Micro-structural characteristics of a phosphoric acid stabilized soil

Khairul Anuar Kassim[1,*], Amin Eisazadeh[1], Hadi Nur[2]

[1]Geotechnic & Transportation Department, Faculty of Civil Engineering, Universiti Teknologi Malaysia
[2]Ibnu Sina Institute for Fundamental Science Studies, Universiti Teknologi Malaysia
[*] Head of Geotechnic and Transportation Department. E-mail address: kanuar@utm.my.
Tel.: +607 5531504; Fax: +6075566157.

Introduction

The supplies of lime in the form of hydrated lime are relatively high in Malaysia, making lime an economically viable option for the treatment of tropical soils. However, the acidic nature of tropical soils (pH<7) has raised doubts about the efficiency of soil-lime reactions in a low pH environment (Kassim and Kok, 2004; Kassim *et al.*, 2005; Eisazadeh, 2010). This research was carried out to assess the changes induced on the mineralogy and morphology of the phosphoric acid treated samples at the particle level.

Research Methodology

The physicochemical properties of the natural soil are presented in Table 1. The phosphoric acid used throughout the sample preparation was a Merck analysed, 85% H_3PO_4, of specific gravity 1.71.

The full-scale testing samples were prepared and cured in a similar manner to that described in the British Standard (BS 1924: Part 2: 1990). Samples were then stored in a room with constant temperature (27±2°C) until being tested after one month, to evaluate the short term reactions and after four and eight months, to assess the long-term behaviour of the stabilized soil.

Table 1. The physicochemical properties of the natural Soil.

PHYSICAL PROPERTIES	VALUES	CHEMICAL COMPOSITION (Oxides)	VALUES (%)
pH (L/S = 2.5)	4.64	SiO_2	39.77
Specific Gravity	2.73	Al_2O_3	32.88
Surface area (m^2/g)	20.63	P_2O_5	4.83
Liquid Limit, LL (%)	46.10	K_2O	1.97
Plastic Limit, PL (%)	28.60	SO_3	0.77
Plasticity Index, PI (%)	17.50	CuO	5.68
BS Classification	ML	ZnO	2.16
Maximum dry density (Mg/m_3)	1.58	CO_2	1.59
Optimum moisture content (%)	20.00		
Unconfined compressive strength (kPa)	197.00		

Powder x-ray diffraction (XRD) patterns for treated samples were measured with a Bruker D8 advance diffractometer using CuKα radiation (λ= 1.54Å) and recording (2θ) angles ranging from 6°-90°. The Mineralogical analysis was carried out based on the characteristic Bragg data available in the standard Powder Diffraction File (JCPDS, 1995). In addition, the morphological feature of treated samples was monitored at different time intervals. Each sample was sputtered with platinum for 120 sec at 30 mA under high vacuum conditions until they were completely coated. The samples were then examined using a JSM-6701F JEOL field emission scanning electron microscope (FESEM).

Unconfined compressive strength (UCS) test was performed on cured specimens at an axial strain rate of one percent per minute. The results were used as an index of soil improvement.

Results and discussion

Figure 1 shows the XRD results for various soil mix designs. As can be seen, kaolinite was the dominant clay mineral present in the soil environment. Comparison of the diffractograms of the acid treated samples with the reference untreated spectrum suggested that all intensities of clay mineral reflections decreased with time. Furthermore, new reflections at 18° and 58° 2θ for phosphoric acid treated samples were observed. These peaks were assigned to the formation of phosphate aluminate hydrate compounds.

