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Engineering Quality Improvement of Kuantan Clay Subgrade using Recycling and Reused Materials as Stabilizer

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Abstract

This paper proposes an engineering quality improvement of Kuantan clay subgrade using fly ash, bottom ash and oil palm empty fruit bunches (OPEFB) ash as stabilizer in highway construction. The research conducts soil engineering properties and strength test for various contents of fly ash, bottom ash and OPEFB ash to different types of clay soil from various sites in Kuantan. Standard compaction and California Bearing Ratio (CBR) were applied in soil samples to estimate the optimum mixture design. The samples were set up by mixing soil samples with various content of stabilizer at optimum water content. The accomplishment of subgrade stabilization depends on the engineering properties of clay and characteristic of stabilizer. The laboratory result shows that the strength gain in stabilization mainly depends on stabilizer content and molding water content. The variation content of fly ash, bottom ash, OPEFB ash were 4%, 8% and 12% by dry total weight (Fauzi and Wan 2010; Fauzi et al. 2010; Fauzi et al. 2011; Hilmi et al. 2006).

Keywords: fly ash; bottom ash; oil palm empty fruit bunches ash; Soil Stabilization; CBR.

1. Introduction

A soft sub grade in construction of roadways is one of the most frequent problems for highway construction in many parts of the world. In Pahang, Malaysia, these problems are also frequently encountered, especially at Kuantan-Pekan region.

The usual approach when soft sub soil encountered is removes the soft soil, and replaces it with stronger materials likes crushed rock. The high cost of replacement causes highway contractors to explore alternative methods. One approach is to use chemical to stabilize the soft sub grade. Instead of using chemical product, recycled, reused material are may offer more economical alternatives for a wide range application of soil stabilization. Soil stabilization using recycle and reused material besides to improve the engineering characteristics also performance of a soil and preservation with the goal of eliminating all environmental concerns is a serious matter (Edil and Craig 2007).

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In general the engineering properties of some Kuantan Clay soils were high plasticity material, classified as A-7-6 by AASHTO Classification System (Fauzi and Wan 2010; Fauzi et al. 2010; Fauzi et al. 2011). Those soils cannot be used as embankment material or have to avoid. If the used of soils cannot reasonably avoided, such material shall be used only on bottom portion of embankment.

In this study the engineering properties quality improved by adding fly ash, bottom ash, OPEFB ash as stabilizer in soil stabilization.

The two general methods of stabilization are mechanical and additive. The effectiveness of stabilization depends upon the ability to obtain uniformity in blending the various materials. Mixing in a stationary or travelling plant is preferred; however, other means of mixing, such as scarifies, plows, disks, graders, and rotary mixers, have been satisfactory. The method of soil stabilization is determined by the amount of stabilizing required and the conditions encountered on the project.

2. The Propertis of Kuantan Clay and Stabilizer

2.1. Kuantan clay

Six types of clay soil from random places in Kuantan, Pahang were used. The Kuantan Clay development of hydration product and chemical element were investigated by integrated electron microscope and energy-dispersive x-ray Spectroscopy (SEM-EDS), the soil particle were observed as can be seen in Figure 1 – 6. The engineering properties and strength such as Sieve Analysis, Atterberg Limit, Shrinkage Limit, Specific Gravity and California Bearing Ratio (CBR), Standard Compaction Proctor tests based on BS 1377-4 1990 (BS 1377-4 1990).The engineering properties and classifications of Kuantan Clay and chemical element were shown in Table 1 and 2.

Table 1. Engineering properties of soils

SAM-PLE	CLASSI-FICATION	PASSING SIEVE NO. (%)			LL (%)	PI (%)	Gs	SL (%)
		10	40	200				
S2	A-7-6	95.98	85.92	55.88	63.5	37.8	2.67	7.86
S4	A-7-6	92.8	83.12	52.82	30.5	11.56	2.65	3.57
S6	A-7-5	78.42	60.17	52.82	51.5	14.5	2.66	9.00
S8	A-7-5	82.52	57.4	54.17	53.5	14.83	2.78	9.36
S24	A-7-6	85.73	52.62	50.09	47.5	12.58	2.65	10.00
S25	A-7-6	85.73	58.03	53.67	40.0	12.58	2.64	8.57

Table 2. Chemical Element for Kuantan Clay

NO	ELEMENT	S2 WEIGHT (%)	S4 WEIGHT (%)	S6 WEIGHT (%)	S8 WEIGHT (%)	S24 WEIGHT (%)	S25 WEIGHT (%)
1	C $CaCO_3$		5.05	8.42	6.05	7.48	10.25
2	O SiO_2	54.21	58.97	56.67	53.15	59.83	58.98
4	Al Al_2O_3	6.82	12.81	13.07	14.04	11.17	8.51
5	Si SiO_2	34.33	18.99	11.99	6.07	18.82	16.13
6	S FeS_2						2.24
7	K MAD	2.23	1.16	0.81		0.92	0.86
9	Ti Ti			0.43	2.37	0.58	
10	Fe Fe	2.41	3.02	8.62	18.32	1.20	3.02

The grain size distribution curves of Kuantan clay Tested by sieve shaker for material retained sieve 0.075 mm and CILAS 1180 Particle Size Distribution for material passing sieve 0.075 mm are presented in Figure 7.

