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STRENGTH PERFORMANCE ON STABILISATION OF SARAWAK SOILS USING GEOCRETE® TECHNOLOGY

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Abstract: This paper presents a study on the stabilisation performance of Sarawak soils using GeoCrete® Technology. GeoCrete is used for stabilisation treatments where the soils are treated with ordinary Portland cement (OPC) as a binder and GeoCrete® powder (GCP) as an alkaline additive to improve their strength and elasticity. The use of GCP in soil stabilisation was proven to improve the compressive strength of soils by more than twice the initial strength after 28 days of being treated, with the treatments carried out on three identified soils: Clay, silt and sand. This technique has been successfully implemented on farm roads, rural roads and highways. Thus, further investigation of stabilisation with GCP was conducted on peat, which is known as a material with high permeability and low bearing capacity behaviour. The peat samples collected are mixed at a designated percentage of OPC and 2% of GCP. The compacted and treated peat samples with OPC and GCP were prepared at the optimum moisture content, mixed thoroughly to a uniform condition using a laboratory mixer and air cured for 7 and 28 days in a single batch. The results showed that peat stabilised with GCP has an average of more than 40% of the unconfined compressive strength, q_u value after 28 days of curing when compared with peat at the natural state.

Keywords: Sarawak soil, eco-friendly concrete, soil stabilisation, GeoCrete Powder.

Introduction

According to Zahri amd Zainorabidin (2019), soft soils such as peat, clay and silt are typically known to have high water content, low shear strength, high compressibility and low permeability. These characteristics lead to many major failures when superstructures are built over it. For many years, it has been a great challenge for geotechnical engineers to construct structures in soft ground areas as many engineering problems such as excessive long-term settlement, bearing capacity failure and slope instability could occur either during construction or after the construction has been completed (Mohamad *et al.,* 2015). However, recent advances in soil stabilisation techniques make it possible to improve the technical properties of problematic soils.

Soil stabilisation has been carried out for many years. It is a process where the physical properties of soil are changed to improve its strength, durability and other designated qualities. It is a modern and efficient method of recycling and strengthening the soils for construction development. Soil stabilisation treats the existing soil with additives such as cement or lime to improve its quality in terms of strength and durability (Abid, 2016).

The GeoCrete technology, using an additive of GeoCrete® powder or GCP consists of mostly alkaline natural earth elements. The mix of GCP with soil and cement will result in an eco-friendly concrete-like structure, subsequently providing stronger construction even with inferior quality soils. The mixture of soil, binder and GCP as additives with water (refer to Figure 1) shows good results in a hydraulically-bound mixture or HBM (Djumic, 2010). HBM is known to have a number of environmental benefits which are (a) significant energy savings associated with the cold mix technology, (b) reduce the demand for primary materials as recycled and secondary materials can be used and (c) the ability to reuse some material excavated on site, thus reducing the amount of waste material going to the landfill (Kennedy & John, 2006).

Furthermore, crystallisation during the hydration process of cement, water and GCP (alkaline) (refer Figure 2) increases the rate of strength exponentially, provides a faster curing process and maintains avoidance of premature cracks compared with normal cement stabilisation. The final product provides hydraulically-bound mixtures that is hard yet flexible, durable and impermeable (waterproofing) (Fakhar & Asmaniza, 2016).

GCP has been used widely for soil stabilisation in the past few years in Malaysia, specifically in Sarawak for treating most of the problematic soils. In general, GCP has been used to treat various types of Sarawak soils, ranging from clay, silt and sand to crusher run mix. Figure 3 presents the stabilisation application using the GeoCrete Technology at Felda Pekoti Timur, Rompin, Pahang. It can be seen that the road is still in a good condition after years of use.

This paper presents the findings on the geotechnical properties and strength improvements of peat mixed with GCP and compared it with three other types of soil: Clay, silt and sand. A series of laboratory tests, namely basic properties determination (i.e., Atterberg Limit, moisture content and specific gravity), Proctor compaction test and unconfined compressive strength (UCS) tests have been performed. The peat stabilised with GCP was carried out in the Geotechnical Laboratory, Faculty of Engineering, UNIMAS. All the experimental investigations were conducted in accordance with BS1377: Part 2: 1990 unless stated otherwise.

