International Conference on Engineering
and Education In The 21st Century
Held In Conjunction with The IEM 50th Anniversary Celebration
23 – 25 March 2009
Hotel Riverside Majestic, Kuching, Sarawak, MALAYSIA

Reusing Soft Soils with Cement-Palm Oil Clinker (POC) Stabilisation

Rafidah binti Robani & Chee-Ming Chan
Research Centre for Soft Soils (RECESS), Universiti Tun Hussein Onn Malaysia, MALAYSIA
gf070002@siswa.uthm.edu.my, chan@uthm.edu.my

Abstract: Malaysia is the largest producer and exporter of palm oil in the world. However the palm oil refineries also produce tonnes of waste products known as palm oil clinker or POC. POC is normally disposed of in landfill or incinerated, incurring costs and causing negative environmental impact, such as pollution. Therefore the appropriate use of POC can help preserve the environment from undesirable effects, while at the same time contributes to cost reduction for the palm oil industry. On the other hand, Malaysia has vast spreads of soft soils with low strength and high compressibility. Continuous development has made it necessary to construct on these weak deposits with pre-treatment, such as cement stabilisation. Nevertheless cement is fast becoming an expensive yet basic construction material, and any alternative materials with similar properties are highly anticipated to ease the economic pressure. By combining cement and POC to form a novel soft soil stabiliser, the soft soil areas can be reused at reasonable costs while the palm oil industrial 'waste' can be reutilised for a good cause. This paper describes the effort expended at the Research Centre for Soft Soils (RECESS) of UTHM to examine the potential of the cement-POC combination for treating soft soils. Various percentages of POC were admixed with 5 % of cement to treat the soft clay collected from the RECESS's test site itself. The specimens were cured up to 28 days, then subjected to the bender element test. The measurements showed that the cement-POC stabiliser can effectively increase the stiffness of the soft clay, where POC significantly complemented the cementatious effect of cement at certain mix proportion. The potential of cement-POC as a soft soil stabiliser was clearly underlined, though further work is necessary for more insights of the stabilised soils.

1 INTRODUCTION

Malaysia is the largest producer of palm oil, contributing about 50.9 % of total production in the world (Teoh, 2002). Palm oil industry is a backbone of Malaysia development especially for rural socio-economic development and political stability. However on the way to extract palm oil, the palm oil refineries also produce tonnes of waste products known as palm oil clinker (POC).

POC produced in the boiler when the burning process of husk fiber and shell of palm oil. This burning process is the phase to generate the energy in order to generate the plant boiler in palm oil mill. According to Tay (1991) about 20 % by weight of ash and other residues (i.e. clinker) are produced after the burning process. The clinker turned as abundance of the factory compared to ash. Researches in palm oil industry had been discovered the uses of the palm oil fuel ash (POFA) either as commercial construction material or as fertilizer for the palm oil plant. Also, the ashes turn to potential usage as a detergent. Less of research of POC caused a large amounts of untreated waste and finally contribute of contaminate land, water and air (Mannan et al., 2004).

On the other hand, soft soils (i.e. marine clay) are sediment that covers much of the southern zone of Peninsular Malaysia and exceeds 40 m depth with water content 80 % and higher (Tenaga Gerudi, 2002). As soft soils, they tend to have lower strength and high compressibility. It is difficult to build any construction directly over the soft clay or it will cause structure failure. Cement stabilisation is a pre-treatment that can be used to face these weak deposits problems.

Nevertheless, there is major economical factor in stabilisation that is the increasing cost of cement (Kukko, 2000). The rising environmental impact awareness induces that the cement stabilisation method may become less favourable with time. Alternative stabilising agents as substitute of cement are highly anticipated to tackle these issues. The use of POC by combining with cement can be form into useful material such is together to minimize wastes, maximize recycling, enhance environmental sustainability and ease the economic pressure.

In order to monitor stiffness properties, the bender element (BE) test was used in this study. BE testing was the suitable test that can be used for chemically treated soil (Anand, 2006). Part of applying nondestructive method, it also provided the repeatable and reliable measurements of shear modulus properties.

Also, this study was conducted as the effort expended at the Research Centre for Soft Soil (RECESS) of UTHM to explore the potential of cement-POC combination for treating soft soils.