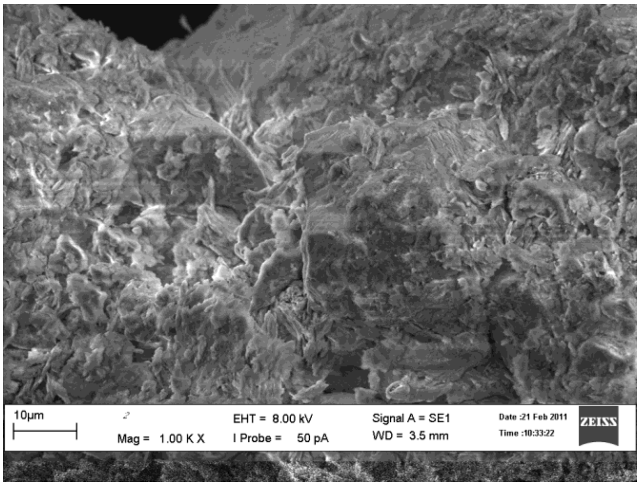

Figure 1. Soil particle for sample No. 2 (S/2)

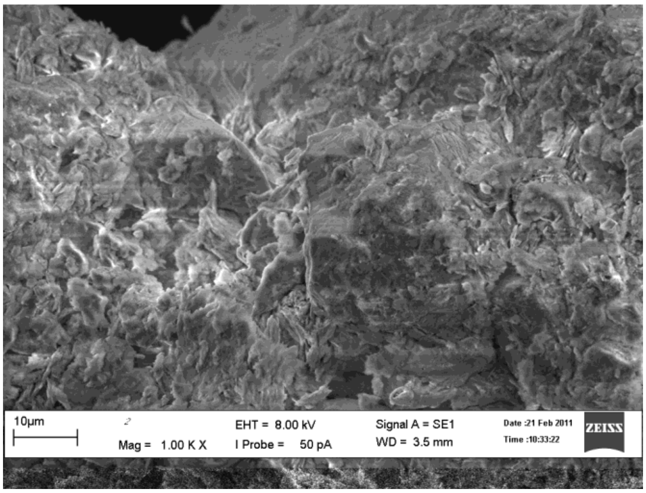

Figure 2. Soil particle for sample No. 4 (S/4)

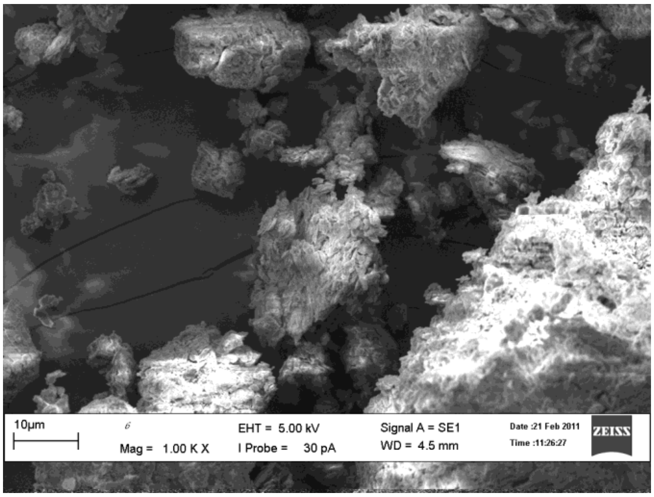

Figure 3. Soil particle for sample No. 6 (S/6)

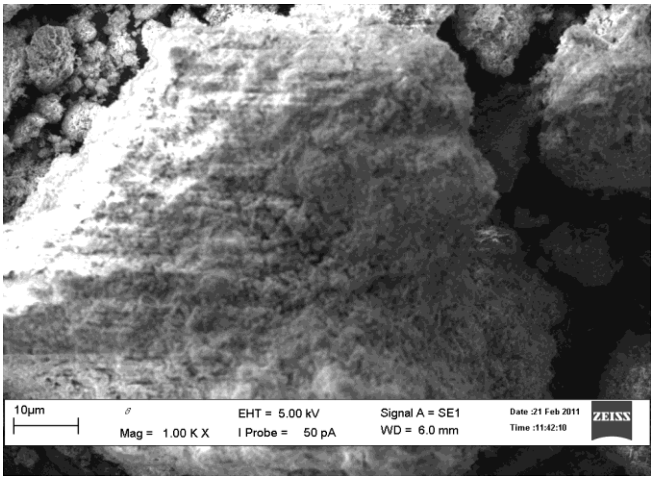

Figure 4. Soil particle for sample No. 8 (S/8)

