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Improvement of Engineering Properties of Peat with Palm Oil Clinker

M. E. Rahman[1]*, M. Leblouba[1] and V. Pakrashi[2]

[1]*School of Engineering and Science, Curtin University Sarawak, CDT 250 98009 Miri, Sarawak, Malaysia.*

[2]*Department of Civil Engineering, University College Cork, Cork, Ireland*

ABSTRACT

The aim of this study is to investigate the effects of Palm Oil Clinker (POC) added as a stabilizer for improving the strength of peat. Cement and POC are added into peat up to 50% of the maximum dry unit weight. Treated peat achieved higher dry unit weight, almost 2.5 times as compared to untreated peat. Unconfined compressive strength (UCS) of treated peat is also investigated for soaked and unsoaked conditions. The results show that curing time improved the unconfined compressive strength of treated sample and increased by a factor of 20 and 11 for unsoaked and soaked conditions after 28 days of curing, respectively. The treated samples added with POC can be related to an increase in unconfined compressive strength for long time curing.

Keywords: Peat, Palm Oil Clinker (POC), Unconfined Compressive Strength (UCS)

INTRODUCTION

The understanding of soil characteristics in terms of bearing capacity is crucial for engineers to ensure construction on all types of ground surface can prove sufficient bearing resistance to the construction load. According to Huat *et al*. (2009), 8% of total Malaysia soil consists of organic soils. A high organic content soil, otherwise known as peat, is of particular concern due to its low durability and high compressibility. Organic soils usually have at least 20% organic contents in the soil. The organic matter in the soil represents an accumulation of partially decomposed vegetation or plants under suitable conditions. High water content and poor ground drainage contribute to the higher rate of dry matter accumulation compared to rate of decay. Hence, ground surface begin to be overlain by organic matters. At the extreme, some soil can contain up to 75% and more of organic contents in the soil (Huat, 2004). Replacing

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Email addresses:
M. E. Rahman (merahman@curtin.edu.my),
M. Leblouba (mlablouba@gmail.com),
V. Pakrashi (v.pakrashi@ucc.ie)
*Corresponding Author

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peat with good quality soil is still a common practice even though this effort may lead to uneconomical design (Said & Taib, 2009).

Some key problems related to peat soil are low shear strength, low bearing capacity and high compressibility leading to excessive settlements (Huat *et al.,* 2009). High water content in peat contributes to its low density and low resistance towards bearing loads when compared to other soil types. Additionally, the shear strength of the peat soil is exceptionally low due to loss of cohesiveness between soil particles in the presence of excessive water as lubricant. These deficiencies related to of strength capacity pose a challenge for construction to be built on peat soil.

Improvement of engineering properties of peat can be investigated by noting the increase in unconfined compressive strength (UCS) of stabilized peat as compared to an untreated sample. Hashim and Islam (2008) found that Unconfined Compressive Strength (UCS) of pure peat ranges between 4.7kPa to 6.9kPa.

Peat stabilization can be performed by adding additives such as silica fume, cement, fly ash and lime. These are some common soil conditioners used for the research in recent studies. Kalantari *et al* (2009) carried out a peat stabilization study using silica fume as additives and found that the untreated peat achieved up to 28kPa of unconfined compressive strength. Said and Taib (2009) carried out a study on peat stabilization with carbide lime and concluded that stabilized peat achieved an unconfined compressive strength of 115kPa. Kolay *et al*. (2011) found that 20% of cement added into peat could achieve up to 115kPa of unconfined compressive strength after 28 days of curing time. For the same 28 days of curing, treated peat added with lime and fly ash achieved 70kPa and 60kPa of unconfined compressive strength, respectively. Kalantari *et al.* (2009) reported an increase of unconfined compressive strength of treated peat with 25% cement and 5% silica fume up to 320kPa after 28 days of curing time.

According to Said and Taib (2009), a longer curing is associated with a higher unconfined compressive strength gained. Similarly, Kolay and Pui (2010) also concluded that curing time do significantly improve the strength of the peat soil. Kolay *et al*. (2011) reported that curing period increased the unconfined compressive strength of treated sample with fly ash and lime from 70kPa up to 90kPa based on 28 days of curing time. The increase of unconfined compressive strength corresponding to the curing period is caused by the hydration process between cement and water. Calcium hydroxide produced through the hydration process could promote the bonding between the particles of peat by acting as a paste.

