Journal of Engineering and Technology

EVALUATING THE PERFORMANCE OF UNCONFINED COMPRESSIVE STRENGTH OF TRONG CLAY STABILIZED WITH GRANITE SLUDGE

R. Che Mamat[1*], A. Ramli[2] , M. R. Mat Yazid[3]

[1,2,3]Department of Civil Engineering, Politeknik Ungku Omar, Jalan Raja Musa Mahadi, 31400 Ipoh, Perak

Article History: Received 14.12.2016; Revised 2.11. 2017; Accepted 24.11.2017

ABSTRACT

This research paper aims to evaluate the potential usability of granite sludge as a stabilizer of Trong clay based on compressive strength. There are eight mixture combination between the clay and the stabilizer with ratios of 0, 1, 2, 3, 4, 5, 6 and 7 wt% granite sludge. The value of shear strength is obtained through unconfined compression tests performed in the laboratory. The research found that the performance of unconfined compressive strength increased with the percentage of stabilizer. Sample S7 which contains 7% granite sludge is found to yield the highest unconfined compressive strength of 585 kN/m^2. This is 187% higher than unstrengthened sample. This study found that, the compressive strength improved with increased granite sludge content in the soil mixture.

KEYWORDS: *Granite sludge, Trong clay, unconfined compressive strength; emission; Plasticity index*

1.0 INTRODUCTION

Reducing negative environmental impact has been a priority in many sectors in the context of sustainable development. In the last five decades, economic and social development has led to rapid environmental degradation (Klemes et al., 2012). Until now, sustainable development has become an important agenda at the global and national level (Lehtoranta et al., 2011). Rapid development in developing countries such as Malaysia has opened doors to various opportunities for more sustainable construction. The Construction Industry Development Board (CIDB) as a body whose main objective is to develop, improve and expand the Malaysian construction industry has also identified sustainability and the environment as a priority agenda in the construction industry (CIDB 2000). Particularly CIDB focuses on waste reduction, environmental management plan, water management and construction sites hazard.

Fine waste produced by the quarrying industry such as quarry dust, marble sludge and granite sludge are hazardous wastes that can lead to serious environmental problems caused by the accumulation and dispersion through air, water and soil (Galetakis & Soultana, 2016). This also brings serious health hazard to humans, especially children and infants. On the other hand, a proper management and application of these wastes can lead to positive impact on the economy and the environment

[*] Corresponding Email: rufaizal@puo.edu.my

Soft soil has undesirable mineral properties to be used in civil engineering projects, such as its low strength and high compressibility (Consoli et al., 2015).

In general, soft soil has a fine particle size such as clay and silt. Clay is usually found on the surface and are exposed to physical, chemical and biological processes (Owliaie et al., 2006; Velde and Meunier, 2009; Cébron et al., 2015). According to Mitchell and Soga (2005), the mineral content in clay consists of Kaolinit, ilit dan Montmorilonit. Montmorilonit is a very reactive mineral, the presence of which leads to a significant change in soil volume (Mitchell and Soga, 2005; Pedarla, 2013). Clay is a soft soil with low strength and high water sensitivity, but can be relatively strong in a dry state (Che Mamat, 2013).

For engineering projects involving soft soil, one of the most common methods to improve soil properties is the mixture with cement substance. The addition of stabilizing materials using chemicals can improve soil consistency, strength, flexibility and permeability (Consoli et al., 2015). Such improvement occurs due to ion exchange on the clay's mineral surface, particle bond and a reduction of hollows from a chemical reaction. Various chemical additives have been developed and used, but the most commonly used are cement and lime due to their lower costs. Stabilization using cement and lime has been extensively researched since the 1960s by highway engineers to improve the materials used in base and sub-base of roads. In these techniques the soft soil is strengthened with homogenous structures that act like a dry crust (Andersson et al., 2001; Jelisic and Leppänen, 2003).

The specific objectives of this study were to evaluate the potential usability of granite sludge as a stabilizer of Trong clay based on compressive strength. Therefore, granite sludge is dried and mixed with clay in the ratio varying and evaluated in terms of unconfined compressive strength.