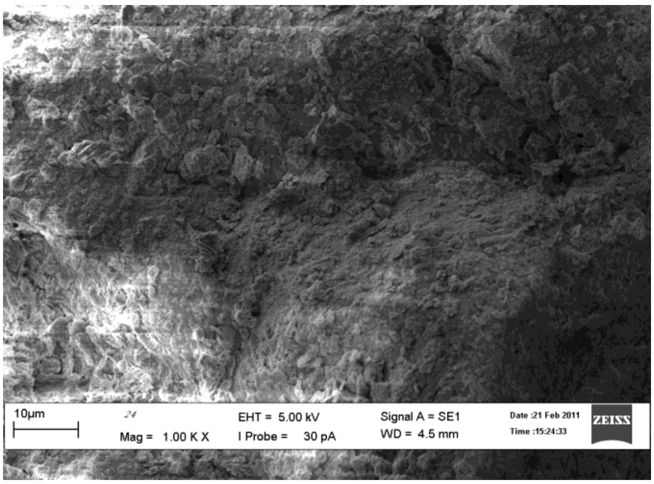

Figure 5. Soil particle for sample No. 24 (S/24)

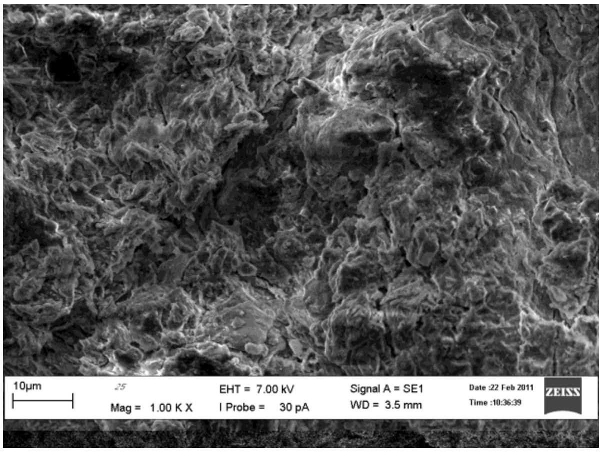

Figure 6. Soil particle for sample No. 25 (S/25)

2.2. Materials stabilizer

Stabilizer: fly ash, bottom ash and OPEFB ash as stabilizer were chosen for this study due to its reliable in Malaysia.

Fly ash and bottom ash refers to part of the non-combustible residues of combustion. In an industrial context, it is generated in vast quantities as a by-product of burning coal at electric power plants and comprises traces of combustibles embedded in forming clinkers and sticking to hot sidewalls of a coal-burning furnace during its operation. The portion of the ash that escapes up the chimney or stack is referred to as fly ash. Bottom ash forms clinkers on the wall of the furnace, with the clinkers eventually falling to the bottom of the furnace.

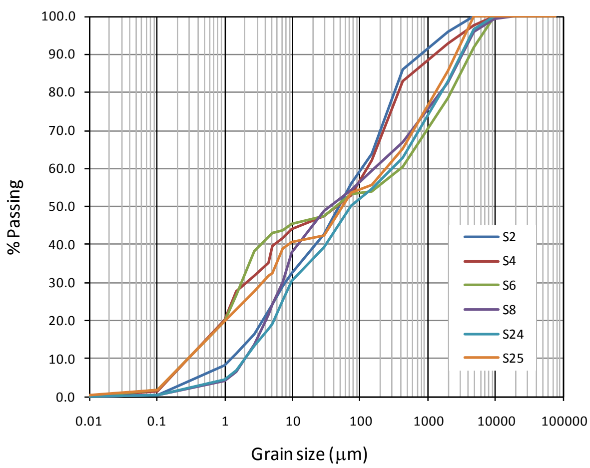

Figure 7. Grain size distribution curves of Kuantan clay

Oil palm belongs to the species Elaeis guineensis of the family Palmacea and originated in the tropical forests of West Africa. Fly, Bottom and OPEFB ash were used in this study is from Sarawak, Malaysia.

The grain size distribution curve of fly ash, bottom ash and OPEFB ash tested by CILAS 1180 Liquid Particle Size Distribution was shown on Figure 8 and Specific Gravity of stabilizer is given on Table 3.

