PAPER • **OPEN ACCESS**

Experimental investigation on strength improvement of lateritic Halmahera soil using quicklime stabilization

To cite this article: Z Saing *et al* 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **419** 012013

View the article online for updates and enhancements.

You may also like

- Social Conflict in Malifut Sub-district of North Halmahera Regency
Ebin E Danius

- The food composition of Halmahera walking shark (*Hemiscyllium halmahera*)
Y Jutan, A S W Retraubun, A S Khouw et al.

- Tonic immobility induction and duration on halmahera walking shark (*Hemischyllium halmahera*)
D A Mukharror, D Susiloningtyas and M Ichsan

This content was downloaded from IP address 114.124.239.159 on 02/06/2022 at 05:22

IOP Conf. Series: Earth and Environmental Science **419** (2020) 012013 doi:10.1088/1755-1315/419/1/012013

Experimental investigation on strength improvement of lateritic Halmahera soil using quicklime stabilization

Z Saing[1], M H Ibrahim[1] and Irianto[2]

[1]Faculty of Engineering, Universitas Muhammadiyah Maluku Utara, Ternate, Indonesia
[2]Faculty of Engineering, Universitas YAPIS Papua, Jayapura, Indonesia

E-mail: zubairsaing.ummu@gmail.com

Abstract. The purpose of this study is to investigate the effects of quicklime on soil strength performance of lateritic Halmahera soil (LHS) on a particular mixture composition. The Lateritic soil consists of three types based on its iron content from three different location in Eastern Halmahera Island. Soil sample labeled according to iron contents, that is LHS-1 for low iron content, LHS-2 for medium iron content, and LHS-3 for high iron content. Soil physical properties were obtained from laboratory test according to ASTM testing standard. The soil sample was mixed with 3, 5, 7, and 10% quicklime addition on maximum dry density (MDD) condition from Proctor standard laboratory test results. The sample were cured for 3, 7, 14, and 28 days before being tested for unconfined compression strength (UCT) test. The results was found that the significant effect of iron content to increase strength. The higher of iron content, then strength increases, it is the novelty of this research and differentiate laterite Halmahera soil with other laterite soil in Indonesia. Therefore, the lateritic Halmahera soil potential to be used as road and construction materials.

1. Introduction

Indonesia is currently focusing on infrastructure development, particularly to support increased of investment, so that the material requirement intended to increase especially for construction and road materials. Certain areas have limited resources to qualified material, especially material (grade) A and B. One such area is particularly the Halmahera Island in North Maluku Indonesia, which has been buying material from other areas, on the other hands the local material content potential to be developed as a road foundation and other construction materials, one of which is a lateritic soil.

The lateritic Halmahera soil is a kind of lateritic soil that contains high ferrous metal content with a range between 40% -70%, depending on the origin of rock-forming minerals from the soil [1-5]. Research on lateritic soil has been widely applied, especially in countries that there are many types of soil such as in Asia and Africa [6, 7]. The higher clay mineral content in the soil causing laterite soil strength decreases [8]. The laterite soil stabilization with lime will increase the soil strength becomes 2-3 larger [9]. The addition of a little lime and cement highly efficient, improve laterite soil by adding 3% only 2% of cement and lime [9]. The laterite soil stabilization using polymer solution (GKS), resulted that the soil strength increases with increasing curing time after 7 days [10]. The laterite soil stabilization using a cane resulted that the ash cane fiber is very effective in stabilizing and strengthening the geotechnical properties of laterite soil [11]. The laterite soil stabilized with ash cane and cement resulted that the ash cane fiber is very effective as a stabilizing agent in 6% content and 5% cement content to reinforce the geotechnical properties of laterite soil, and can be used for construction road as a sub-base [12]. The laterite soil stabilization using corn cob ash (CCA), resulted that the maximum dry density decreases in ash content of 1.5% CCA, optimum water content increase of 0 to 7.5%. CBR value increased at the CCA content of 1.5% and then decreased with the addition of CCA [13]. Unconfined compressive strength increased by 1.5% content and decreased with the addition of CCA. Study on the behavior of bentonite is used to strengthen the laterite soil resulted that the bentonite can enhance the performance of hydraulic and mechanical of laterite soil [14]. The laterite soil