In this study, classification of peat was carried out for geotechnical testing such as natural moisture and organic content, specific gravity, particle size distribution and Atterberg limits. In addition, unconfined compression strength of peat stabilized with POC is determined and the effect is investigated as compared to untreated peat soil.

MATERIALS

The main materials used for this study are peat soil, cement and palm oil clinker (POC). Cement used for laboratory testing is Ordinary Portland cement. Peat soils were transported from Matang, Kuching, Sarawak, while POC was collected from Lambir, Sarawak.

Peat

According to Huat *et al.* (2009), 8% of total Malaysia soil consists of organic soils. Peat soils used for this study are collected from Matang area. The area is near the river in Kuching, Sarawak and is swampy. The peat samples collected are at a depth between 500mm to 1000mm. All obvious large foreign objects such as wood bark and man-made objects were removed on the spot. Peat soils are collected in bags and were subsequently taken out and dried under the sun.

Palm Oil Clinker

Palm Oil Clinker (POC) collected from the furnace at Lambir Palm Oil mill were brought to CMS cement Sdn. Bhd. for grinding. POC was ground to fines passing 35 micron and stored inside containers.

POC is the residue waste following combustion of fibres used for steam turbine in palm oil mill. Palm oil mill is abundant nationwide in Malaysia, the second highest palm oil exporter in the world and POC production is significant. Generally POC is used for land-fills. Land-filling of POC has a negative effect on environment and occupies large land space. Hence, POC is often regarded as an industrial waste material with little commercial value. However, POC has also been reported to contain up to 81.8% of silica oxide (Rafidah & Chan, 2009). Presence of silica oxide is important for the longer term strength gain in stabilized peat soil (Kalantari *et al.*, 2009). Hence, silica oxide–rich POC can promote secondary pozzolanic effects of stabilized peat soil. With a longer time of curing, stabilized peat soil rich in calcium hydroxide will react with silica oxide supplied by POC which will result in further strength gain. The chemical composition of Palm coil clinker is presented in Table 1.

TABLE 1
Palm Oil Clinker Properties (Rafidah & Chan, 2009)

Element	Symbol	Concentration (%)
Sillicca 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 Dioxide	P_2O_5	0.76
Titanium Dioxide	TiO_2	0.17
Sodium Oxide	Na_2O	0.14

METHODOLOGY

Before peat soils were stabilized, classification of the peat soil was carried out. Geotechnical tests of peat were performed to determine the moisture and organic content, specific gravity, particle size distribution and Atterberg limits.

Peat Soil Classification

Moisture and organic contents were determined for 11 packs of peat soil. The range of the peat moisture and organic content is shown in Table 2. The specific gravity test was performed in accordance with ASTM Method A 854. Particle size analysis was carried out in accordance to ASTM D 422-63 by performing hydrometer and sieving test. The test procedures were carried out according to Cheng and Evett (2003). The particle size distribution is illustrated in Fig.1. Atterberg limits are determined for both liquid and plastic limit of the peat soil in accordance to BS1377 (Huat, 2004). Table 2 shows the list of the geotechnical properties of the peat soil.

TABLE 2
Geotechnical Properties of Peat

Geotechnical Properties	Value
Natural moisture content	306% – 450%
Organic content	80.0 % – 93.1%
Specific gravity	1.39
Liquid limit	203
Plastic limit	143
Plasticity index	60
Liquidity index	-1.69