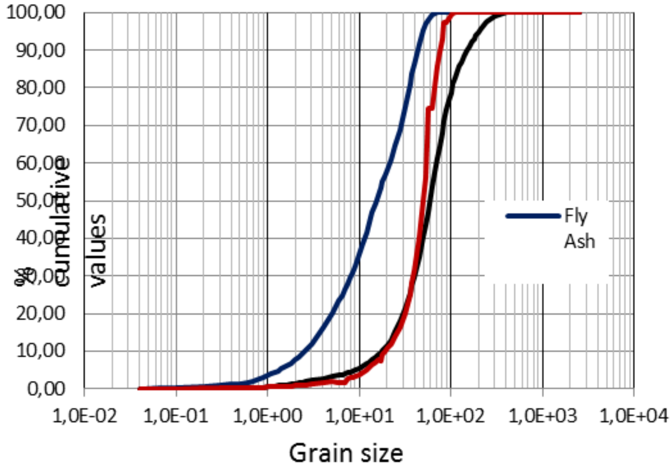

Figure 8. Grain size distribution curves of Stabilizer

Table 3. Specific gravity of stabilizers

Stabilizer	OPEFB ash	Fly ash	Bottom ash
Gs	2.58	2.60	2.55

Table 4. Chemical element for stabilizer

NO	ELEMENT	FLY ASH WEIGHT (%)	B. ASH WEIGHT (%)	OPEFB ASH WEIGHT (%)
1	C $CaCO_3$		15.22	25.59
2	O SiO_2	51.5	53.36	48.8
3	Mg MgO	1.05	-	0.93
4	Al Al_2O_3	13.34	0.71	4.98
5	Si SiO_2	23.87	6.56	12.46
6	S FeS_2	-	0.65	-
7	K MAD	4.24	0.23	0.60
8	Ca Wollastonite	1.94	22.73	2.33
9	Ti Ti	0.74	-	0.33
10	Fe Fe	3.32	0.53	3.98

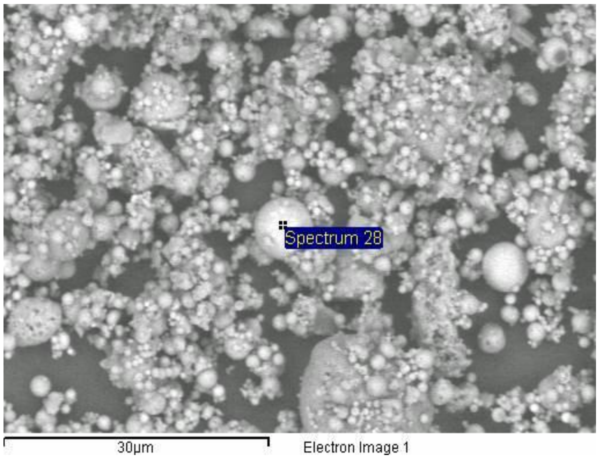

Figure 9. Fly ash particle element

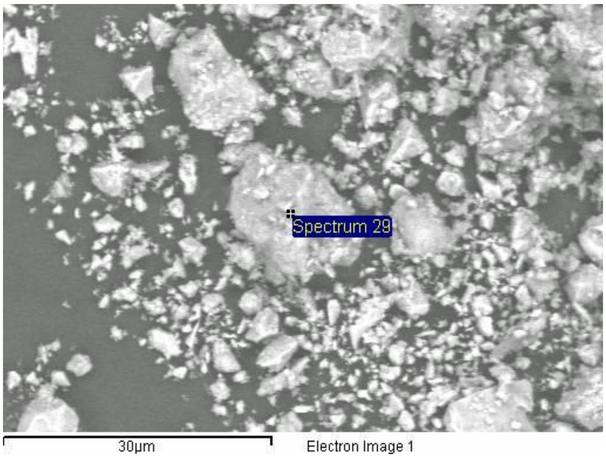

Figure 10. Bottom ash particle element

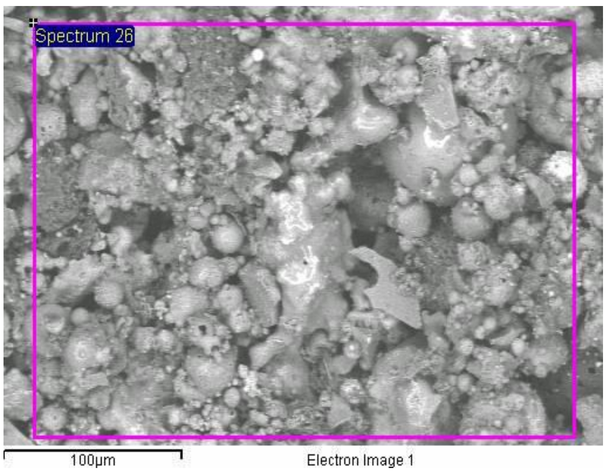

Figure 11. OPEF ash particle element

Stabilized soil specimens were prepared at 4, 8, 12% fly ash and bottom ash, OPEPB ash content (on dry weight basis). CBR and Standard Compaction Proctor tests for stabilized soil conduct based on BS 1377-4 1990.The soil stabilized particles were observed as can be seen in Figure 9 – 11 and Chemical Element was given in Table 4.