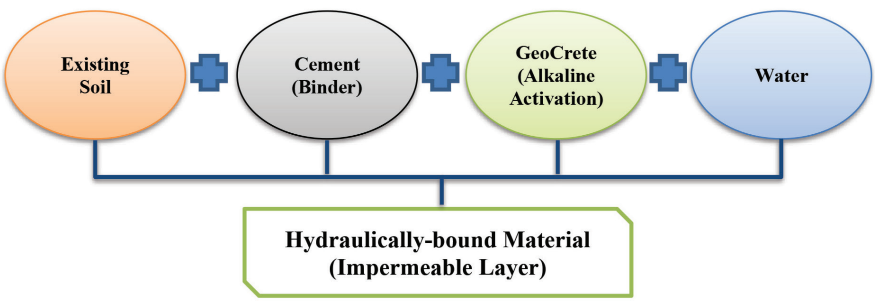

Figure 1: Mixing combination of GeoCrete soil stabilisation

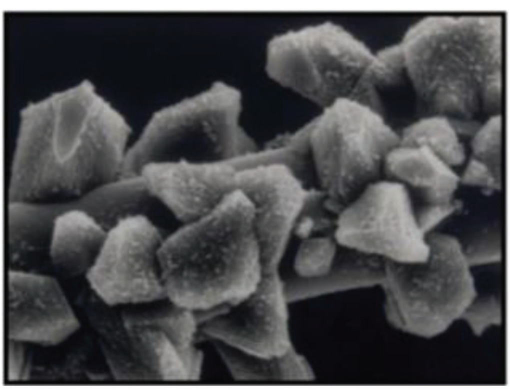

Figure 2 (a): Cement soil stabilisation – low crystal interlocking connectivity

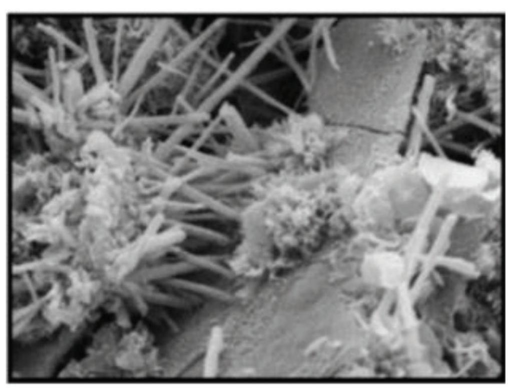

Figure 2 (b): Cement-GeoCrete soil stabilisation – high crystal interlocking

(a) Road construction in 2006

(b) Condition of road after years of use

Figure 3: The GeoCrete Technology at Felda Pekoti Timur, Rompin, Pahang (Djumic, 2010)

Materials

Sarawak Soils

Clay, silt, sand and peat covers most of the populated Sarawak coastal areas along the South China Sea as shown in Figure 4. According to Yee and Kaniraj (2011), the most populated areas of Sarawak are covered with peat and other types of soft soils where roads and buildings in these areas requiring considerable soil improvement techniques. Hassan (2006) stated that peat soils cover about 1.66 million hectares and constitutes 13% of the state. Peat is a non-homogenous soil of more or less decomposed plant (humus) material that accumulated in a water-saturated environment and in the absence of oxygen. Its structure is an amorphous, colloidal mass (Rahman *et al.,* 2011). Kolay *et al.* (2011) also mentioned that peat represents the extreme form of soft soil with an organic content of more than 75%. Peat exhibits very high compressibility and natural moisture content with low strength and bearing capacity and long-term settlement (Hashim *et al.,* 2008). This makes it unsuitable for the construction of embankments, highways, buildings or any other load-bearing engineering structures. In common practice, for constructions on peat, the material is removed and replaced with other good materials such as those with higher density and lower moisture content, which in most cases, imported sand fill is used to improve the subgrade soils (Sa'don *et al.,* 2021).

In this study, the soil samples collected are tabulated in Table 1, which summarises the engineering properties of peat, clay, silt and sand covering various locations of the Sarawak coastal areas. Further classification of peat as organic material is carried out. From the Von Post classification, the peat is classified as Sapric or Amorphous which falls under

