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The Use of By-Product Ashes to Improve the Strength of Soft Bangkok Clay

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Abstract: *The pozzolanic material which is the by-product material from many industries is an alternative material to compensate Portland cement in soil improvement field. The aim of this research is to study the strength behavior of the soft Bangkok Clay admixed with Rice-husk Ash and Biomass Ash. The ratios of cement replaced with rice husk ash and Biomass Ash are at 0, 20, 40, 50, 60 and 80. The initial water content of soft Bangkok Clay is 0.8LL, LL and 1.2LL, where LL is the liquid limit of the soft clay. The water binder ratio is 2.5, 5.0 and 7.5. The admixed soils are tested to find the unconfined compressive strength after curing time 7 and 28 days. From the results, it is found that both rice husk ash and biomass ash can be used instead to cement and the percent of replacement can be higher than 50 percent depend on the initial water content and water binder ratio.*

Keywords: *Soil cement; Rice Husk Ash; Mixed Forest Wood Ash; Unconfined Compressive Strength; Soft Bangkok Clay.*

1. Introduction

To construct any structure on soft clay layer have to main problems which are 1) low strength of soft clay 2) high compressible that cause structure failure or large settlement. In the present, there are many techniques to improve the soft clay properties. The chemical method by mixing the soil with chemical material to increase the strength of soft clay is often used since this method can improve both increasing strength and reducing settlement. The chemical material used is cement since it is the common material that used in civil engineering field. The advantage of cement mix is that it can be admixed with the soft clay at both shallow level and deep level of the soil layer. However, the cement is expensive and the manufacturing process pollutes the environment. So the by-product ash which is the pozzolan waste from various industries can be used instead of cement. There are many types of ash that used in soil cement such as rice husk ash, biomass ash and palm fuel ash etc. [1-5]. The aim of this research is to study the use of rice husk ash (RHA) and wood ash (WA) to improve the strength of soft clay. The replacement ratios of cement by the by-product ash are 0, 20, 40, 50, 60 and 80 percent. The effects of the initial water content of Soft Bangkok Clay (w_n) and ratio of the moisture content to pozzolanic material (water binder ratio, w/B) are also studied.

2. Material and Method

2.1. Material Used

Soft Bangkok clay (SBC) was collected as disturbed sample from approximately 3-5 m. from the ground surface at Thammasat University, Rangsit Campus, Thailand. It has liquid limit (LL) 78.3 – 86.5%, plastic limit 27.1 – 32.3% and the plasticity index (PI) 51.2 – 54.2. The specific gravity is 2.6 and can be classified as high plasticity clay (CH) by USCS.

The Portland cement used in this research is the Portland cement type I.

The rice husk ash (RHA) was the by-product ash from the brick industry, black colure and was sieve by sieve no. 40. The RHA used is smaller than 0.425 mm and the specific gravity is 2.14.

The wood ash (WA) was the by-product ash from the earthen ware industry, brown colure and was sieve by sieve no. 100. The WA used is smaller than 0.15 mm and the specific gravity is 2.51.

2.2. Methodology

The soft Bangkok clay was mixed with cement and both ashes for unconfined compression test. Table 1 shows the cement replacement ratio by the by-product ashes for unconfined compression test. The initial water contents of the soft clay are compared with liquid limit, 0.8LL (62.8%), LL (78.6%) and 1.2LL (94.3%). The water binder ratios (w/B) were 2.5, 5.0 and 7.5. Table 2 shows the condition for unconfined compression test. In each set, three samples were prepared and tested. The size of the sample is approximately 50 mm diameter and 100 mm length. The required water was calculated in order to meet the requirement of initial water content then the cement and by-product ash were prepare with required water binder ratio. The soft clay and binder material were thoroughly mixed and then were compacted into the PVC pipe and wrapped with plastic wrap as shown in Figure 1. The finished samples were cured in the water for 7 and 28 days. Unconfined compression tests in accordance with ASTM D2166-85 were carried out. The rate of loading was 1.2 mm/min. Figure 1 also shows the unconfined compression test set-up.