3. Engineering Properties of Stabilised Soil

3.1. Chemical Element for stabilized soil

The chemical elements for stabilized soil were investigated by integrated electron microscope and energy-dispersive x-ray Spectroscopy (SEM-EDS), those element were observed given in Table 5 – 9.

Table 5. Chemical element for S/2stabilizedsoil

NO	ELEMENT	S/2	S/2 + F.ASH	S/2 + B.ASH	S/2 + OPEFB
		WEIGHT (%)	WEIGHT (%)	WEIGHT (%)	WEIGHT (%)
1	C $CaCO_3$	-	14.15	11.2	6.65
2	O SiO_2	54.21	50.96	55.07	57.52
3	Mg MgO	-	-	-	-
4	Al Al_2O_3	6.82	8.7	5.49	12.89
5	Si SiO_2	34.33	19.83	26.02	19.32
6	K MAD	2.23	2.91	1.47	2.66
7	Ca Wollastonit	-	-	-	-
8	Ti Ti	-	-	-	-
9	Fe Fe	2.41	3.45	0.76	0.96
10	Zr Zr	-	-	-	-

Table 6. Chemical element for S/4 stabilized soil

NO	ELEMENT	S/4	S/4 + F.ASH	S/4 + B.ASH	S/4 + OPEFB
		WEIGHT (%)	WEIGHT (%)	WEIGHT (%)	WEIGHT (%)
1	C $CaCO_3$	5.05	8.6	7.9	7.01
2	O SiO_2	58.97	65.37	59.13	60.57
3	Mg MgO	-	-	-	-
4	Al Al_2O_3	12.81	9.64	13.83	12.61
5	Si SiO_2	18.99	15.78	14.58	13.45
6	K MAD	1.16	0.61	0.93	0.73
7	Ca Wollastonit	-	-	-	-
8	Ti Ti		-	-	-
9	Fe Fe	3.02	-	1.41	0.55
10	Zr Zr	-	-	2.22	-
11	Pt Pt	-	-	-	5.07

Table 7. Chemical element for S/6 stabilized soil

NO	ELEMENT	S/6	S/6 + F.ASH	S/6 + B.ASH	S/6 + OPEFB
		WEIGHT (%)	WEIGHT (%)	WEIGHT (%)	WEIGHT (%)
1	C $CaCO_3$	8.42	7.33	8.8	30.13
2	O SiO_2	56.67	61.36	63.13	36.79
3	Mg MgO	-	-	-	-
4	Al Al_2O_3	13.07	9.36	12.47	5.86
5	Si SiO_2	11.99	15.12	11.86	4.91
6	K MAD	0.81			
7	Ca Wollastonit	-	-	-	-
8	Ti Ti	0.43	0.46	-	-
9	Fe Fe	8.62	2.65	3.73	22.31
10	Zr Zr	-	3.72	-	-

Table 6. Chemical element for S/8 stabilized soil

NO	ELEMENT	S/8	S/8 + F.ASH	S/8 + B.ASH	S/8 + OPEFB
		WEIGHT (%)	WEIGHT (%)	WEIGHT (%)	WEIGHT (%)
1	C $CaCO_3$	6.05	4.18	4.63	10.01
2	O SiO_2	53.15	68.02	62.29	60.13
3	Mg MgO	-	-	-	-
4	Al Al_2O_3	14.04	13.47	12.89	10.71
5	Si SiO_2	6.07	5.28	8.57	4.68
6	K MAD		-	-	-
7	Ca Wollastonit	-	-	-	1.21
8	Ti Ti	2.37	1.56	1.72	0.43
9	Fe Fe	18.32	7.5	9.89	8.83
10	Zr Zr	-	-	-	-
11	Pt M	-	-	-	4.00

Table 8. Chemical element for S/24 stabilized soil

NO	ELEMENT	S/24	S/24 + F.ASH	S/24 + B.ASH	S/24 + OPEFB
		WEIGHT (%)	WEIGHT (%)	WEIGHT (%)	WEIGHT (%)
1	C $CaCO_3$	7.48	10.52	6.02	20.15
2	O SiO_2	59.83	64.02	67.73	54.2
3	Mg MgO	-	-	-	-
4	Al Al_2O_3	11.17	9.74	4.99	11.48
5	Si SiO_2	18.82	15.11	21.26	12.1
6	K MAD	0.92	0.62		0.84
7	Ca Wollastonit	-	-	-	-
8	Ti Ti	0.58	-	-	-
9	Fe Fe	1.2	-	-	1.22
10	Zr Zr	-	-	-	-