2 MATERIALS

2.1 *Palm Oil Clinker (POC)*

POC categorized as waste by-product and has appearance of a porous stone with gray in color. The clinkers forms are usually flaky and irregular with rough and spiky broken edges as shown in Fig. 1. The POC for this study was collected from a palm oil mill factory located at Kahang, Kluang. To ensure a better bonding with the clay, the clinker has been ground to powder form before combined together with clay and cement. The physical and chemical properties of POC are as listed in Table 1 and Table 2.

Fig. 1. Palm oil clinker.

Table 1. Physical properties of fine POC and coarse POC (Ahmad, 2008).

Physical properties	Fine	Crushed stone
Specific gravity(*SSD condition)	2.17	2.60
Moisture content (%)	0.08	0.05
Water adsorption (%)	4.65	1.79
Bulk density (kg/m^3)	863.65	1815.23
Fineness modulus	2.84	2.65

*saturated surface dry

Table 2. Chemical properties of POC.

Element		Concentration (%)
Silicca dioxide	SiO_2	81.8
Feric oxide	Fe_2O_3	5.18
Potassium	K_2O	4.66
Aluminium oxide	Al_2O_3	3.5
Calcium oxide	CaO	2.3
Magnesium oxide	MgO	1.24
Phosphorus pentoxide	P_2O_5	0.76
Titanium dioxide	TiO_2	0.17
Natrium oxide	Na_2O	0.14

2.2 *Soft soils*

The soft soil used in this study was retrieved from RECESS test site, UTHM at a depth of ± 1.8 m with small organic content of grass blades, roots and fragment of wood. The sample was disturbed sample and the basic characteristics of the in-situ soft soil are given in Table 3 with the average moisture content was about 84 %.

Table 3. Physical properties of original soil.

Properties Values	Characteristics	
Liquid limit, LL (%)	68	
Plastic limit, PL (%)	32	
Plasticity index, PI (%)	36	
Moisture Content (%)	84.19	
Grain size distribution	Silt (%)	89.20
	Clay (%)	10.23
	Sand (%)	0.57
pH	Soil	3.32
	Groundwater	3.82
Color	Light gray	
Specific gravity, G_s	2.62	

2.3 *Cement*

The ordinary Portland cement was used in this study and the X-ray fluorescence (XRF) test was conducted to reveal the chemical properties of cement that shown in Table 4.

Table 4. Chemical properties of cement.

Element		Concentration (%)
Silicca dioxide	SiO_2	19.0
Feric oxide	Fe_2O_3	2.58
Potassium	K_2O	0.83
Aluminium oxide	Al_2O_3	4.68
Calcium oxide	CaO	65.1
Magnesium oxide	MgO	1.47
Sulfite	SO_3	5.62
Titanium dioxide	TiO_2	0.19
Natrium oxide	Na_2O	0.14

3 METHODS

The specimen consisted of 5 % cement and various amounts of POC that was 5, 10 and 15 % respectively. Different particle size range of POC initially prepared and was experimented in this study i.e. 'a' is for size that passing 425 μm and 'b' is for size retaining 425 μm. The mixtures were then compacted into cylindrical specimens of 38 mm diameter and 76 mm high. In order of comparison purposes, a pair of control specimens with 0, 5 and 10 % cement addition only was included in the test. All the specimens were then cured for 3, 7, 14 and 28 days before being tested.

The specimens were tested with GDS instruments BE equipment test under laboratory conditions. BE are made from strips of piezoelectric material constructed in such way that the application of an electrical voltage causes the element to bend in one direction or the other. The transmitter element is mounted in the top cap and the receiver element in the pedestal as shown in Figure 2.

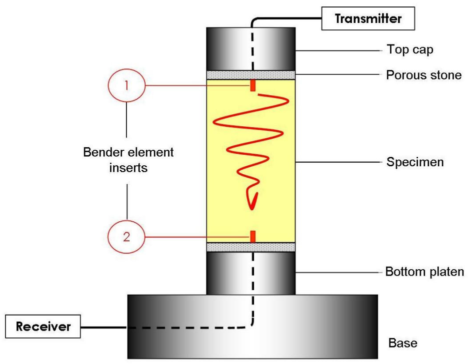


Fig. 2. Bender element test.