Table1. *The Cement Replacement Ratio by By-product Ash*

Type	PC (%)	RHA (%)	WA (%)	Symbol
1	80	10	10	PC : RHA + WA = 80 : 10 + 10
2	60	20	20	PC : RHA + WA = 60 : 20 + 20
3	50	25	25	PC : RHA + WA = 50 : 25 + 25
4	40	40	20	PC : RHA + WA = 40 : 40 + 20
5	40	20	40	PC : RHA + WA = 40 : 20 + 40
6	20	60	20	PC : RHA + WA = 20 : 60 + 20
7	20	40	40	PC : RHA + WA = 20 : 40 + 40
8	20	20	60	PC : RHA + WA = 20 : 20 + 60

Table2. *The Condition for Unconfined Compression Test*

Initial water content	Water binder ratio	%Cement	%RHA	%WA	Total samples
0.8LL, LL, 1.2 LL	2.5, 5.0, 7.5	80, 60, 50, 40, 20	10, 20, 25, 40, 60	10, 20, 25, 40, 60	216

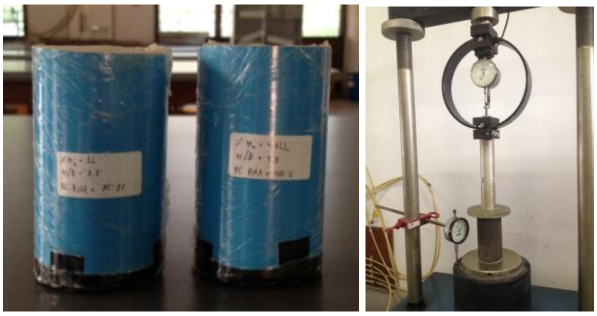


Fig1. *Sample prepared and unconfined compression test set up*

3. Result and Discussion

3.1. Chemical Properties and Micro-structure of By-product Ash

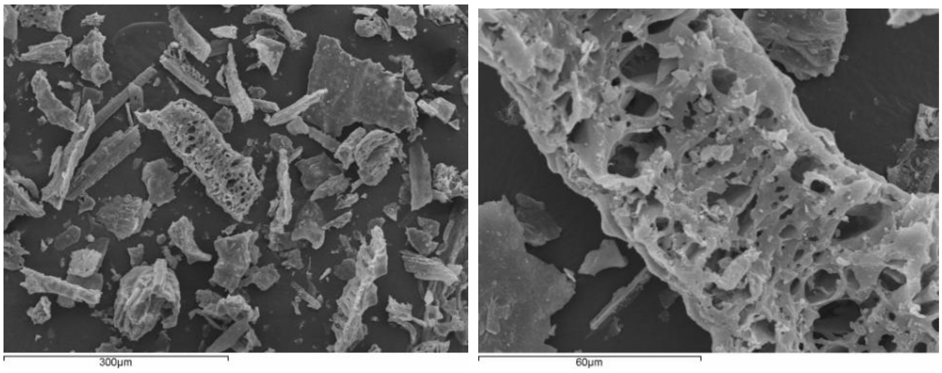
Table3. *Chemical Compounds of all Material Used.*

Chemical Compounds	Rice Husk Ash, RHA	Wood Ash, WA	Type I Portland Cement *	Soft Bangkok clay*
% SiO_2	85.29	1.90	20.90	63.83
% Al_2O_3	0.41	0.33	4.76	21.34
% Fe_2O_3	0.25	0.28	3.41	8.41
% MgO	0.26	5.56	1.25	1.54
% CaO	1.08	52.55	65.41	0.94
% Na_2O	0.09	0.30	0.24	0.28
% K_2O	0.67	3.43	0.35	2.45
% SO_3	0.16	1.16	2.71	1.22