Table 9. Chemical element for S/25 stabilized soil

NO	ELEMENT	S/25	S/25 + F.ASH	S/25 + B.ASH	S/25 + OPEFB
		WEIGHT (%)	WEIGHT (%)	WEIGHT (%)	WEIGHT (%)
1	C $CaCO_3$	10.25	5.11	3.25	24.42
2	O SiO_2	58.98	57.75	62.02	52.27
3	Mg MgO	-	0.41	-	-
4	Al Al_2O_3	8.51	10.91	3.63	5.13
5	Si SiO_2	16.13	20.61	28.02	15.64
6	S FeS_2	2.24			
7	K MAD	0.86	3.28	0.93	1.5
8	Ca Wollastonit	-	-	-	-
9	Ti Ti		0.27	-	-
10	Fe Fe	3.02	1.66	0.37	1.05
11	Zr Zr	-	-	1.78	-

3.2. Compaction

For the subgrade condition, the samples were prepared at the optimum water content. The compaction curve corresponding to the standard Proctor effort was determined for each soil specimen following the procedure in BS 1377-4 1990.

Air-dried soils that pass a 20 mm test sieve are mixed homogeneously with the proposed percent of fly ash and bottom ash, OPEFB ash. Then the required amount of water was sprayed on the soil–fly ash/bottom ash mixture. All mixtures were prepared with fly ash, bottom ash, OPEFB ash content which are 4, 8 and 12% on dry density of soil(Fauzi and Wan 2010; Fauzi et al. 2010; Fauzi et al. 2011; Hilmi et al. 2006). The relationship between the dry density of all mixture samples and lime, PC, fly ash and bottom ash contents are shown in Figure 12-14. The relationship between the optimum water content of all mixture samples and fly ash, bottom ash, OPEFB ash contents are shown in Figure 15-17.