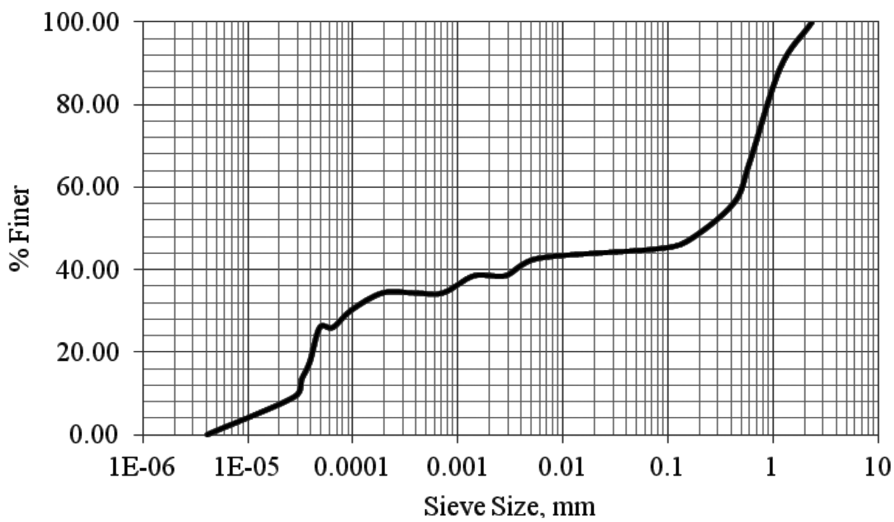

Fig.1: Particle Size Distribution

Compaction Test

Compaction test is performed in accordance with BS1377 for 5 types of binder ratio and untreated peat, as shown in Table 3 (British Standards, 1990). By using an automated compactor machine, a 2.5kg hammer was placed 300mm above the surface of the mould and it was ensured that all soil particles pass through a 20mm sieve. Stabilized peat soil was filled into one third of a 1L mould and blown 27 times for each layer. Once the peat sample is finished compacted, the mass of the peat is weighted and the dry unit weight (ρ_d) is computed using the following equation:

$$\rho_d = \frac{1000\rho g}{w + 100} \tag{1}$$

where ρ is the bulk unit weight of the peat sample, g is the gravitational acceleration and *w* is the water content of the peat sample. The air void lines for 0%, 5% and 10% of air voids are computed as (2).

$$\rho_d = \frac{\left(1 + \frac{V_a}{100}\right)g}{\frac{1}{\rho_s} + \frac{w}{100\rho_w}} \tag{2}$$

where V_a is the air void ratio, ρ_s and ρ_w are the soil and water density, respectively. The maximum dry unit weight is the peak point of the line on the compaction curve and the corresponding moisture content is the optimum moisture content for the peat sample.

TABLE 3
Binder Ratio Summary

Binder	Peat Soil (%)	Palm Oil Clinker (%)	Cement (%)	OMC (%)
1	100	0	0	83.1
2	50	50	0	39.9
3	50	35	15	49.8
4	50	25	25	29.1
5	50	15	35	22.5
6	50	0	50	38.5

Unconfined Compression Strength Test

Peat soils are passed through 2mm sieve and compact using Humboldt Compactor Apparatus. The mould used for preparing the peat sample is 38mm in diameter and 76mm in height. Water was added at 5mL per 100g of peat sample to produce moisture content about 27% of water content. The peat sample was weighed to ensure the weight is between 1620g to 1700g. This ensured that the unit weight of the peat samples fall close to the optimum dry unit weight range. The peat samples were extruded using the Humboldt extruder and tested using unconfined compression strength (UCS) apparatus. The load shall be applied at the rate of about 2 revolutions per second to achieve the 0.5% to 2% per minute axial strain rate, as stated in Cheng and Evett. (2003) The area, A_0 of the contacting surface of the peat sample to the platen of the UCS machine (3) and the axial strain, ϵ were computed with respect to the change in height of sample as

$$A_0 = \frac{\pi D_0^2}{4} \tag{3}$$

$$\varepsilon = \frac{\Delta H}{H_0} \tag{4}$$

where After obtaining the loading, N value form the proving ring dial of the UCS machine, the pressure of upon the peat sample is computed based on the reduced area, A, following:

$$A = \frac{A_0}{1 - \varepsilon} \tag{5}$$

$$P = \frac{N}{1000A} \tag{6}$$

where A is the corrected area, A_0 is the original area, N is the axial load and p is the axial stress.

Curing Time

The treated peat samples added with 15% POC and 35% cement, 25% POC and 25% cement, 35% POC and 15% cement were air-cured for 7 days and 28days, respectively. According to Kalantari *et al*. (2009), air-curing period allowed the cement to complete almost all its reactions after being cured for 90 days, and the water content of the peat was also reduced, resulting in an increase in strength.

Furthermore, both soaked and un-soaked stabilized peat samples were prepared for cured sample. Consequently, the unconfined compressive strength gained after curing could be obtained for both conditions. Soaked conditions, however, would portray a more realistic value as the ground conditions for construction. The ratio of the maximum dry unit weight achieved by treated peat sample to untreated sample was about 2.5.