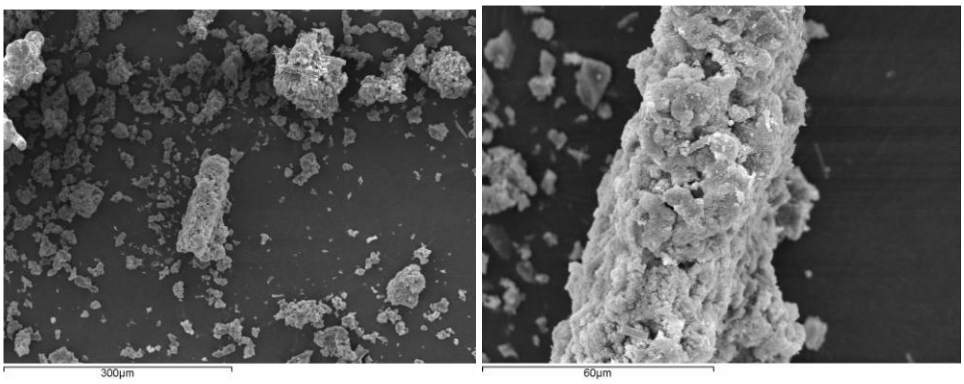
**Ref. [2]*

From the chemical analysis of the RHA and WA by ASTM C 618 as shown in Table 3, it is found that both ashes have SiO_2, Al_2O_3 and Fe_2O_3 about 85.95% and 2.51% respectively. It compounds of Na_2O about 0.09% and 0.30% respectively. The loss of ignitions of RHA and WA are 11.26% and 29.68%. The RHA can be classified as pozzolanic Class F but the WA cannot be classified as pozzolanic material. Anyway the WA compounds with CaO about 52.55% which almost the same as cement. So the WA can have hydration and pozzolanic reactions as cement.

Figure 3 shows the micro structure from Scanning Electron Microscope of RHA and WA. It is found that the RHA is plate-like and prism shape. For the WA, the particle is irregular shape with rough surface. Both ashes have like porous material but the WA looks higher density than RHA which is confirmed by the specific gravity that the WA has specific gravity 2.51 where the specific gravity of RHA is 2.14.