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

stabilization using sodium silicate liquid indicate that the addition of sodium silicate more than 9% decrease soil compressive strength [15]. The laterite soil characteristics as a coating material that is fed gasoline, hydraulic conductivity increase in line with the increase in the hydraulic gradient [16]. Soils mixed with fly-ash based geopolymer tend to give a higher state of the peak shear strength for curing sample about two times of soils mixed with tap water [17,18].

The research development on lateritic soil utilization, indicating that the soil is very potential to be used in various constructions materials [19-21]. However, still not much research on the iron lateritic soil. The potential of East Halmahera lateritic soil as a local asset (local content) that has been attempted to be used as road and construction materials, as the first phase has been carried out laboratory tests on the characteristic of soil strength which has been stabilized with quicklime (CaO) to curing up to 28 days.

2. Materials and methods

The material used in this study is lateritic Halmahera soil obtained from the eastern Halmahera Island, with three different sampling locations, with coordinates 1^{0}3'46,24" N and 128^{0}8'28,56" E (Subaim area), 0^{0}55'13,29" N and 128^{0}21'5,15" E (Buli area), and 0^{0}40'17.80" N and 128^{0}16'51,20" E (Maba area). Soil sampling by conventionally using a pick and shovel, then placed in a sample sack and wrapped to maintain the original moisture content, and labeled initials correspond to the location of the sample that is LHS-1 (low iron content), LHS-2 (medium iron content), and LHS-3 (high iron content) as seen in Fig. 1.

Figure 1. Sampling location of laterite soil (Halmahera Island in North Maluku Province, Indonesia).

This study is a laboratory experiment, with some steps, was conducted as follows; first, literature review and a preliminary survey to identify the problem and identification of the sampling location; second, pre-testing of samples that have been taken to determine the characteristics of the lateritic soil. Laboratory tests to know the physical properties which include water content, Atterberg limits, and specific gravity, while testing the mechanical properties include compaction test, compressive strength test (UCT), and bearing capacity test (CBR). The soil consistency using the Atterberg limit tests, compaction using Proctor standard test. Furthermore, the result of compaction test that used as an initial condition of UCT sample preparation, curing time was conducted of 3, 7, 14, and 28 days then samples testing. Table 1 shows the Standardized testing of both physical and mechanical properties which is used [22].

Table 1. The standard test used.

Type of Testing	ASTM Standard Number
Grain Size Analysis	C-136-06
Liquid Limit (LL)	D-423-66
Plastic Limit (PL)	D-424-74
Plasticity Index (IP)	D-4318-10
Specific Gravity (Gs)	D-162
Water Content (Wc)	D-2216-98
Uniconfined Compression Test (qu)	D-633-1994
Compaction Test	D-698
CBR Laboratory Test	D-1833

Figure 2. Unconfined compression strength testing procedure: a) compaction test, b) cylindrical untreated and treated soil sample, c) curing process, d) unconfined compression test (UCT), e) sample weighing after testing, f) drying in an oven.

The strength test was conducted for both untreated and treated soil. Stabilized material that using in this study is quicklime with 98% CaO and 2% SiO2 contents. The addition of quicklime with 0, 3, 5, 7, and 10% composition (by mass was modified based on some previous study) in Proctor MDD condition, while the treated soil was cured for 3, 7, 14, and 28 days, as shown in Fig. 2 [8, 9, 23]. The data were analyzed to generate a relationship between the untreated and treated soil strength with quicklime addition percentage and its relation to the curing time based on descriptively qualitatively method.

3. Results and discussions

The laboratory tests for physical and mechanical properties were conducted for three different lateritic Halmahera soil using ASTM standard on Table 1, as shown in table 2.