RESULTS AND DISCUSION

Moisture Content – Dry Unit Weight Relationship

The compaction curve for all the treated and untreated peat samples are illustrated in Fig.2. The untreated peat (100/0/0) showed a lower optimum dry density at 5.4kN/m^3. Meanwhile, the stabilized peat sample containing 50% peat, 15% POC and 35% cement shows that the optimum dry density achieved is 12.6kN/m^3. This indicates that mixing of more cement than POC produces higher compatibility, resulting in lesser air voids. Furthermore, peat sample containing 50% peat, 35% cement and 15% POC can achieve close to maximum dry unit weight as compared to binder with 50% peat and 50% cement at 9% lower water content, as shown in Fig.3 below. Hence, it can be observed that POC can reduce cost by substituting cement as filler for achieving compatibility similar to peat stabilized using cement.

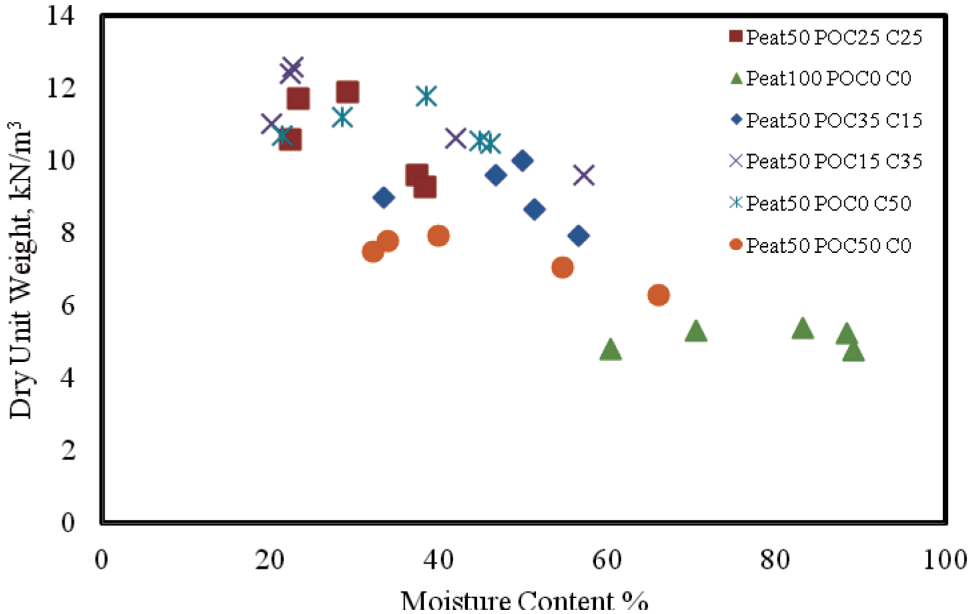

Fig.2: Compaction curves

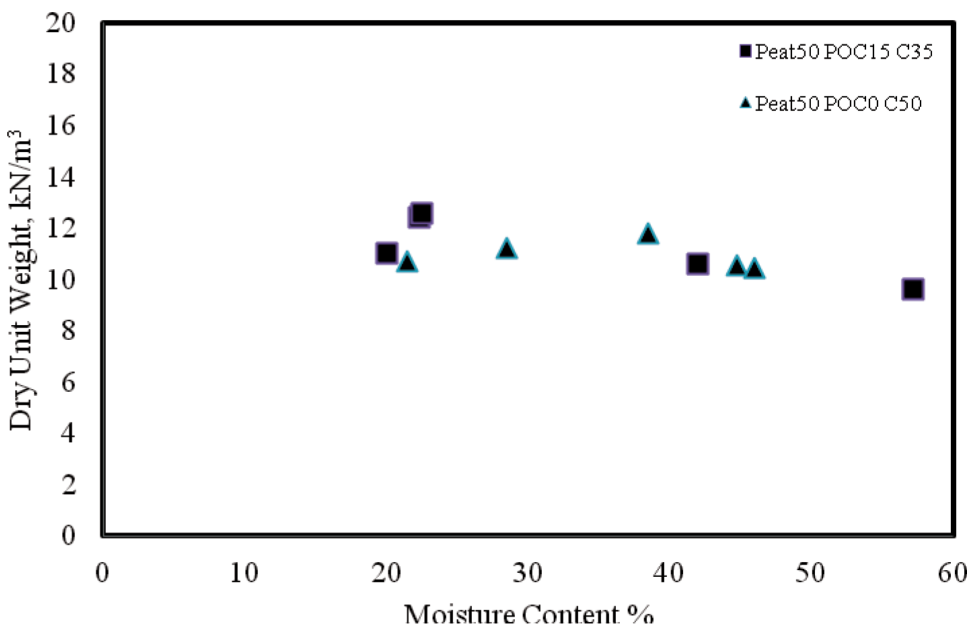

Fig.3: Compaction Curve for Peat Sample Containing 50% Cement and Peat Sample Containing 35% Cement and 15% POC

