples at 7 days with initial water content 0.8LL

Table 2: The average unconfined compressive strength of the samples.

Initial water content (all)	% Palm fuel ash	% NaOH	Average unconfined compressive strength (kPa)	
			7 days	28 days
0.8	5	8	33.27	61.44
		10	53.20	81.54
		12	60.98	123.62
	10	8	55.46	76.88
		10	59.02	82.85
		12	63.97	121.88
	15	8	64.22	78.88
		10	67.99	109.09
		12	71.43	207.59
	20	8	80.92	87.15
		10	105.76	128.30
		12	184.15	224.73

Table 2: The average unconfined compressive strength of the samples. (cont.)

Initial water content (xLL)	% Palm fuel ash	% NaOH	Average unconfined compressive strength (kPa)	
			7 days	28 days
1.0	5	8	13.57	32.27
		10	22.39	47.44
		12	40.36	65.90
	10	8	15.73	31.64
		10	26.14	48.41
		12	45.32	77.93
	15	8	19.73	44.29
		10	36.46	52.27
		12	48.76	91.10
	20	8	20.43	51.33
		10	36.28	56.86
		12	63.56	99.40
1.5	5	8	2.24	7.81
		10	2.92	8.29
		12	10.45	10.01
	10	8	2.55	13.63
		10	5.17	16.68
		12	12.97	21.55
	15	8	5.18	19.55
		10	9.03	26.44
		12	13.08	29.86
	20	8	5.54	30.71
		10	13.68	45.20
		12	13.78	53.86

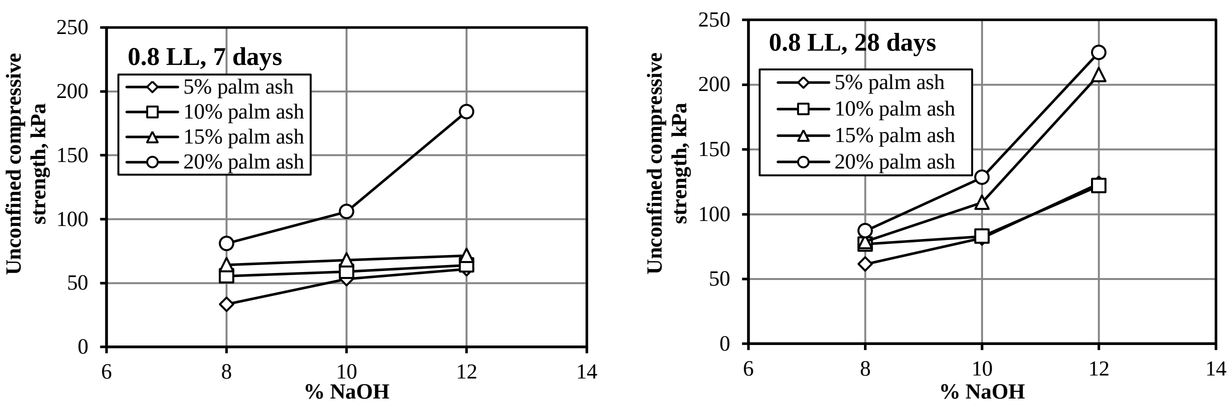

Figure 5 shows the relationship between the unconfined compressive strength and percentage of NaOH.