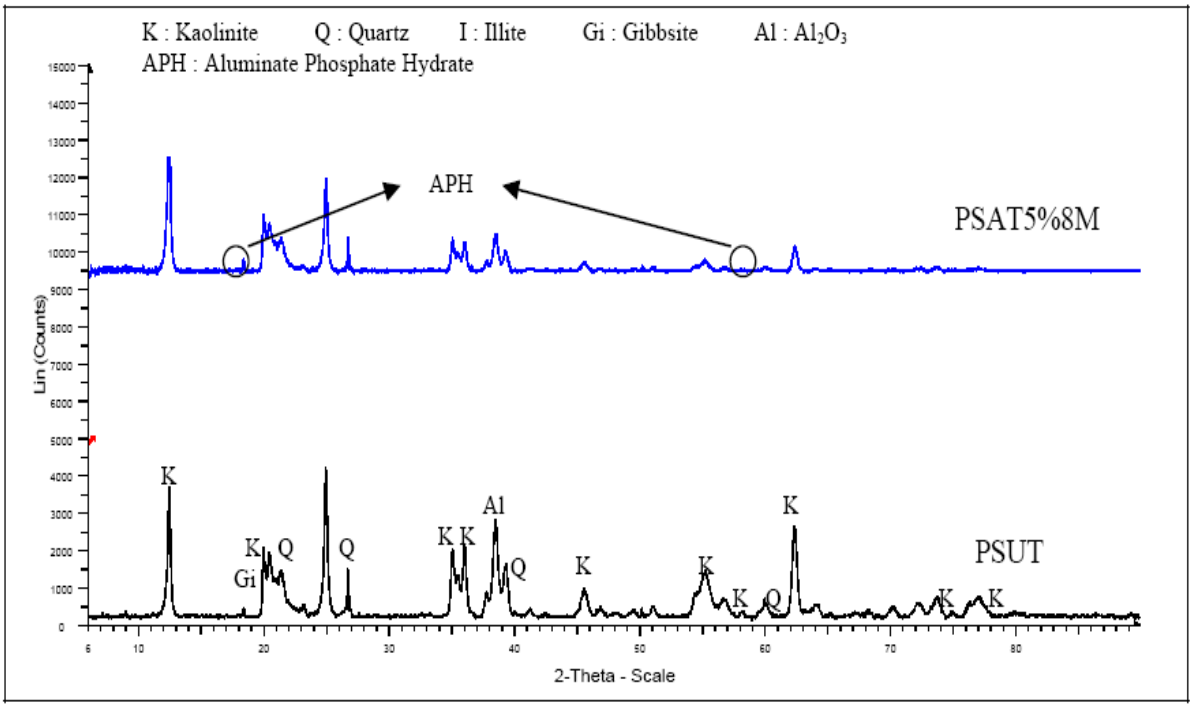

Fig. 1. XRD patterns of untreated (Bottom) and 5% phosphoric acid-treated soil (Top).

The FESEM results for untreated and acid treated soil samples after 8 of months curing are presented in Figure 2. As can be seen, formation of new reaction products in the form of white lumps was evident.

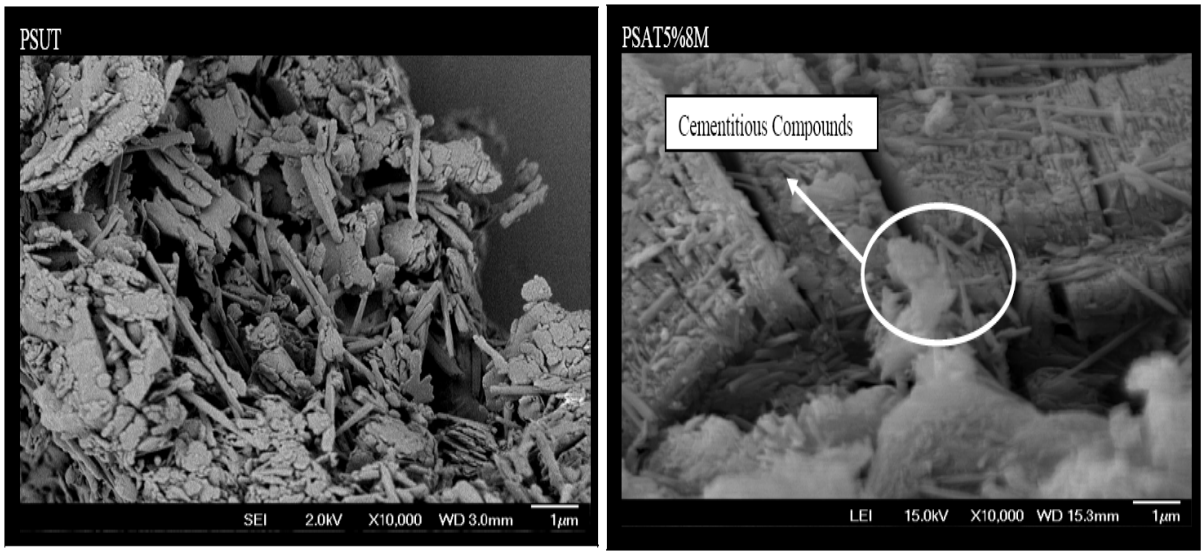

Fig. 2 FESEM images of natural (PSUT) and acid treated samples (PSAT5%8M).