Unconfined Compressive Strength

Unconfined Compression Strength (USC) test was carried out for cohesive soils in order to obtain an approximate value of un-drained shear strength (Bardet, 1997). A summary of UCS for the treated and untreated peat samples is illustrated in Fig.4. The treated peat samples were cured for 7 days and 28 days respectively for both the soaked and un-soaked conditions so as to simulate realistic condition of construction, where the soils are often in soaked condition. From Fig.4, it can be seen that the untreated peat portrays a much lower unconfined compressive strength at 18kPa on average. The stabilized peat sample, containing 50% peat, 25% POC and 25% cement respectively, showed higher unconfined compressive strength at 109kPa after 7 days of curing time. Meanwhile, the corresponding soaked sample showed a lower unconfined compressive strength at 67kPa. For both un-soaked and soaked peat samples of 50% peat, 35% POC, 15% cement, the unconfined compressive strengths were 101kPa and 82kPa, respectively, after 7 days of curing time. In contrast, for both the un-soaked and soaked binder of 50% peat, 15% POC, 35% cement, the unconfined compressive strengths were 128kPa and 88kPa respectively after 7 days of curing.

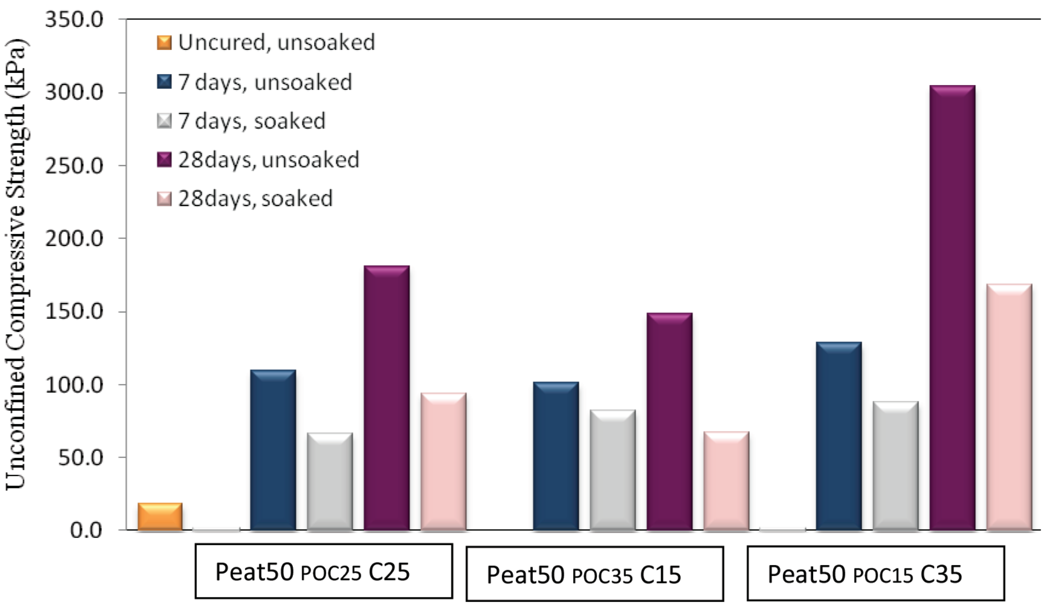

Fig.4: Unconfined Compressive Strength for All Peat Sample

At 28 days, stabilized peat sample containing 50% peat, 25% POC and 25% cement shows an increment of unconfined compressive strength at 181kPa and 94kPa for the un-soaked and soaked samples, respectively. This pattern is evident for un-soaked binder of 50% peat, 35% POC, 15% cement, showing a compressive strength of 149kPa. When compared to 7 days of curing, the 28days cured un-soaked and soaked samples with binder of 50% peat, 15% POC, and 35% cement showed an increase in unconfined compressive strength up to 304kPa and 169kPa, respectively.