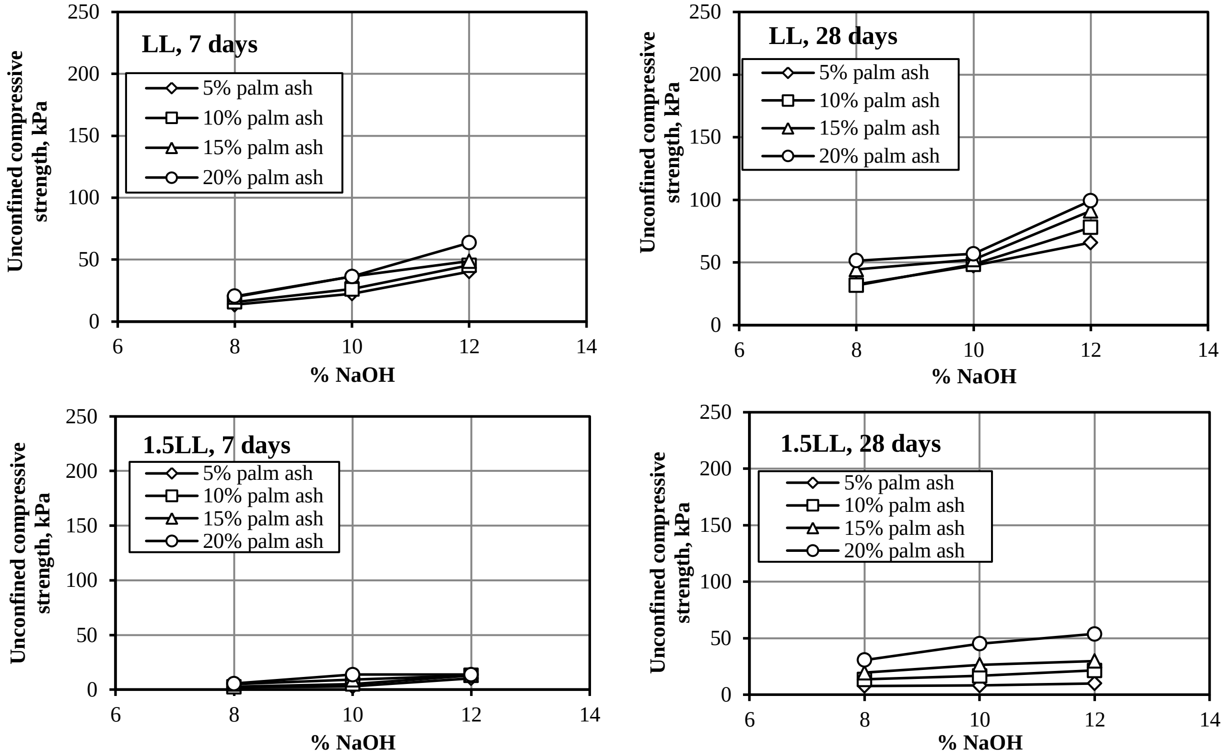

Figure 5 the relationship between the unconfined compressive strength and percentage of NaOH (Cont.)

Figure 6 shows the relationship between unconfined compressive strength and percentage of palm fuel ash. It can be seen that the higher the percentage of palm fuel ash, the higher the unconfined compressive strength. At the same percentage of palm fuel ash, the increasing of the percentage of NaOH also increases the strength. When the initial water content 0.8LL, the strength increases slowly when the percentage of palm fuel ash increases from 5% to 15% and it increases rapidly when the percentage of palm fuel ash is 20 for both 7 and 28 days curing. In the cases of initial water content at LL and 1.5LL, the unconfined compressive strengths increase linearly with the increasing of palm fuel ash.

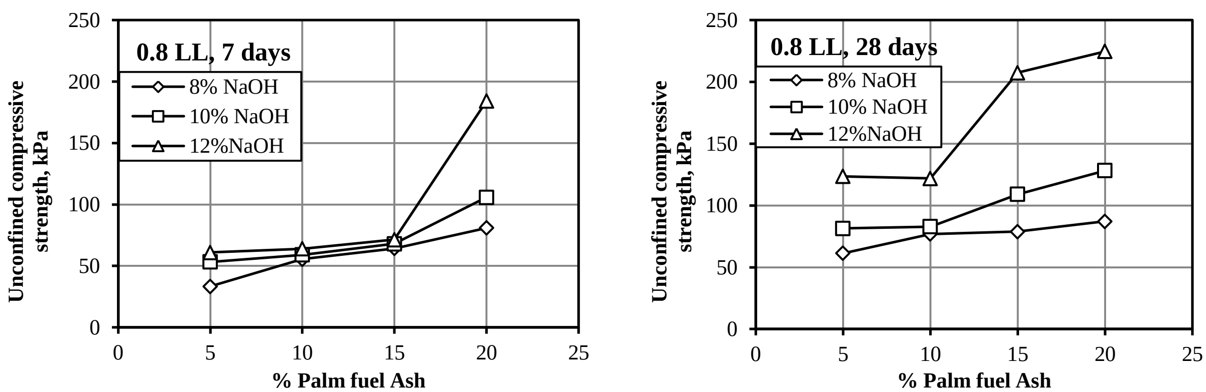

Figure 6 the relationship between the unconfined compressive strength and percentage of palm fuel ash