Table 2. Physical properties of Halmahera lateritc soil.

Physical and Mechanical Properties	Lateritic Halmahera Soil (LHS)		
	1	2	3
Water content (%)	20.26	18.86	22.25
Specific gravity	2.73	2.66	2.62
% Passing #200	92.32	91.75	94.89
Liquid limit (%)	65.98	67.77	68.73
Plastic limit (%)	47.92	48.86	41.96
Plasticity index (%)	18.06	18.91	26.77
AASTHO soil classification	A-7-6	A-7-6	A-7-6
USCS soil classification	CH	CH	CH
Optimum moisture content (%)	19.45	20.50	20.7
Maximum dry density (ton/m^3)	1.769	1.780	1.773
CBR (%) – unsoaked	11.24	12.33	21,02
UCS (kPa)	71.44	75.61	128.88

Table 3. Chemical properties of laterite soil obtained from EDS test.

Elemental Compound	Lime Treated LHS - 1 (Days)				Lime Treated LHS - 2 (Days)				Lime Treated LHS - 3 (Days)			
	3	7	14	28	3	7	14	28	7	14	21	28
MgO	3.56	2,22	1,32	1,84	4,45	1,48	0,94	2,29	2,48	2,19	1,36	3,4
A12O3	3.28	3,89	2,6	3,38	7,91	5,42	4,35	6,86	7,01	8,07	4,3	8,69
SiO2	23	19,9	22,8	20,7	4,52	2,3	1,55	0	3,37	3,63	2,52	4,56
K2O	0.25	0,31	0	0	0,29	0,05	0	0	0,29	0,32	0	0
TiO2	0	0,3	0	0	0	0,3	0	0	0	0,52	0,53	0
FeO	50.1	56,2	57,6	57,6	61	72	76,8	69	62,3	65,7	77,5	64,8
NiO	1.25	0,87	1,45	0	2,17	1,93	2,24	0	1,08	1,27	0,74	0
Cr2O3	1.16	0,9	1,33	1,61	1,33	1,91	1,51	2,17	2,19	2,02	2,45	1,88
P2O5	0.24	0,36	0	0,54	0,76	0	0	0	0,2	0,42	0	0
SO3	0.49	0,47	0,39	0	1,02	0,79	0,37	0	0,3	0,26	0	1,55
Na2O	1.16	1,82	0,83	1,6	2,2	1,34	0,41	0,81	1,14	1,57	0,04	2,39
CaO	15.5	12,8	11,7	12,7	14,4	12,8	11,9	15,5	19,7	14	10,5	12,7

Based on table 2, it is shown that lateritic Halmahera soil is dominated by clay minerals shown by grain size analysis results (91.75% - 94.89% passed #200 sieve). The dominance of clay minerals in accordance with microstructure test results showed that lateritic Halmahera soil was dominated by montmorillonite minerals [1-5]. The results of physical properties test in Table 2 according to AASTHO (A-7-6) and USCS (CH) soil classification method indicate that Halmahera lateritic soil included in clay soil with high plasticity. In addition, it is also seen that the higher of iron content (FeO) in the soil, the mechanical capacity of soil are better seen from the results of UCT and CBR test for native soil. This explains that there is an effect of FeO content in soil capacity as seen on Table 3.

Furthermore, the unconfined compression test (UCT) result of stabilized lateritic Halmahera soil with 3%, 5%, 7%, and 10% quicklime addition then cured for 3, 7, 14, and 28 days as shown in Fig. 3. Based on Figure 3, it is shown that the unconfined compressive strength changes during the curing time. The stress-strain curve shape of mixture soil indicating that the soil is hard and rigid (stiff). Furthermore, after maximum strength, the failure occurs without residual stresses. This condition indicates that the soil becomes very fragile [9, 23].