2.0 LITERATURE REVIEW

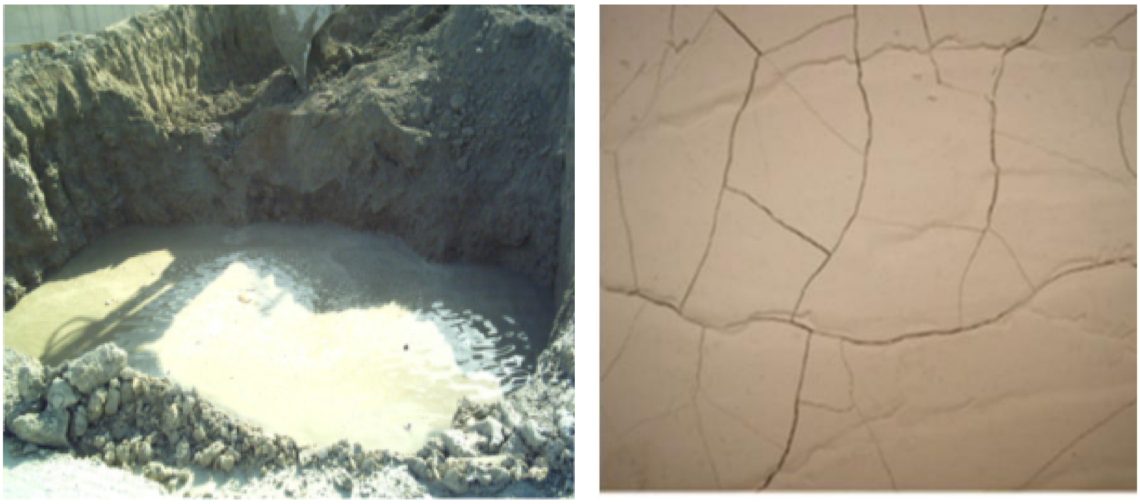
2.1 Quarry Waste

Construction aggregate and ornamental stones are extracted from quarrying activities and used extensively in construction worldwide. The production of these materials in large quantities, lead to wastes such as quarry dust and marble sludge.

Table 1: The chemical composition and the size of aggregate quarry wastes (Galetakis et al., 2012).

Chemical compounds (%)	Marble dust	Granite dust	Limestone dust
SiO_2	0.57	69.88	0.115
Al_2O_3	0.16	12.21	0.22
Fe_2O_3	0.11	7.73	0.23
MgO	0.2	0.07	0.97
CaO	55.26	3.17	55.44
Na_2O	0.05	3.00	-
SO_3	0.06	0.05	-
ZrO_2	0.01	-	-
P_2O_5	0.02	0.03	-
SrO	0.03	-	-
TiO_2	-	0.05	-

During the extraction, hauling and crushing processes in the production of aggregates, limestone fines are as quarry dust produced. Table 1 shows the chemical composition and size grading of quarry waste produced from the ornamental stone and aggregate industry. At the crushing and screening process, airborne particles such as silt and dust are released into the atmosphere (Galetakis & Soultana, 2016). The crusher dust is fine material formed primarily during the process of crushing and sieving rocks. In coarse aggregates used in concrete, this fine material is found on the surface and interferes with the bond between aggregate and cement. Figure 1 shows one of the most important issues facing the quarry industry.



(a) (b)

Figure 1. (a) Deposition of quarry dust, (b) Dried ornamental stone sludge (Galetakis & Soultana, 2016).

The waste generated from the ornamental stone industry can be classified into two types – solid waste and stone slurry which is also referred to as marble sludge. Solid waste is produced as a result of products which do not meet the required specification either at the quarry site or during processing, while stone slurry is a semi-liquid substance and consist of particles that are mixed with water during the sawing and polishing process which use water to cool and lubricate the sawing and polishing machines. Among the current alternatives in the ornamental stone industry to reduce waste discharge to landfills is the application of such waste in other industries. Whenever stone slurry is disposed in landfills, the water content reduces drastically, generating rock dust that is harmful to the environment (Almeida et al., 2007). As such, the application of such waste in the construction industry will contribute towards reducing environmental pollution.