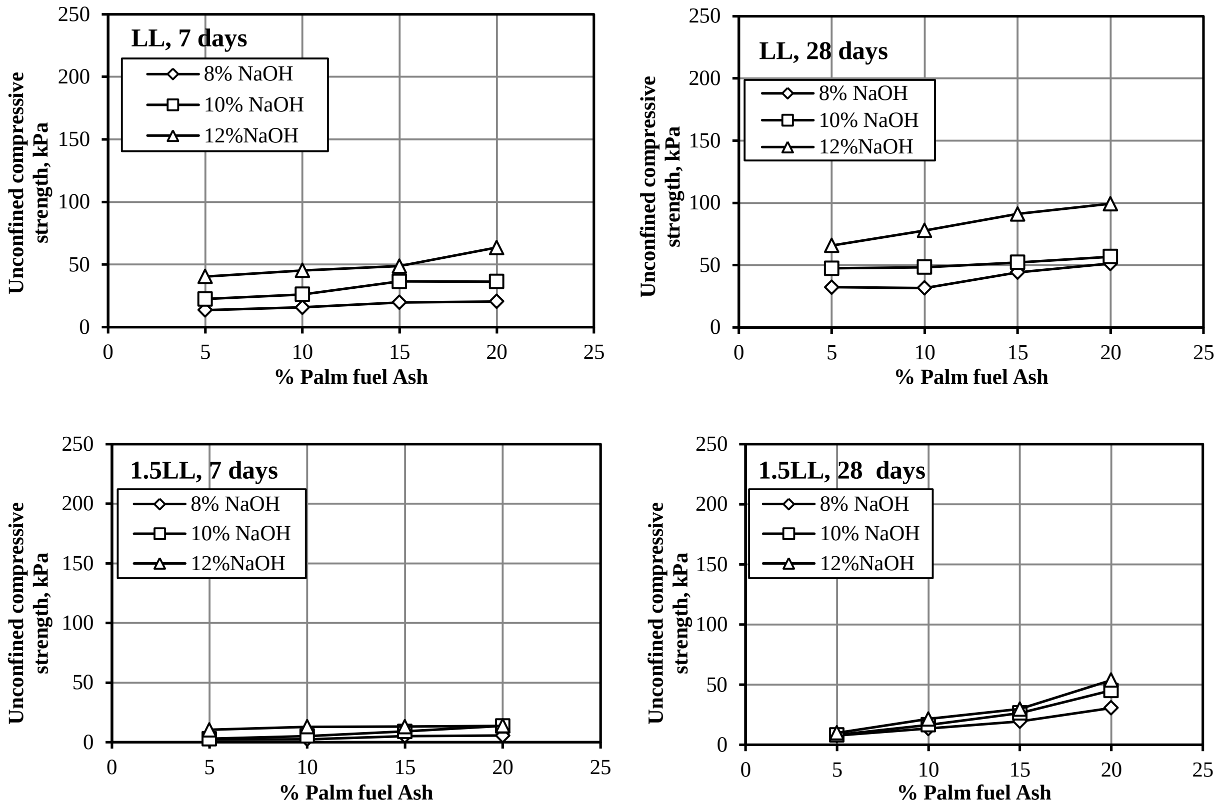

Figure 6 the relationship between the unconfined compressive strength and percentage of palm fuel ash (Cont.)

Figure 7 shows the relationship between water content of the sample after the unconfined compression test and percentage of NaOH. It can be seen that the water contents decrease with the increasing of percentage of NaOH for all cases [2]. That because NaOH absorbed water during geopolymerisation. And it can be seen that, the percentage of palm fuel ash has a little effect with the water content. Figure 8 illustrates the distribution of strength with water content. The lower the water content was, the higher the strength was, due to the polymerization and hardening process that caused the dry unit weight increased. This behavior is the same as soil cement that the controlled variables of unconfined compressive strength of soil cement are the clay-water and cement ratio, w_c/C, and the curing time[4].