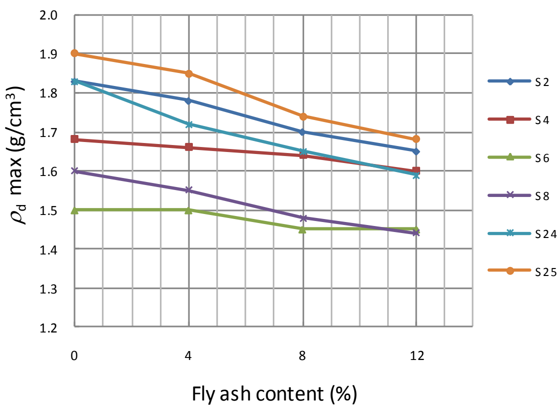

Figure 12. The relationship between soil-fly ash mixtures and dry density

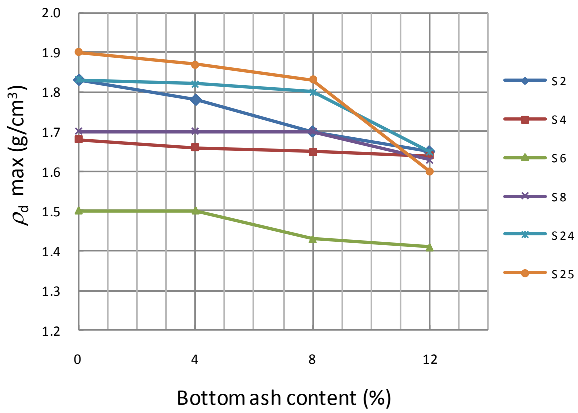

Figure 13. The relationship between soil-bottom ash mixtures and dry density

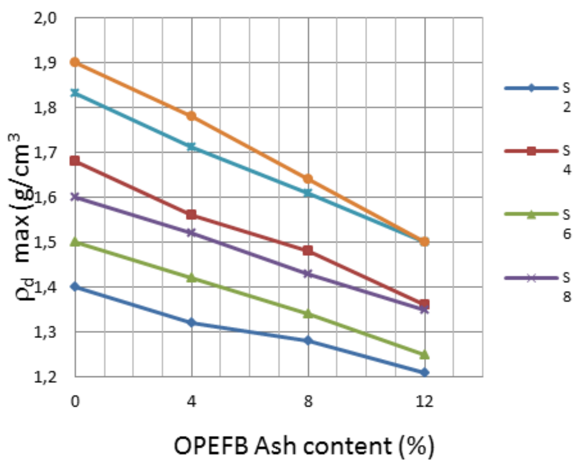

Figure 14. The relationship between soil-OPEFB mixtures and dry density

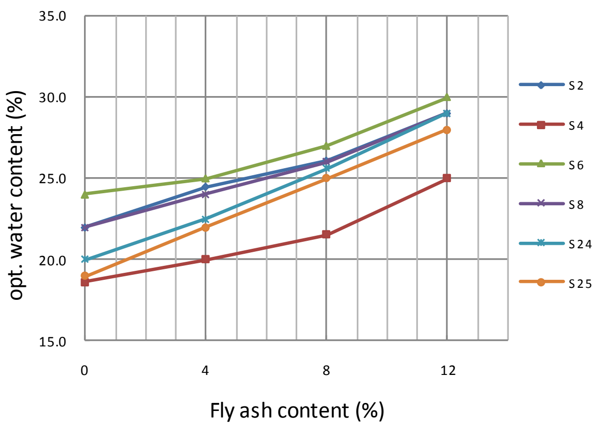

Figure 15. The relationship between soil-fly ash mixtures and optimum water content

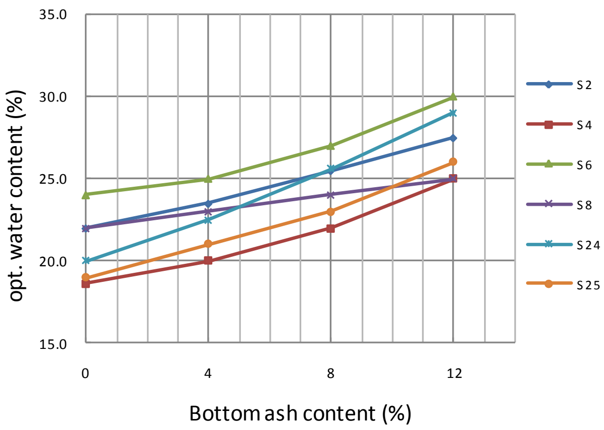

Figure 16. The relationship between soil-bottom ash mixtures and optimum water content

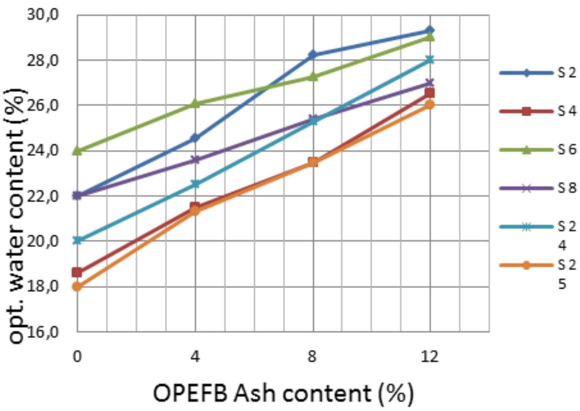

Figure 17. The relationship between soil-bottom ash mixtures and optimum water content

3.3 *CBR*

CBR values are widely used to design the base and sub base layer for the pavement construction. Air-dried samples were sieved through 20 mm standard sieves before they were used. To determine the CBR of the natural soil, a clay sample without additives tested in its natural condition, close to natural water content.

The CBR (soaked) tests were performed on stabilized soils with various fly ash, bottom and OPEFB ash content. Then, some specimens were prepared near the optimum of the optimum water content from the compaction test by using the standard Proctor compaction effort. Then the CBR tests were performed in accordance with BS 1377-4 1990. The CBR values of the soil samples were determined. The fly ash, bottom ash and OPEFB ash mixtures of all sites were prepared for 4, 8 and 12% of total weight soil. The CBR results of the soils and mixtures with fly ash, bottom ash, OPEFB ash are given in Figure 18-20.