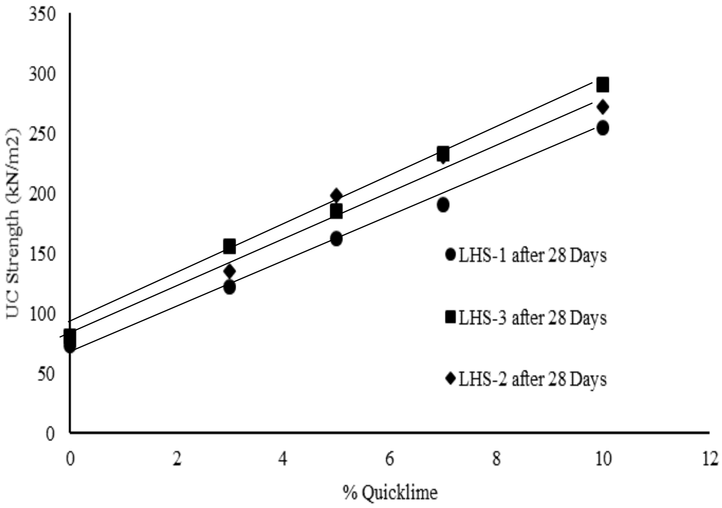

Figure 3. Treated LHS compressive strength vs quicklime addition and curing time.

Based on figure 3, it is shown that the increase of quicklime percentage and curing time lead to increased treated soil strength. In 10% quicklime addition with 28 days curing time, an increase of soil strength 72 kPa-254 kPa for LHS-1, 80 kPa - 272 kPa for LHS-2, and 156 kPa-291 kPa for LHS-3, shows that treated

LHS-3 better than LHS-1 and LHS-2. This represents an increase of soil strength is almost three times greater than untreated soil. It is seen that the condition of 10% quicklime at 28 days cured, produce the highest soil compressive strength. These results are very consistent with the results has been conducted before [23-28]. In addition, the iron content of the soil has an effect on increasing strength. Increased iron content leads to increased soil strength although not significant.

Lateritic Halmahera soil dominated by clay minerals that have a high plasticity such as mineral montmorillonite (smectite) and illite. This is related to the composition of the base layer mineralogy or the mineral montmorillonite unit structure. The structure of the mineral montmorillonite is an element that is formed of alumina octahedral sheet between two sheets of silica tetrahedra. An alumina octahedral structure composed of one atom of aluminum and 6 hydroxyls in the which the silica tetrahedral octahedral shape consisting of a silicon atom and four oxygen atoms in a tetrahedral shape [24]. The addition of quicklime (CaO) to the lateritic soil directly undergoes a hydration process due to its chemical combination with water and heat release [24-26]. The soil becomes dry because the water in the soil is reacted and evaporates. During stabilization and increasing the amount of CaO and H2O contents, pH of soil directly rises above 10.5 causing the clay particles to broken. Silica and alumina react with calcium from CaO in the form of calcium silicate hydrate (C-S-H) and calcium aluminate hydrate (C-A-H) [1-4] [28]. This forms a matrix that contributes to producing strength layers of laterite soil with lime stabilization [25, 27]. This condition leads to an increase in soil strength.

The increased compressive strength of this mixed soil, microstructures showed that lateritic Halmahera soil reaction with quicklime had a significant effect on soil capacity improvement. The microstructural conditions of the three mixed untreated and treated soil are shown in figure 4-6 [28].