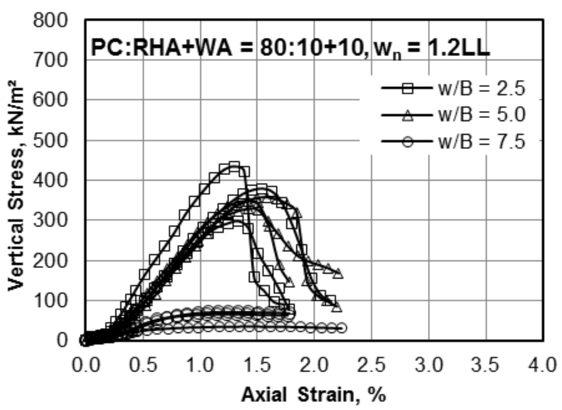
(a) Rice Husk Ash

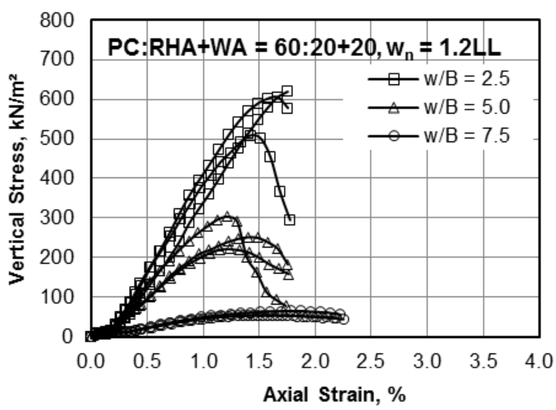


(b) Wood Ash

Fig2. *The microstructure of RHA and WA*

3.2. Stress-Strain Behaviour of Mixed Soil





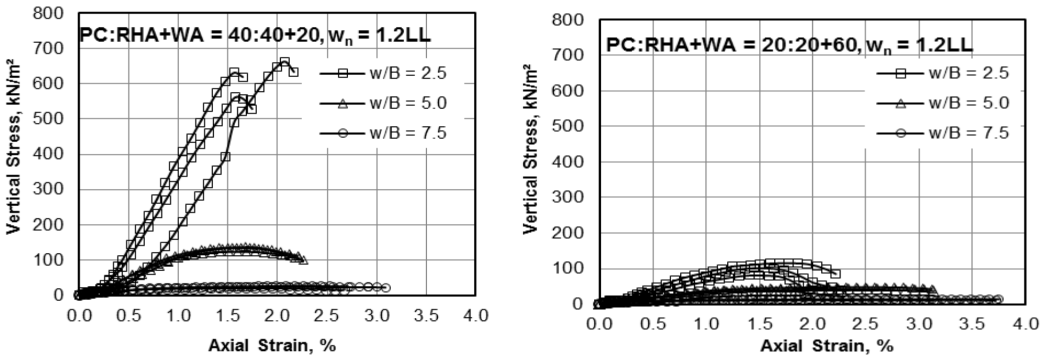


Fig3. *Stress-strain curves of samples from unconfined compression test at 28 days*

The typical stress-strain curves of the samples with the initial water content 1.2LL and with all w/B ratios from the unconfined compression test at 28 days curing as shown in Figure 3. It can be seen that for w/B = 2.5, the stress-strain curves are linear and shows peak clearly when the cement replacement ratio is up to 60%. For w/B = 5.0, the stress-strain curves show clearly peak strength when the cement replacement ratio is up to 40%. For w/B = 7.5, the stress-strain curves are non-linear and no peak. At higher w/B means lower binder content, ductile behaviour is manifested in the manner similar to that occurred in natural soft clay. At lower w/B means higher binder content, the soil cement becomes more brittle, similar to concrete material. [6]