In Figure 3, the unconfined compressive strength of untreated and acid treated Pink Soil at different time intervals are presented. As can be seen, cylindrical specimens of 5% acid treated samples attained an unconfined compressive strength of 1509 kPa, over 8 months curing period. This indicated an increase of approximately 7-fold in comparison to the strength of the natural soil.

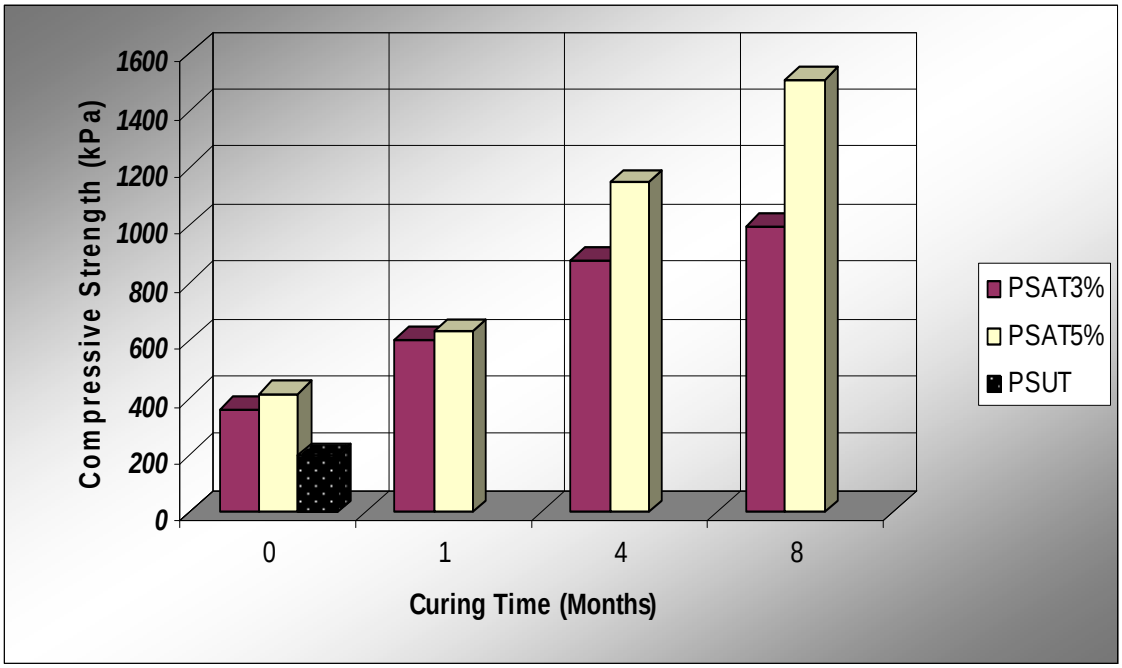

Fig. 3. Strength development for Pink Soil mix designs with curing time.

Conclusions

Based on the collected data, the formation and presence of aluminate phosphate hydrate compounds on the surface of soil particles and their role in improving the mechanical properties of the soil with curing time was confirmed.

References

BSI (1990) Stabilized materials for civil engineering purposes: Part 2, Methods of test for cement-stabilized and lime-stabilized materials. BS1924, British Standards Institution, London

Eisazadeh A (2010) Physicochemical behaviour of lime and phosphoric acid stabilized clayey soils. Universiti Teknologi Malaysia (UTM), Ph.D. Thesis

JCPDS (1995) Index to the powder diffraction file. International Center for Diffraction Data, Swarthmore, Pa

Kassim, K. A. and Kok, K. C. (2004). Lime stabilized Malaysian cohesive soils. *Jurnal Kejuruteraan Awam*. 16(1): 13-23.

Kassim, K. A., Hamir, R., and Kok, K. C. (2005). Modification and stabilization of Malaysian cohesive soils with lime. *Geotechnical Engineering, Journal of the South East Asian Geotechnical Society*. 36(2): 123-132.