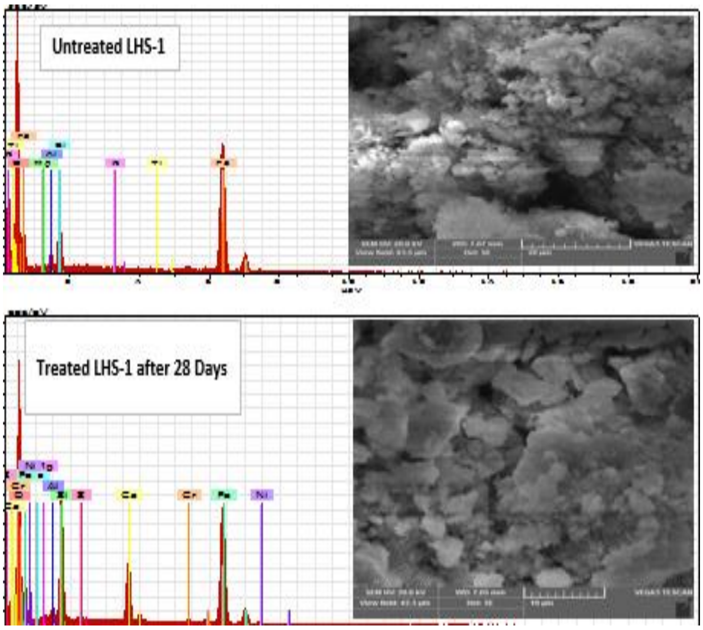

Figure 4. SEM/EDS tests results of LHS-1 after 28 days curing time.

There is an exchange of K^+ (potassium) and Na^+ (sodium) ions contained in clay by Ca^{++} and Mg^{++} ions contained in the quicklime. The exchange of cations on the clay particles makes the particle size larger and reduces the soil plasticity index followed by a decrease in the soil swelling potential. An increase in acidity degree (pH) of the soil resulting in an increase in exchange capacity of positive ions (cations) [25, 27]. The mixing of silica (SiO_2), and alumina (Al_2O_3) from soil with water to form a paste that binds clay particles and covering the soil pore, cavities surrounded by cementation materials that are more difficult to penetrate water will make treated soil more resistant to absorption of water thereby decreasing plasticity. Increasing the soil maximum density due to the increased SiO_2, Al_2O_3, and Fe_2O_3 elements, the pozzolan process occurs between calcium hydroxide reacting with silicate (SiO_2) and aluminate (Al_2O_3) to form a binding material which comprises calcium silicate or aluminate silicates; the reaction of Ca^{2+} ions with silicates (SiO_2), and aluminate (Al_2O_3) from the surface of clay particles to form a cement paste (hydrated gel) to bind soil particles [24, 26].

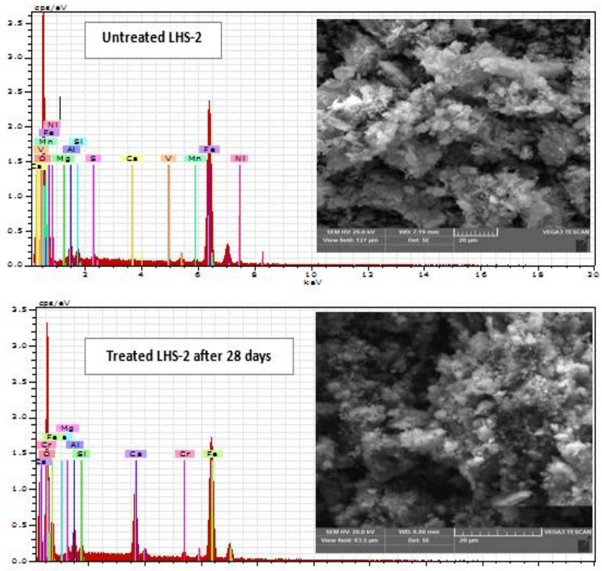

Figure 5. SEM/EDS tests results of LHS-2 after 28 days curing time.

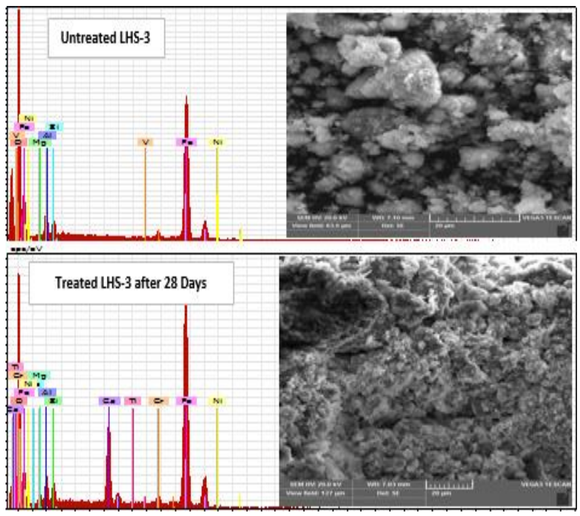

Figure 6. SEM/EDS tests results of LHS-3 after 28 days curing time.