The stabilized peat samples showed strength gain after 7 days of curing. The pozzolanic effects of cement promoted the strength gain in the stabilized peat samples. On the other hand, peat added with POC is results in a higher strength gain for a longer curing time. A possible reason behind this is that the high content of silica in POC that reacts with calcium hydroxide, which is produced through the hydration process between water and cement. During the first few days of curing, calcium hydroxide production is rapid, since presence of water is sufficient for hydration process to take place. After 7 days, the water content decreased, causing the strength gain in stabilized peat to slow down. Therefore, secondary pozzolanic reaction takes places generating secondary cement hydration with silica oxides contained in POC. Therefore, the peat samples having higher amount of POC result in a higher strength gain for longer curing times. The curing effect can be observed in Fig.5 for the stabilized peat sample for 7 days and 28days, respectively.

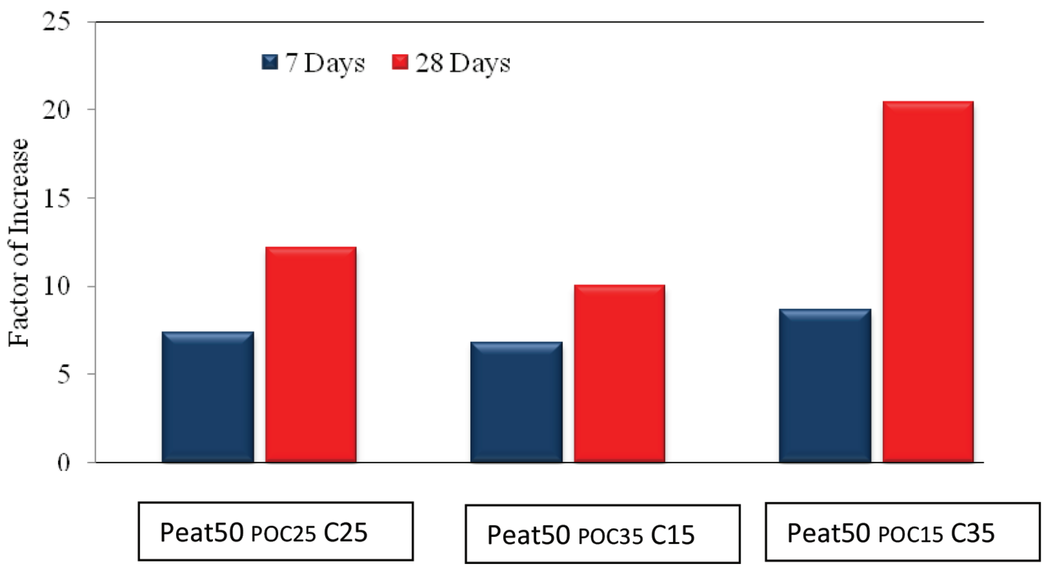

Fig.5: Factor of Increase in Unconfined Compressive Strength to Curing Period

CONCLUSION

Palm Oil Clinker (POC), an industrial waste, was found to be suitable for use in stabilizing peat soil in this paper through a number of experiments. Peat, comprising of around 8% of the soil of Malaysia, is often regarded as problematic due to its low strength related to high water retention and presence of organic content. However, POC is abundant around Malaysia and can be employed to strengthen such soils.

From the UCS test, the stabilized peat with ratio of 50% peat, 15% POC and 35% cement showed the highest optimum dry density at12.6kN/m3. Furthermore, 28 days cured the un-soaked peat sample with ratio of 50% peat, 15% POC and 35% cement showed the highest unconfined compressive strength at 304kPa. Hence, the bearing strength of the peat soil is increased through stabilization.

Furthermore, the results showed that POC produced higher strength gain at longer curing duration. Curing duration has effect on the strength gain of stabilized peat. In addition, addition of POC as peat soil stabilizer portrayed increase in soil optimum dry density and unconfined compressive strength by promoting secondary cement hydration.

Hence, POC is suitable to be utilized as soil stabilizer for peat soil as POC does contribute to the strength gain of treated peat soil. Peat soil that is stabilized by using POC portrays a higher strength gain for long-term curing.

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