2.2 The Use Of Quarry Waste In Engineering Studies

So far, the primary use of these wastes in the construction sector consist of the use of slurry stone as fine aggregates or as cement replacement. The using solid waste can be primarily found as aggregates in concrete mixtures. This will significantly reduce carbon emission due to lower consumption and production of cement, as cement production contributes about 5-7% of global CO_2 emissions (Bacarji et al., 2013 & Charkha, 2013). Currently, there are three categories in the quarry waste development, such as concrete technology, cement and building elements. The use of quarry waste in the research on concrete technology is mainly focused on self-compacting concrete, high performance concrete, fibre reinforced concrete, lightweight concrete, ordinary concrete products and controlled low-strength material. Many researchers have studied mortar properties to enhance the behavior of producing concrete. Gesoglu et al, 2012 studied fresh and hardened properties of self-compacting concrete produced using marble powder, limestone powder and fly ash. This study found that 5% of limestone powder produced concrete in 28 days of curing has a compressive strength value of 63 MPa, while limestone and fly ash has a higher compressive strength value of 71 MPa. Elmoaty, 2013 in his study found that 5% granite dust in concrete increases tensile strength compared to other mixtures.

3.0 RESEARCH PROGRAMME

Trong clay (TC) used in this study has physical properties as shown in Table 2. The sample used for this study has been taken 500 m from the surface. Figure 3 showed that 59% exceeds 0.002 mm particle size. According to the National Lime Association (2004), at least 25% soil exceeding 74 mm grain size and with a Plasticity Index (PI) exceeding 10% can undergo the stabilizing method. Based on the plasticity chart, this TC can be categorized as inorganic clays of low plasticity, and can undergo the stabilizing method to improve soil properties.

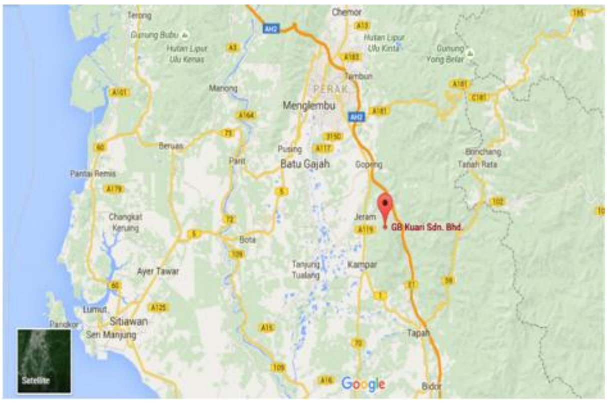


Figure 2. Location of sampling

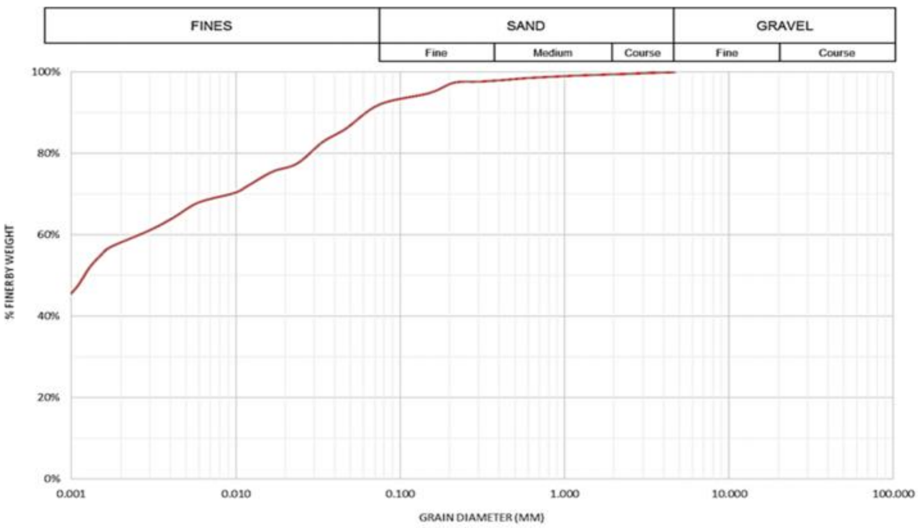


Figure 3. The particle size distribution of Trong Clay (TC)

Granitic quarry sludge (GS) as in Figure 4 is oven-dried with a temperature of 105±5°C for 24 hours taken from a site GB Quarry in Kuala Dipang, Perak. The location map is in Figure 2. The particle size distribution and chemical composition of the GS are shown in Tables 3 and 4 respectively.