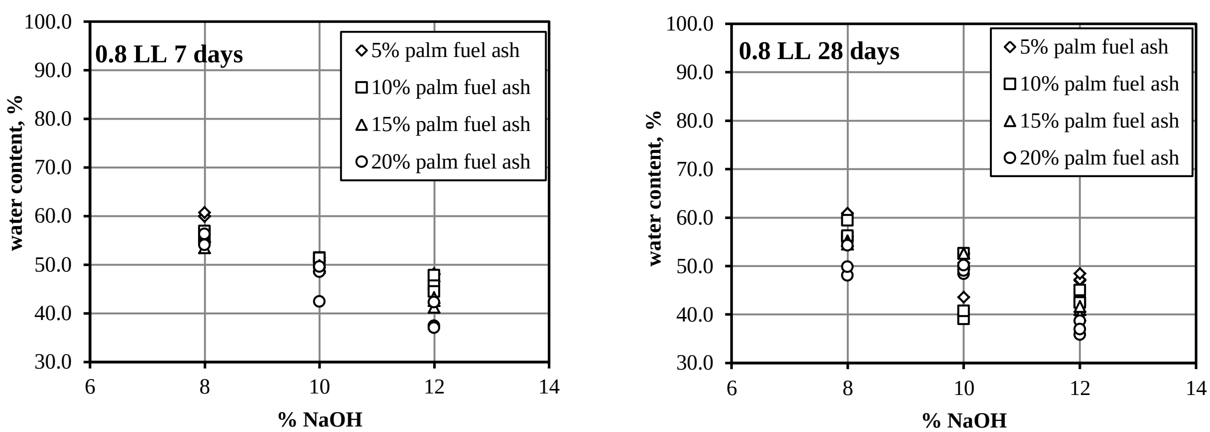

Figure 7 the relationship between water content and percentage of NaOH

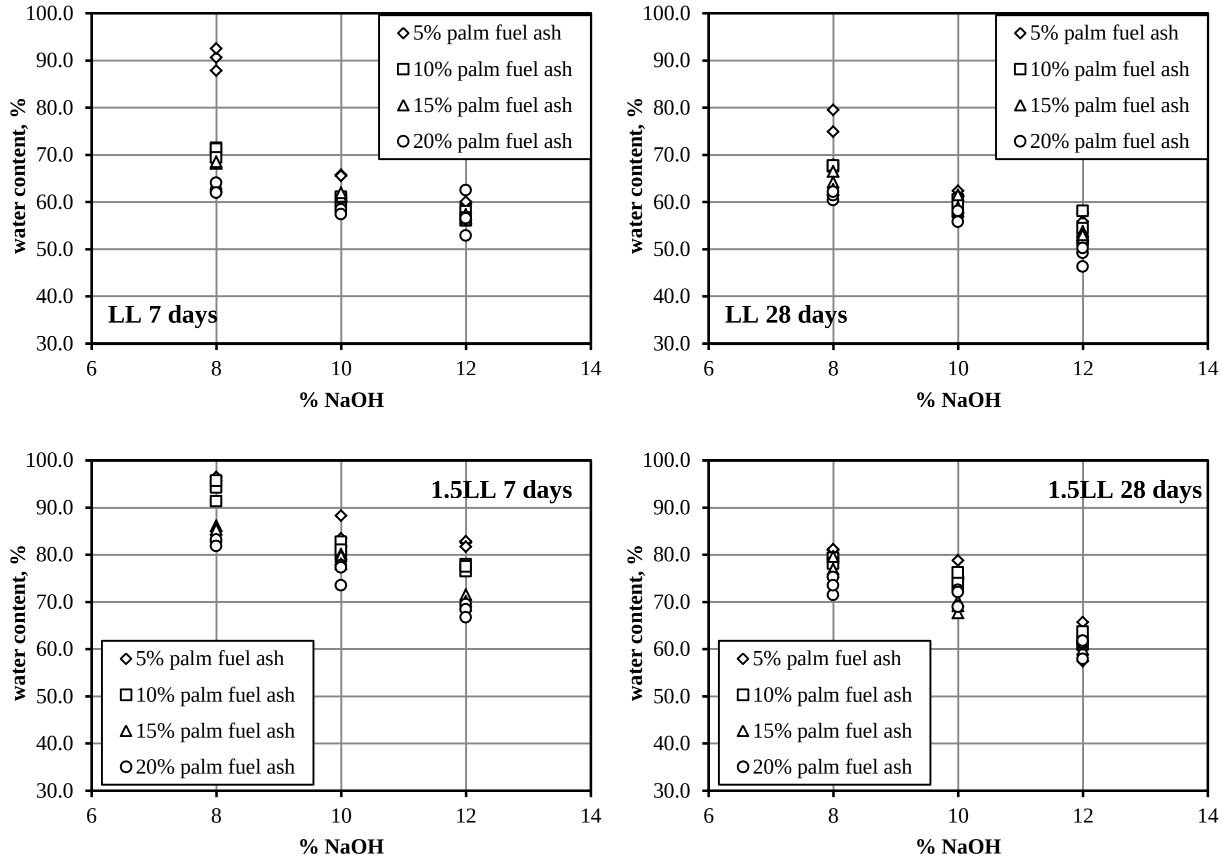

Figure 7 the relationship between water content and percentage of NaOH (Cont.)