The shear wave velocity at small strain, v_s through the soil specimen was estimated as follows:

$$v_s = l/t \quad (1)$$

Where l is the travel length of the shear waves through the specimen, t is the travel time of shear waves from top to bottom of the specimen.

According to Yamashita et al. (2001), there is no standard developed for this technique, mainly due to the fact that the method requires and educated judgment on the quality of the measurement by the user himself. There are also conflicting guidelines for the selection of travel time for shear wave velocity determination with bender elements.

Nevertheless there are various methods to determine the arrival time such as visual picking (t_o), first major peak-to-peak (t_{pk}-t_{pk}), and cross-correlation (Chan, 2006). The visually picked and first major peak-to-peak shear wave arrival time were shown at Fig. 3. Peak-to-peak method had been applied for determining the travel time for the specimens for this study. However, first major trough-to-trough (t_t-t_t) also had been considered for comparison purpose.

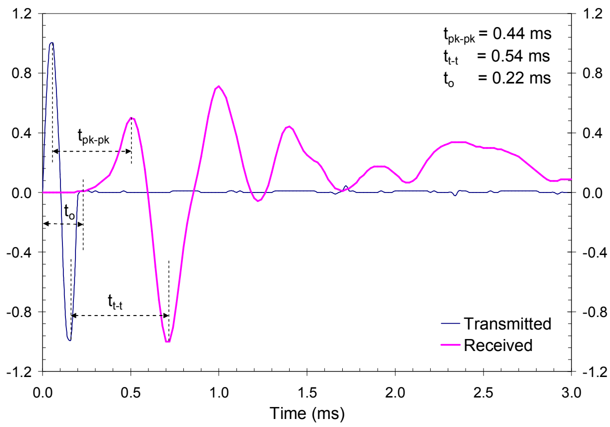


Fig. 3. Visually picked and first major peak-to-peak shear wave arrival time.

For the identification of different addition of specimens, a simple notation system was followed throughout the study. CONTROL was corresponded to the original clay. Symbol C denotes cement stabiliser in treatment and POC denotes the addition of palm oil clinker. The numbering symbol (i.e. 5, 10 etc.) indicates the percentages of material that been used as examples 5C5POCa indicates the 5 % of cement stabiliser used in the treatment with addition of 5 % of POC passing 425 µm in size.

4 RESULTS AND DISCUSSIONS

The original clay were tested and the shear wave velocity is low at 51 ms^{-1}. This observation agrees with reports of past researcher (i.e. Anand, 2006) that the increases of moisture content will reduce the shear wave velocity because of the increase in void ratio.

For cement treated specimens, it provided rapid enhancements to shear wave velocity with respect to elapse curing time. The 10C specimen attained higher v_s values ranging from 173 ms^{-1} to 269 ms^{-1} increase with curing time compared to the rest of specimens. The overall observation presented in Table 5 and 6.

Though for the specimen adding with POC either with presence of cement or POC only, the v_s valued are excessive the v_s of 5C specimen. The v_s increase in a significant manner with addition of various percentages of POC and curing time.

Also, the variation of v_s of the stabilised either with cement-POC or POC only is clearly observed lay below those of the 10C specimen. These findings are depicted in Fig. 4(a, b) and 5 (a, b).

However, Fig. 5 (a, b) showed the higher v_s of specimen with the addition of POC only. The increasing of v_s was respectively with the increasing of percentages of POC compared to cement-POC specimen (Fig.4 (a, b)). The addition of 15 % POC for both sizes showed the v_s with 141 ms^{-1}. It clearly indicated that the various sizes of POC did not show signs of direct relationship with the v_s. On the other hand, the added of POC in the soil stabilisation can improve the shear wave of the soil but not as stiff as 10C specimen and can be seen not to full fill the criteria as a replacement material for cement. However, POC showed a potential to be an additive in soil stabilisation.

Table 5. Shear wave velocity for specimen with addition of clay and cement-POC.