Figure 4. Granitic quarry sludge (GS)

Table 2. Physical properties of Trong Clay (TC)

Features	value
Water content (%)	19
Liquid limit (%)	27
Plastic Limit (%)	16
Plasticity index (%)	11
Optimum moisture content (%)	12.5
Maximum dry density (kg/m^3)	1850
Specific gravity	2.67

The eight samples were prepared for this research with different combination of mixture ratio to determine the unconfined compressive strength of each sample including the control sample. To examine the replicability, each composition sample underwent additional tests, twice.

Table 3. Particle size distribution of GS

d_{10} (μm)	**d_{50} (μm)**	**d_{90} (μm)**
2.35	15.25	60.3

Samples with a diameter of 38 mm and height 76 mm were prepared. Dry samples exceeding 0.425mm grain size mixed with GS and distilled water based on the optimum moisture content obtained from the standard compression test conducted on TC. The distribution of samples of composition mixture is shown in Table 5.

Table 4. Chemical composition of GS

Composition	(% mass)
SiO_2	58.35
Al_2O_3	17.22
Fe_2O_3	3.15
$SiO_2 + Al_2O_3 + Fe_2O_3$	85.2
CaO	3.15
MgO	1.25
Na_2O	2.70
K_2O	4.50
SO_3	0

The unconfined compression test (USC) was conducted on all samples consisting on the unstabilized sample (0% GS) and stabilized samples (1%, 2% , 3%, 4% , 5%, 6%, 7% and 8% with GS based on dry soil weight) to determine the unconfined compressive strength properties. Each sample underwent the test until a 20% tension was reached.

Table 5. Mixture recipe

Name of mixture	Specification
S0	Soil and 0 wt% GS
S1	Soil and 1 wt% GS
S2	Soil and 2 wt% GS
S3	Soil and 3 wt% GS
S4	Soil and 4 wt% GS
S5	Soil and 5 wt% GS
S6	Soil and 6 wt% GS
S7	Soil and 7 wt% GS

4.0 RESULTS AND DISCUSSION

This research aimed at investigating the impact of GS on TC with regard to unconfined compressive strength. The first part of this discussion explains the behavior between stress and strain of each soil sample stabilized with GS. The second part contains the analysis result of the unconfined compressive strength of the stabilized sample.

The stress-strain properties of each of the eight samples are plotted on a curve as in Figure 6. The results from the UCS are consistent with each other and demonstrates a significant impact that the increase in GS into TC improves the stress-strain properties and compressive strength.

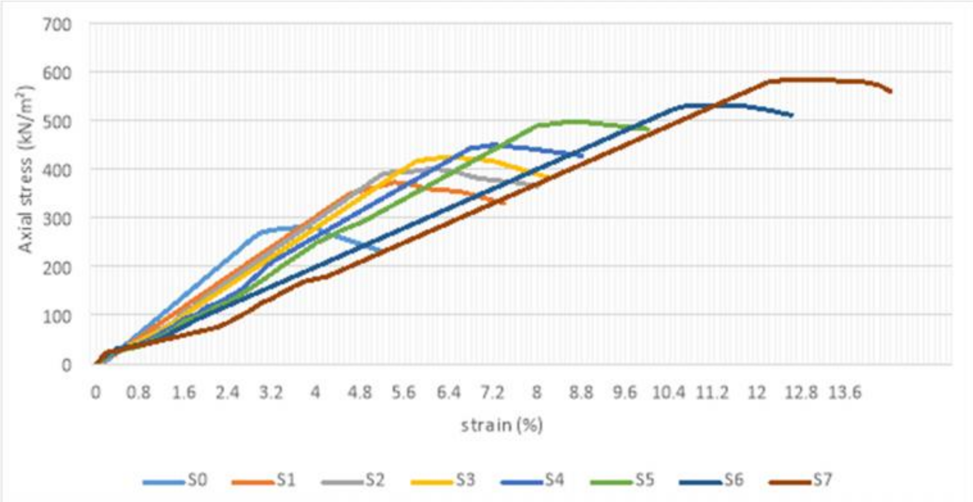


Figure 6. Compressive stress and strain of TC reinforced with various amount of GS.