3.3. Effect of Initial Water Content and Water-binder Ratio

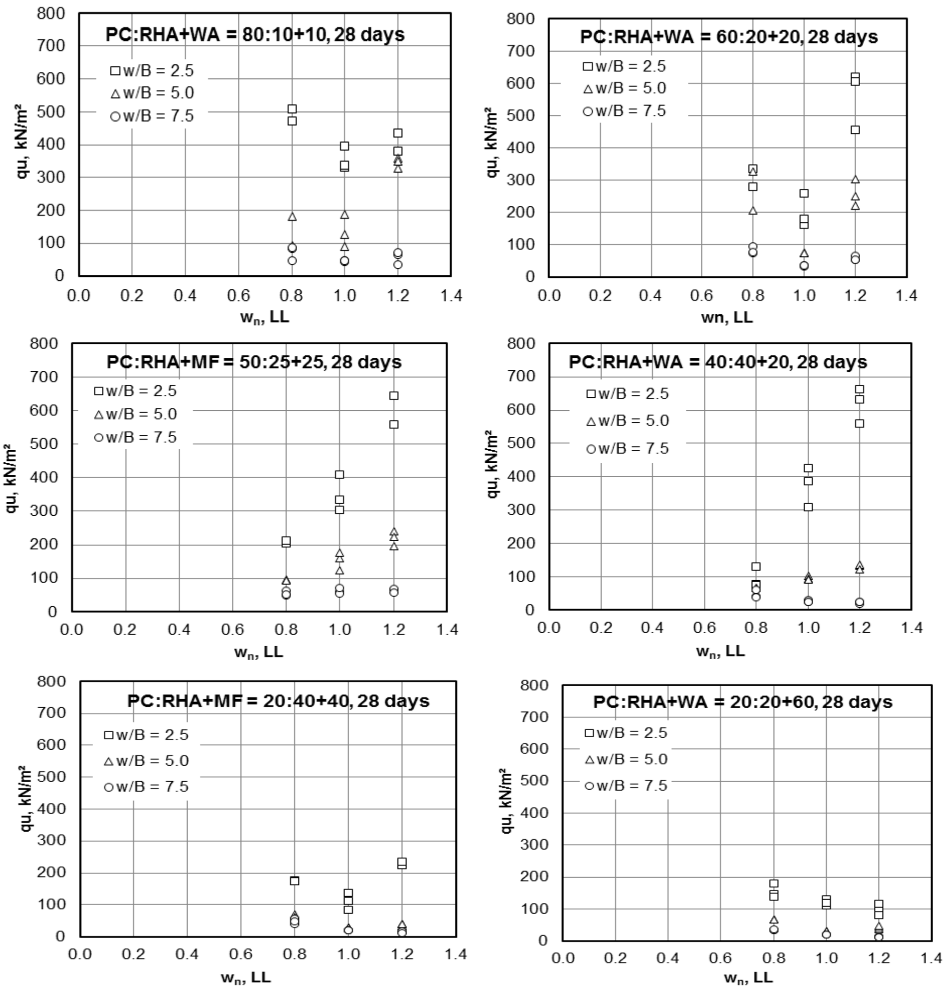


Fig4. *Relationship of initial water content and unconfined compressive strength (Cont)*

Figure 4 shows the relationship between the initial water content and unconfined compressive strength. When w/B = 2.5, it is found that the initial water content has significant effect to the unconfined compressive strength when the cement replacement ratio is the range of 40 - 60%, the higher initial water content, the higher unconfined compressive strength. When the cement replacement ratio lower than 40 or higher 60%, it is found that the initial water content has little effect with unconfined compressive strength. When w/B = 5, the initial water content has effect to the unconfined compressive strength when the cement replacement ratio is the range of 20 – 50%. But for w/B = 7.5, the initial water content has little effect to the unconfined compressive strength for all replacement [5]. For the effect of water-binder ratio, it can be seen that they affect the unconfined compressive strength for all the cases, the higher water-binder ratio, the less unconfined compressive strength. This means that the degree of strength improvement of the soil cement is dependent upon the initial water content and water-binder ratio. [7]

3.4. Effect of Cement Replacement Ratio

Table 4 shows the unconfined compressive strength of soft Bangkok clay admixed with cement and rice husk ash and wood ash. Figure 5 shows the relationship of unconfined compressive strength and PC: RHA+WA varied from 0 to 80%. It can be seen that the by-product ashes can be replaced cement for soil improvement when w/B = 2.5. It is found that at the replacement ratio 60%, the unconfined compressive strength is the highest for all initial water content and trends to decrease with the by-product ashes content. When w/B = 5.0 and 7.5, the unconfined compressive strengths decrease with the percent cement replacement for all initial water content. This means the cement replacement ratio, w/B and initial water content are the influencing factors to the unconfined compressive strength development of cement-by product ashes admixed with soft Bangkok clay. [7]

From Figure 5, it can be seen that rice husk ash has higher efficient than wood ash. With the same cement replacement ratio, if the percent of rice husk ash is higher than wood ash, the unconfined compressive strength is higher for all w/B ratios.

Table3. *Unconfined Compressive Strength of Admixed Soft Bangkok Clay*

% PC: RHA+WA	W_n	Average q_u (kN/m^2)					
		7 days			28 days		
		w/B			w/B		
		2.5	5.0	7.5	2.5	5.0	7.5
80 : 10+10	0.8LL	181.34	119.46	63.93	250.46	143.65	66.49
	LL	137.89	90.89	26.28	298.55	92.99	36.85
	1.2LL	322.43	190.05	54.55	407.47	345.45	68.96
60 : 20+20	0.8LL	196.12	118.19	85.34	336.51	327.93	86.97
	LL	189.72	73.51	31.35	200.77	79.90	35.98
	1.2LL	260.96	205.89	53.34	612.26	236.53	54.35
50 : 25+25	0.8LL	116.18	78.61	49.66	209.27	95.55	53.55
	LL	244.18	120.45	35.89	319.24	168.46	56.22
	1.2LL	524.85	110.01	38.06	601.83	231.44	66.69
40 : 40+20	0.8LL	337.73	51.54	31.57	337.73	66.46	39.91
	LL	316.17	106.39	19.76	405.81	103.56	27.34
	1.2LL	418.03	94.07	13.76	646.9	131.54	24.62
40 : 20+40	0.8LL	181.34	119.46	63.93	250.46	143.66	66.48
	LL	137.89	90.89	26.28	298.55	92.99	36.85
	1.2LL	176.99	41.21	21.29	324.42	51.28	35.59
20 : 60+20	0.8LL	65.35	65.99	35.40	126.67	47.44	23.08
	LL	122.54	19.53	13.55	150.76	25.98	17.55
	1.2LL	147.96	11.29	9.35	147.39	19.42	14.73
20 : 40+40	0.8LL	208.75	61.59	47.01	175.15	65.32	51.68
	LL	63.87	22.64	14.44	124.89	27.93	19.91
	1.2LL	129.26	29.40	9.09	228.70	37.36	14.57
20 : 20+60	0.8LL	138.08	47.81	18.61	141.80	66.21	34.99
	LL	78.75	19.32	15.3	115.45	29.92	19.64
	1.2LL	84.95	31.17	11.17	108.47	44.50	12.40