4. Conclusions

In this paper, three different lateritic Halmahera soil were conducted to improve strength characteristic using quicklime stabilization. The main aim was to investigate the effects of quicklime on soil strength performance of lateritic Halmahera soil (LHS) on a particular mixture composition to be used as road and construction materials. Based on physical properties, the lateritic Halmahera soil was A-7-6 for AASHTO soil classification system and CH for USCS soil classification system. While for the microstructural test, the lateritic Halmahera soil was dominated by montmorillonite mineral and FeO content.

The addition of 10% quicklime on 28 days cured, increase the unconfined soil strength 300% than untreated soil. This condition due to pozzolanic strength layers formed of Calcium Silicate Hydrate (C-S-H), Calcium Aluminate Hydrate (C-A-H), and Calcium Ferrous Hydrate (C-F-H). Based on these results, the significant effect of iron content to increase strength. The higher of iron content, then strength increases, it is the novelty of this research and differentiate laterite Halmahera soil with another laterite soil in Indonesia. Therefore, the lateritic Halmahera soil potential to be used as road and construction materials, subsequently for field implementation required detail tests especially for the model test.

IOP Conf. Series: Earth and Environmental Science **419** (2020) 012013 doi:10.1088/1755-1315/419/1/012013

5. Acknowledgment
We would like to special thank Directorate General Development and Research Strengthening Ministery of Research Technology and Higher Education for funding this research in scheme of PDD Grant No. 125/SP2H/LT/DRPM/\/IV/2017 and BSLN grant. We also Thank to Hasanuddin University for the use of soil mechanics laboratory, and to all who have assisted in the completion of this research.

References

[1] Saing Z, Samang L, Harianto T and Patanduk J 2014 Microstructural and mechanical characteristic of potential ferro laterite soil as subbase material, *IJIRAE* **3(2)** 42-48

[2] Saing Z, Samang L, Harianto T and Patanduk J 2017 Mechanical characteristic of ferro laterite soil with cement stabilization as a subgrade material, *IJCIET* **8(3)** 609–616

[3] Saing Z 2017 Vertical Deformation of lime-treated base (LTB) model of laterite soil using numerical analysis, *IJCIET* **8(5)** 758–764

[4] Saing Z, Samang L, Harianto T, Patanduk J 2017 Study on characteristic of laterite soil with lime stabilization as a road foundation, *IJAER* **12(14)** 4687-4693

[5] Saing Z and Djainal H 2018 Effect of lime stabilization on vertical stabilization of laterite Halmahera soil, *IOP Conf. Series: Earth and Environmental Science* **140** 012071

[6] Horpibulsuk S, Suddeepong A, Chamket P and Chinkulkijniwat A 2013 Compaction behavior of fine-grained soils, lateritic soils and crushed rocks, Soils and Foundations **53(1)**

[7] Van D B and Kennedy O 2018 Adsorbed complex and laboratory geotechnics of Quarry Dust (QD) stabilized lateritic soils, *Environmental Technology & Innovation* **10**

[8] Sree D, Ajitha AR, Evangeline Y and Sheela 2010 Study on amended soil liner using lateritic soil, *Indian Geotechnical Conference*, GEOtrendz December 16–18, IGS Mumbai Chapter & IIT Bombay, 381-284

[9] Portelinha FHM, Lima DC, Fontes MPF and Carvalho CAB 2012 Modification of a lateritic soil with lime and cement: an economical alternative for flexible pavement layers, *Soils and Rocks*, São Paulo, **35(1)** 51-63