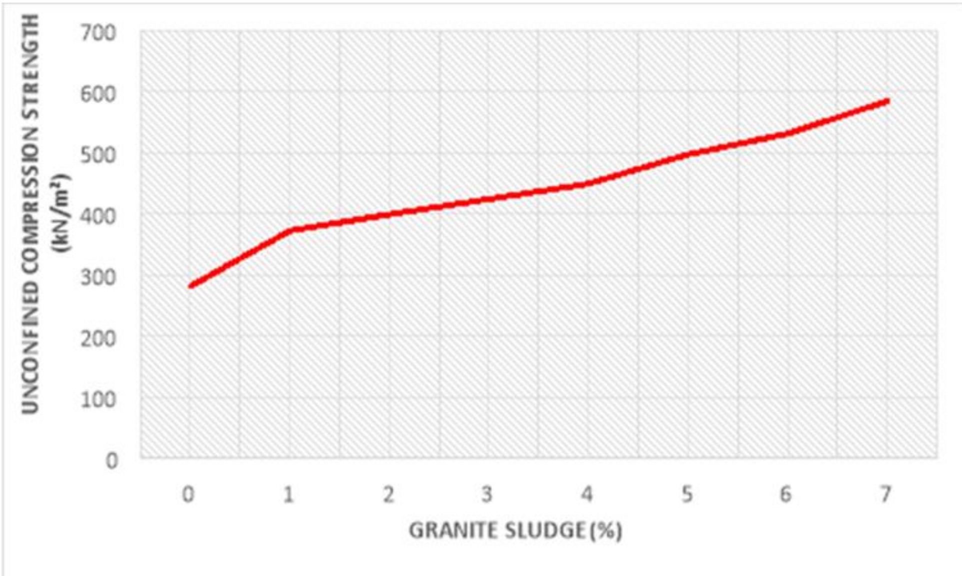


Figure 7. The relation between unconfined compressive strength and GS content of TC composite.

The behavior as shown in Figure 6 implies that a higher percentage of GS to stabilize TC leads to a higher axial stress and strain percentage values. The results show that maximum strength can be found in sample S7 followed by samples S6, S5, S3, S2, S1 and S0. Figure 3 shows the impact of unconfined compressive strength with the increased GS content in TC. Figure 7 clearly shows a significant increase in compressive strength value in line with the increase in the stabilizing material. Sample S7 produced compressive strength of 585 kN/m^2 compared to unstabilized Trong clay which has a compressive strength of 282 kN/m^2, yielding a 107% improvement. The increase is possibly due to the interaction between the soil and the stabilizer that produces a stronger bond.

5.0 CONCLUSION

The stabilized and unstabilized characteristics of Trong clay using granite sludge were investigated using unconfined compression test and the results were discussed in this paper. The main results from the experiment are summarized as follows:

1. The unconfined compressive strength without stabilizer is 282 kN/m^2.

2. There is a significant increase of 32%-107% in unconfined compressive strength between unstabilized soil and Trong clay stabilized with granite sludge.

3. The highest increase in compressive strength is found in sample S7, which is 7% granite sludge mixed into Trong clay.

4. Each sample strengthened with different levels of stabilizer shows significant increase in unconfined compressive strength values. It shows that mixing granite sludge into the soil strengthens the soil and increases compressive strength values.

ACKNOWLEDGEMENT

The author would like to acknowledge the cooperation and support given by the Politeknik Ungku Omar in conducting this research work.

REFERENCES

Almeida, N., Branco, F., DeBrito, J., Santos, J.R. (2007). *High-performance concrete with recycled stone slurry,* Cem. Concr. Res, Vol.37, pp.210–220.

Andersson, R., Carlsson, T., Leppänen, M. (2001). *Hydraulic cement based binders for mass stabilization of organic soils*. Soft Ground Technology. ASCE, pp. 158–169.

Bacarji, E., TFilho, R.D., Koenders, E.A.B., Figueiredo, E.P., Lopes, J.L.M.P. (2013): *Sustainability perspective of marble and granite residues as concrete fillers*, Constr. Build. Mater, Vol.45, pp.1–10.