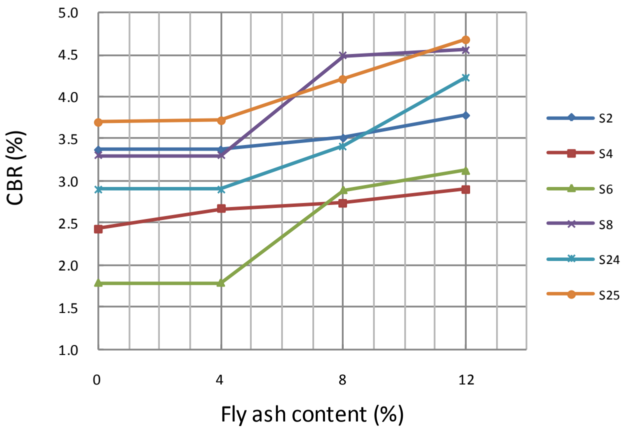

Figure 18. The relationship between soil-fly ash mixtures and CBR value

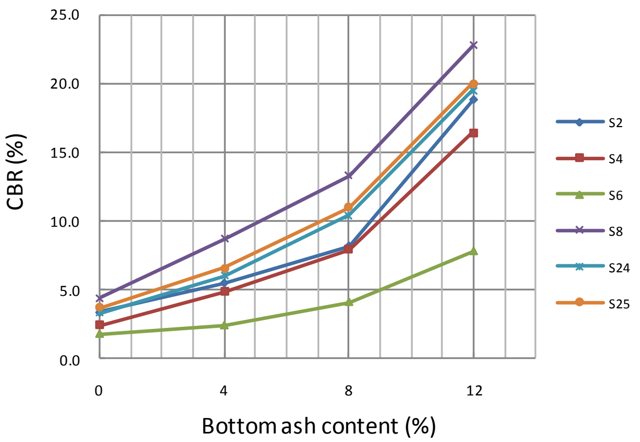

Figure 19. The relationship between soil-bottom ash mixtures and CBR value

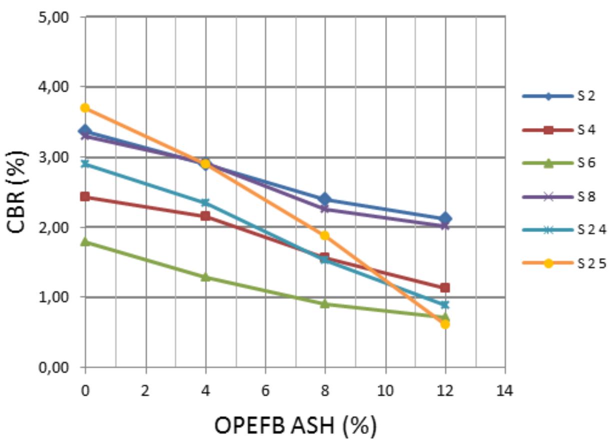

Figure 20. The relationship between soil-OPEFB mixtures and CBR value

4. Results and Discussion

Clay minerals are an important group of minerals because they are among the most common products of chemical weathering. Based on their structures and chemical compositions, all soil samples were included in Smectites group, as Montmorillinite**.** The most important aspect of this group is the ability for H_2O molecules to be absorbed between the T-O-T sheets, causing the volume of the minerals to increase when they come in contact with water. Thus, the smectites are expanding clays.

Montmorillinite is a dangerous type of clay to encounter if it is found in tunnels or road cuts and subgrade. Because of its expandable nature, it can lead to serious slope or wall failures and pavement cracking.

Most of sample were high plasticity clay and classified as A-7-6 by AASHTO Classification. These soils cannot be used as embankment material or have to avoid. If the used of soils cannot reasonably avoided, such material shall be used only on bottom portion of embankment. The engineering properties of these soil improved by stabilizer: fly ash and bottom ash.

For compaction test, the maximum dry density decreased and the optimum water content increased when the fly ash, bottom ash, and OPEFB as content increased.

A general trend of increasing CBR values with increasing fly and bottom ash contents were observed. The increasing CBR value with increasing fly ash, bottom ash content for all samples were significant, but fly ash mixtures for Sample S2 and S4 were not significant(Fauzi and Wan 2010; Fauzi et al. 2010; Fauzi et al. 2011; Senol et al. 2003). The gain in CBR values depend on the amount of fly ash, bottom ash and water content in the mixture. For all the stabilized soil mixtures, the highest CBR values were obtained on bottom ash mixtures.

Fly ash and bottom ash as soil additives were provided the benefits to improve soil engineering properties, eliminates need for expensive borrow materials, expedites construction by improving excessively wet or unstable subgrade by improving subgrade conditions, promotes cost savings through reduction in the required pavement thickness

5. Conclusion

All soil samples were included in Smectites group. Smectites such as Montmorillinite are expanding clays.

The engineering properties tested result shown that almost all of samples were high plasticity material, classified as A-7-6 by AASHTO Classification System. That material cannot be used as embankment material for highway construction. In this study the engineering properties quality improved by adding PC, fly ash and bottom ash as stabilizer in soil stabilization.

Soil stabilization mixtures were prepared at different fly ash, bottom ash and OPEFB ash contents: 4, 8, 12% by total weigh with the specimens compacted at the optimum water content and CBR tests were then performed on these mixtures. Fly ash and bottom ash stabilization increased the CBR values substantially for the mixtures tested and have the potential to offer an alternative for clay soil sub grades improvement of highway construction and this will reduce the construction cost and solving disposal problems. For addition of OPEFB Ash, this will decrease in CBR value.

Acknowledgement

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