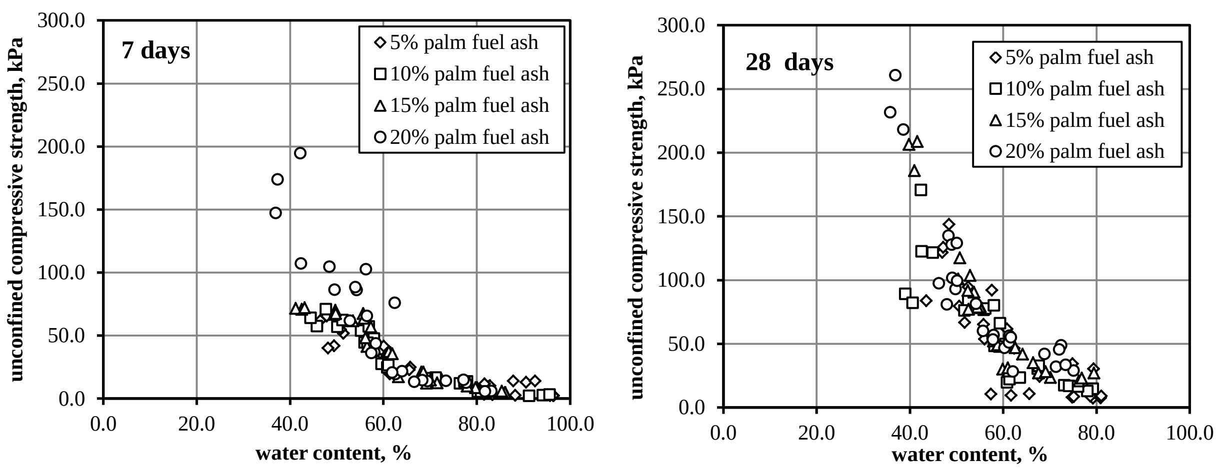

Figure 8 The relationship between unconfined compressive strength and water content

The soft Bangkok clay with its water content corresponding to liquidity indices at 0.8, 1.0 and 1.5 was mixed with cement and palm fuel ash to attain the w_c/B values of 2.5, where B is the binder content (cement + palm fuel ash). The replacement ratio of the palm fuel ash is 80% and 100% by weight of cement (Cement:Palm fuel ash = 20:80 and 0:100)[5]. Figure 9 shows the unconfined compressive strength and initial water content using LL as a standard of soil-cement-palm fuel ash samples and soil-geopolymer from palm fuel ash. It can be seen that the geopolymer from palm fuel ash can be used instead of cement. In the case of geopolymer, the unconfined compressive strength higher than soil that admixed with only palm fuel ash which mean the geopolymerization improve the strength of soft clay. With the appropriate %NaOH and % palm fuel ash, the required unconfined compressive strength can be reached.

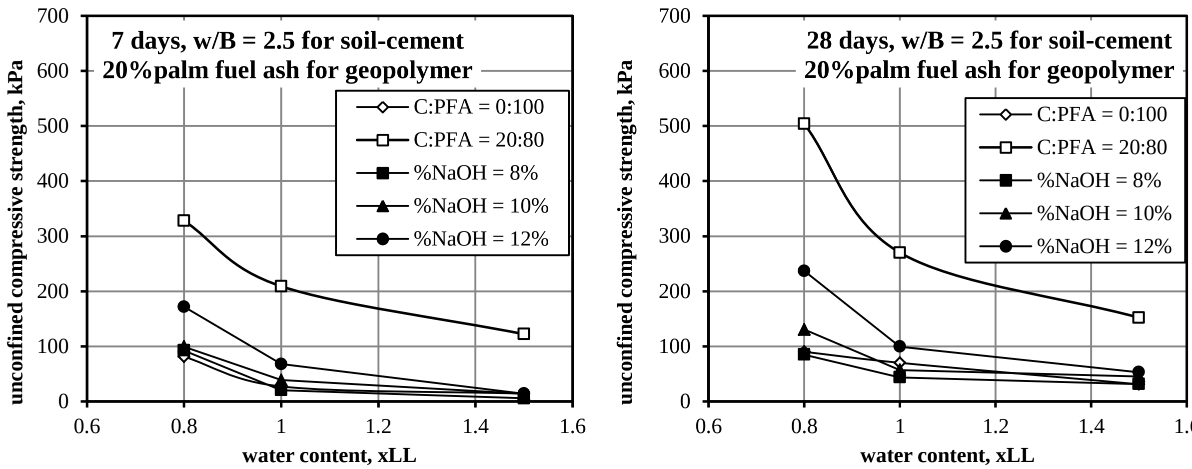

Figure 9 the relationship between unconfined compressive strength and initial water content using LL as a standard of soil-cement-palm fuel ash and soil-geopolymer from palm fuel ash

Conclusion

In conclusion, the initial water content is the main parameter to increase the strength, and also the NaOH and the palm fuel ash is the minor parameter to increase strength. It can be concluded that the higher the percentage of either NaOH or palm fuel ash is, the higher the strength will be. In the opposite way, the lower water content is, the higher the strength will be. When the percentage of NaOH and palm fuel ash increase, the water contents of the samples decrease. The geopolymer from palm fuel ash can be used instead of cement in soil stabilization.

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