Cébron, A., Beguiristain, T., Bongoua-Devisme, J., Denonfoux, J., Faure, P., Lorgeoux, C., Ouvrard, S., Parisot, N., Peyret, P., Leyval, C. (2015). *Impact of clay mineral, wood saw-dust or root organic matter on the bacterial and fungal community structures in two aged PAH-contaminated soils*. Environ. Sci. Pollut, R, pp.1-15

Charkha, S.D. (2013). Experimental investigation of M30 design mix concrete with partial replacement of conventional ingredients, *Int. J. Res. Civ. Eng. Archit. Des*, Vol.1 No.2, pp.38–45.

Che Mamat, R. (2013). *Engineering properties of Batu Pahat soft clay stabilized with lime, cement and bentonite for subgrade in road construction*, Master Thesis, Universiti Tun Hussein, Malaysia.

Consoli, N.C., Winter, D., Rilho, A.S., Festugato, L., Teixeira, B.S. (2015). *Engineering Geology*, Vol.195, pp.327–334,

Construction Industry Development Board (CIDB). (2000). *Malaysian Construction Industry*: Technology Foresight Report. CIDB Malaysia and APEC Technology Foresight Center, Bangkok.

Construction Industry Development Board (CIDB). (2006). CIDB Focus Groups. Available at: http://www.cidb.gov.my. (accessed Febuary, 2016).

Corinaldesi, V., Moriconi, G., Naik, T.R. (2010). *Characterization of marble powder for its use in mortar and concrete*, Constr. Build. Mater, Vol. 24, pp.113–117.

Elmoaty, A. (2013). *Mechanical properties and corrosion resistance of concrete modified with granite dust*, Constr. Build. Mater, Vol.47, pp.743–752.

Galetakis, M., Alevizos, G., Leventakis, K. (2012). *Evaluation of fine limestone quarry byproducts,for the production of building elements – an experimental approach*,Constr. Build. Mater, Vol. 26, pp.122–130.

Galetakis, M., Soultana, A. (2016). *Construction and Building Materials*, Vol.102 Iss 1, pp.769–781,

Gesoglu, M., Güneyisi, E., Kocabag, M.E., Bayram, V., Mermerdas, K. (2012). *Fresh and hardened characteristics of self-compacting concretes made with combined use of marble powder, limestone filler, and fly ash*, Constr. Build. Mater, Vol.37, pp.160–170.

Jelisic, N., Leppänen, M., (2003). *Mass stabilization of organic soils and soft clay*. Grouting and Ground Treatment. ASCE, pp. 552–561.

Klemes, J.J., Varbanov, P.S., Huisingh, D. (2012). Recent cleaner production advances in process monitoring and optimization. *J. Cleaner Prod*. Vol 34, pp.1-8

Lehtoranta, S., Nissinen, A., Mattila, T., Melanen, M. (2011) Industrial symbiosis and the policy instruments of sustainable consumption and production. *J. Cleaner Prod*, Vol.19, pp.1865-1875

Mitchell, J.K., Soga, K. (2005*). Fundamentals of Soil Behavior*. third ed. John Wiley and Sons Inc., Hoboken, New Jersey

National Lime Association. (2004) *Lime-Treated Soil Construction Manual*, Lime Stabilisation & Lime Modification, Bulletin 326, pp.6.

Owliaie, H.R., Abtahi, A., Heck, R.J., (2006). Pedogenesis and clay mineralogical investigation of soils formed on gypsiferous and calcareous materials, on a transect, southwestern *Iran. Geoderma*, Vol. 134, pp.62–81

Pedarla, A. (2013). *SWCC and clay mineralogy based models for realistic simulation of swell behavior of expansive soils*. Dissertation Submitted to the Department of Civil Engineering, University of Texas at Arlington, Tx.

Velde, B., Meunier, A. (2009). *The Origin of Clay Minerals in Soils and Weathered Rocks*.Springer, Berlin

Vijayalakshmi, M., Sekar, A.S.S,. Prabhu, G.G. (2013). *Strength and durability properties of concrete made with granite industry waste*, Constr. Build. Mater, Vol.46, pp.1–7..