Specimen	Shear wave velocity (m/s)			
	3 d	7 d	14 d	28 d
CONTROL	51	51	51	51
5C	73	86	95	116
10C	173	220	251	269
5C5POCa	86	95	105	123
5C10POCa	81	93	107	129
5C15POCa	79	93	102	114
5C5POCb	70	83	88	119
5C10POCb	78	88	93	120
5C15POCb	78	86	89	116

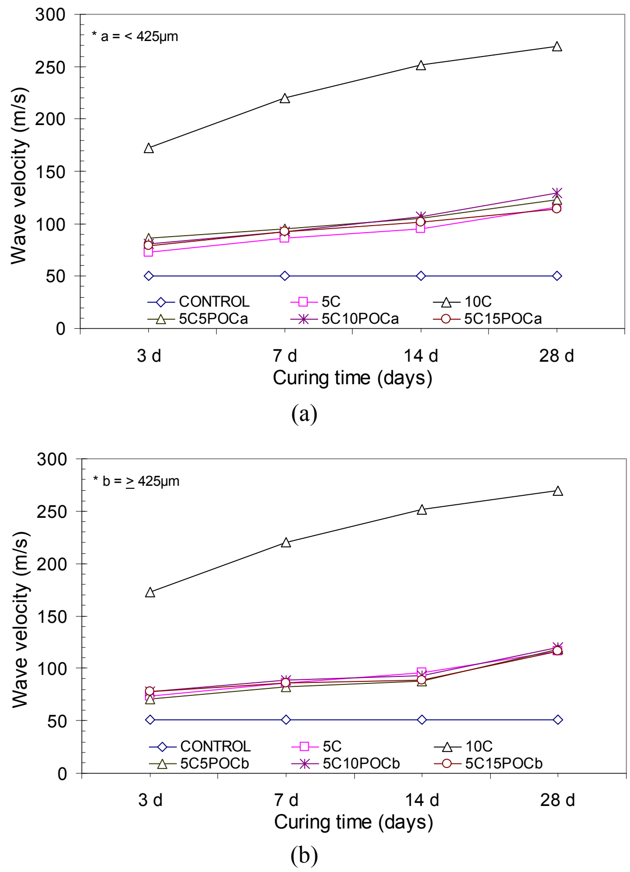


Fig. 4. The variation of shear wave velocity against curing time with addition of clay and cement-POC, (a) POC passing 425 µm (b) POC retaining 425 µm.

Fig. 5. The variation of shear wave velocity against curing time with addition of clay and POC, (a) POC passing 425 µm (b) POC retaining 425 µm.

The comparison between the values of v_s obtained from v_{pk-pk} and v_{t-t} methods is about 1 % for this dataset. The Fig 6. determined the correction factor between v_{pk-pk} and v_{t-t} is:

$$v_{pk} = 1.195\ v_t \qquad (2)$$

By the correction factor equation, the wave velocity technique of determine the travel time either $v_{pk\text{-}pk}$ or $v_{t\text{-}t}$ method can be chosen and applied.

Table 6. Shear wave velocity for specimen with addition of clay and POC.

Specimen	Shear wave velocity (m/s)			
	3 d	7 d	14 d	28 d
CONTROL	51	51	51	51
5C	73	86	95	116
10C	173	220	251	269
5POCa	51	62	88	97
10POCa	56	69	100	127
15POCa	66	83	119	141
5POCb	57	64	86	106
10POCb	49	55	91	123
15POCb	47	52	84	141

5 CONCLUSION

From the study, it can be concluded that the shear wave velocity increases in a significant manner with addition of various percentages of POC and curing time. However, the different sizes of POC did not show signs of direct relationship with the shear wave velocity. It clearly observed that all the specimens stabilised with cement-POC or POC only, always lay between those of the 10 % cement added for stabilised specimens and control specimen. This indicated that the POC was not full filling the criteria as a replacement material for cement but had a potential to be an additive in soil stabilisation. The comparison between the values of v_s obtained from $v_{pk\text{-}pk}$ and $v_{t\text{-}t}$ methods is about 1 % for this dataset.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the financial support provided by the Ministry of Science, Technology and Innovation (MOSTI), Malaysia.