[10] Aminaton M, Nima L and Houman S 2013 Stabilization of laterite soil using GKS soil stabilizer, *EJGE Journal* **18** 521-532

[11] Amu OO, Ogunniyi SA and Oladeji OO 2011 Geotechnical properties of lateritic soil stabilized with sugarcane straw Ash, *American Journal of Scientific And Industrial Research, Science Huβ* 323-331

[12] Kiran SP, Ramakrishna AN, Shrinivas HR 2014 Stabilization of lateritic soil by using sugarcane straw ash and cement, *Journal of Civil Engineering Technology and Research* **2(1)** 615-620

[13] Yinusa AJ, Ahmed OP 2014 An evaluation of the influence of corn cob ash on the strength parameters of lateritic soils, *Civil and Environmental Research* **6(5)**

[14] Liu Y, Bai Q, Nie Y 2004 Properties of bentonite enhanced loess and laterite, Chinese *Journal Chemical Engineering* **12(1)** 37-41

[15] Nima L, Amin E and Aminaton M 2014 Strength behavior and microstructural characteristics of tropical laterite soil treated with sodium silicate-based liquid stabilizer, *Environ. Earth Sci.* **72** 91–98.

[16] Wisley MF, Geraldo RB, Éder SM, Fabrício BFC, José CC and Edi MG 2014 Chemical and hydraulic behavior of a tropical soil compacted submitted to the flow of gasoline hydrocarbons, Environmental Risk Assessment of Soil Contamination, *Intech* 638-655.

[17] Soe T, Chanodorm L and Decho P 2018 Shear strength enhancement of compacted soils using high-calcium fly ash-based geopolymer, *International Journal of GEOMATE* 15, **48** 1-9.

[18] Jonathan RD and Edward ET 2018 Fly-Ash-based geopolymer SS stabilizer for silty sand embankment materials, *International Journal of GEOMATE* 14, **46** 143-149.

[19] Phummiphan I, Horpibulsuk S, Sukmak P, Chinkulkijniwat A, Arulrajah A and Shen SL 2016 Stabilisation of marginal lateritic soil using high calcium fly ash-based geopolymer, *Road Materials and Pavement Design* **17(4)** 877-891.

[20] Van DB, Onyelowe K and Nguyen VM 2018 Capillary rise, suction (absorption) and the strength development of HBM treated with QD base geopolymer, *International Journal of Pavement Research and Technology* **04**

[21] Onyelowe KC, Bui VD, and Nguyen VM 2018 Swelling potential, shrinkage and durability of cemented and uncemented lateritic soils treated with CWC base geopolymer, *IJGE* 1 **16**

[22] American Standard for Testing and Material
[23] Olugbenga O A, Oluwole FB and Iyiola AK 2011 The suitability and lime stabilization requirement of some lateritic soil samples as pavement, *Int. J. Pure Appl. Sci. Tech.* 2, **1** 29-46
[24] Jaritngam S, Somchainuek O and Taneerananon P 2014 Feasibility of laterite-cement mixture as pavement base course aggregat, *International Journal of Science and Technology Transaction of Civil Engineering* **38** 275-284
[25] Tanh DT, Yu-Jun C, Tang AM, Martin A and Roger C 2014 Effect on lime treatment on the microstructure and hydraulic conductivity of Hericourt clay, *Journal of Rock Mechanics and Geotechnical Engineering* **6** 399-404.
[26] Pranshoo S and Musharraf Z 2012 Microstructural and mineralogical characterization of clay stabilized using calcium-based stabilizers, Scanning Electron Microscopy, Dr. Viacheslav Kazmiruk (Ed.)
[27] Ken OC and Okoafor FO 2012 Geochemistry of soil stabilization, *Journal of Earth Science Asian Research Publishing Network* 1 **1** 32-35
[28] Saing Z, Samang L, Harianto T and Patanduk J 2018 Bearing capacity characteristic of subgrade layer quicklime treated laterite soil, *MATEC Web of Conferences* **181**, 11001