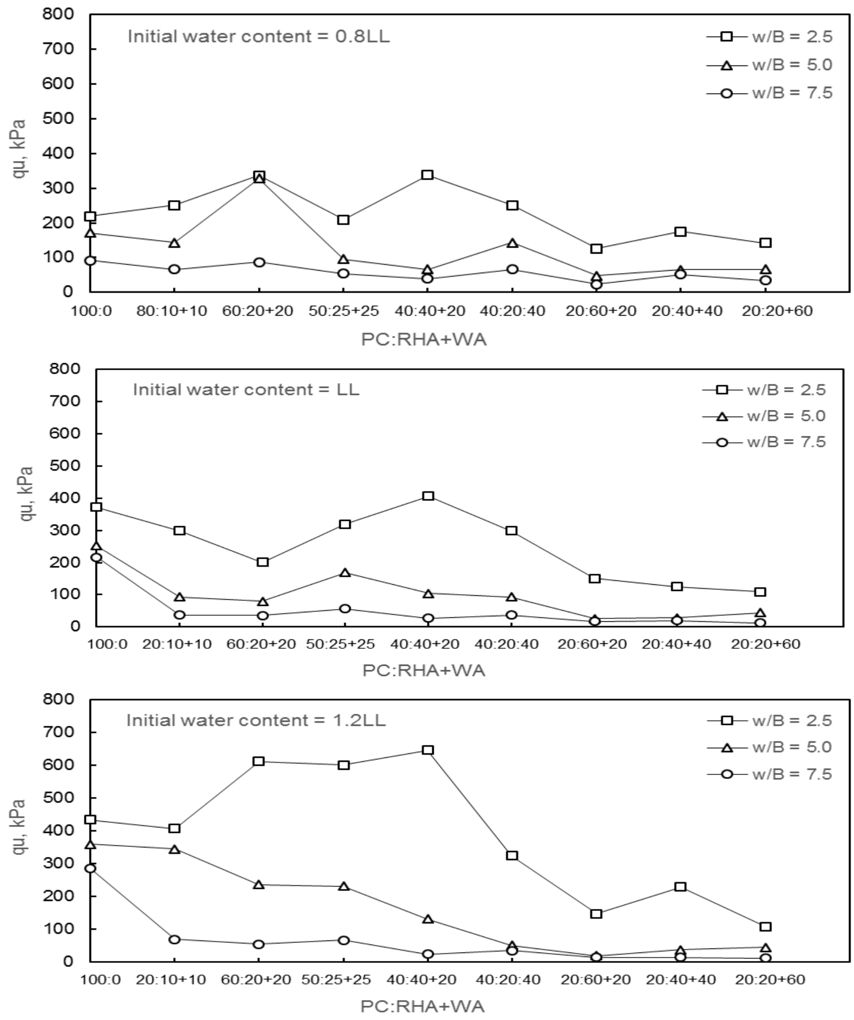


Fig5. *Unconfined compressive strength with binder content (Cont)*

4. Conclusion

This research deals with the investigation of utilizing of by-product ashes as pozzolanic material. The unconfined compression test is used to find the efficiency of by-product ashes. It is found that the by-product ashes both RHA and WA can be used to replace cement in soil improvement field. The factors that influence the strength of the admixed soil are initial water content, w/B and percent replacement ratio. From the results, at w/B = 2.5 the percent replacement can be up to 60%. It is found that the RHA is more efficient than WA.

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