REFERENCES

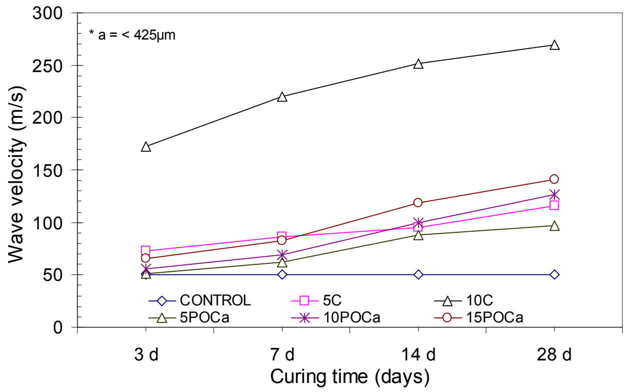
Ahmad, M. H. *et al.* 2008, March. Water Permeability of Malaysian Palm Oil Clinker Concrete. *Proceeding of MUCET2008*, Perlis, Malaysia. 396–400.

Anand, J.P. *et al.* 2006, March. Small-strain shear moduli of chemically stabilized sulfate-bearing cohesive soil. *Journal of Geotechnical & Geoenvironmental Eng.* ASCE. 322–336.

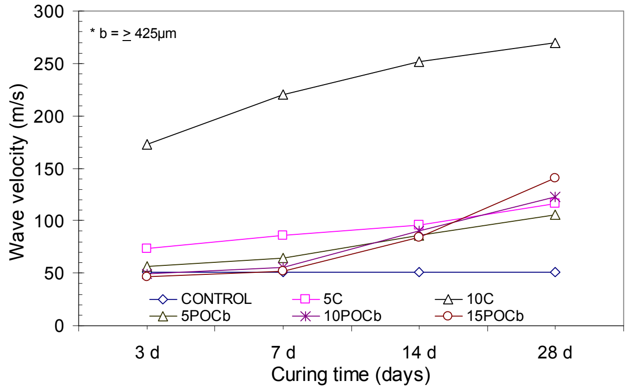
Chan, C-M. 2006, A laboratory investigation of shear wave velocity in stabilized soft soils. *Ph.D. thesis*, University of Sheffield, United Kingdom.

Kukko, H. 2000, November. Stabilization of clay with inorganic by-products. *Journal of Materials in Civil Engineering*. ASCE. 12(4): 307–309.

Mannan, M.A. & Ganapathy, C. 2004. Concrete from agricultural waste-oil palm shell (OPS). *Building and Environment*. 39: 441–448.



(a)



(b)

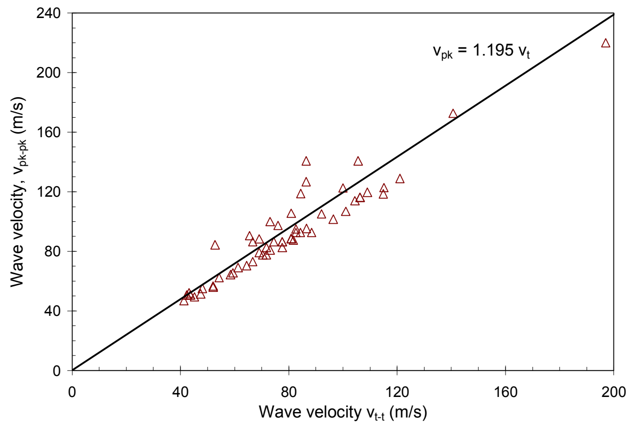


Fig. 6. Correction factor of shear wave velocity between $v_{pk\text{-}pk}$ and $v_{t\text{-}t}$.

Tay, J.H. & Goh, A.T.C. 1991, March/April. Engineering properties of incinerator residue. *Journal of Environmental Eng*. ASCE. 11(2): 224–235.

Tenaga Gerudi Sdn. Bhd. 2002. *Soil Investigation works for: Cadangan Pembangunan KUiTTHO.* Soil Specialist, Kuala Lumpur.Teoh, C.H. 2002. The palm oil industry in Malaysia :

From seed to frying pan. Report of WWF Switzerland.

Yamashita, S., Kohata, H., Kawaguchi, T. and Shibuye, S. 2001. International round robin test organized by TC29. Advanced *laboratory stress strain testing of geomaterials,* Tatsuko, F., Shibuya, S. & Kuwano, R. (eds). 65–110:Balkema.