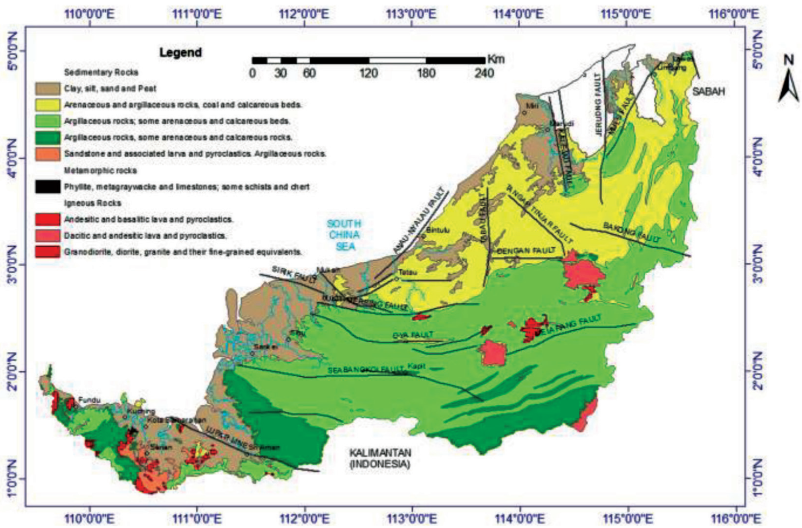

Figure 4: Geological map of Sarawak (Department of Mineral and Geoscience, 2019)

category H7, in which when it is squeezed, it releases dark brown and almost pasty water and about one-half of the peat escapes between the fingers. The peat samples recorded an average moisture content (MC) of 495% when compared with clay (15%-21%), silt (17%-33%) and sand (3%-21%), with 88% to 95% of organic content (OC) and undrained shear strength, c_u of 16 kPa. Table 2 presents the particle size distribution conducted for the three types of soil, clay, silt and sand while Figure 5 presents the particles size distribution conducted for peat ranges from

Table 1: The physical properties of the collected samples

Soil	Location	Soil Properties			
		Moisture Content, MC (%)	Liquid Limit, LL (%)	Plastic Limit, PL (%)	Specific Gravity, G_s
Peat	Kampung Endap	495.08	365	-	1.16
Clay	Sungai Anak	19.70	31	22	2.70
	Jalan Kim San	21.40	45	25	2.67
	Kampung Mentu	15.29	27	20	2.67
Silt	Sungai Mador	31.90	57	35	2.70
	Rumah Dawai	33.00	50	34	2.60
	Kampung Bengang	17.90	44	31	2.76
Sand	Telok Melano	2.90	-	-	2.72
	Kampung Hulu Kabong	14.58	-	-	2.77
	Institut Aminuddin Baki	21.00	32	-	2.65

Table 2: Particle size distribution classification

Types of Soil		Clay		
Location		**Sungai Anak**	**Jalan Kim San**	**Kampung Mentu**
Soil Description		Brown sandy CLAY with some gravel, CL	Light brown and white CLAY with some sand, CI	Light Grey-White Sandy CLAY, CL
Particle Size Distribution (%)	Clay	18	31	20
	Silt	20	40	120
	Sand	49	28	60
	Gravel	13	1	0
Types of Soil		**Silt**		
Location		**Sungai Mador**	**Rumah Dawai**	**Kampung Bengang**
Soil Description		Dark brown SILT with some sand, MH	Dark brown sandy SILT, MH	Red sandy SILT with some gravel, MI
Particle Size Distribution (%)	Clay	12	13	13
	Silt	75	36	27
	Sand	9	50	55
	Gravel	4	1	5
Types of Soil		**Sand**		
Location		**Telok Melano**	**Kampung Hulu Kabong**	**Institut Aminuddin Baki**
Soil Description		Light grey SAND with some decayed vegetal matter	Dark brown SAND	Brown SAND with some shale and decayed vegetal matter
Particle Size Distribution (%)	Clay	5	8	4
	Silt	6	3	5
	Sand	89	89	90
	Gravel	0	0	1

10 mm to 0.063 mm. From the figure, it can be seen that the D_{60}, D_{30} and D_{10} of peat collected in Kampung Endap are 0.640 mm, 0.250 mm and 0.075 mm, respectively.

GeoCrete® Powder (*GCP*)

GCP is a very fine powder that is white to grayish in colour as shown in Figure 6. This powder consists of mostly alkaline natural earth elements, with a mean density of 2.47 Mg/m^3 which when mixed with soil and binder, results in an eco-friendly concrete-like structure. The GCP used in this study is supplied by GeoCrete Specialist Sdn. Bhd., a construction company located in Kuching, Sarawak which specialises in soil stabilisation using GeoCrete® Technology.

Methodology - Experimental Programme

A series of laboratory tests, such as the standard proctor and unconfined compression strength tests, were conducted on the collected samples.

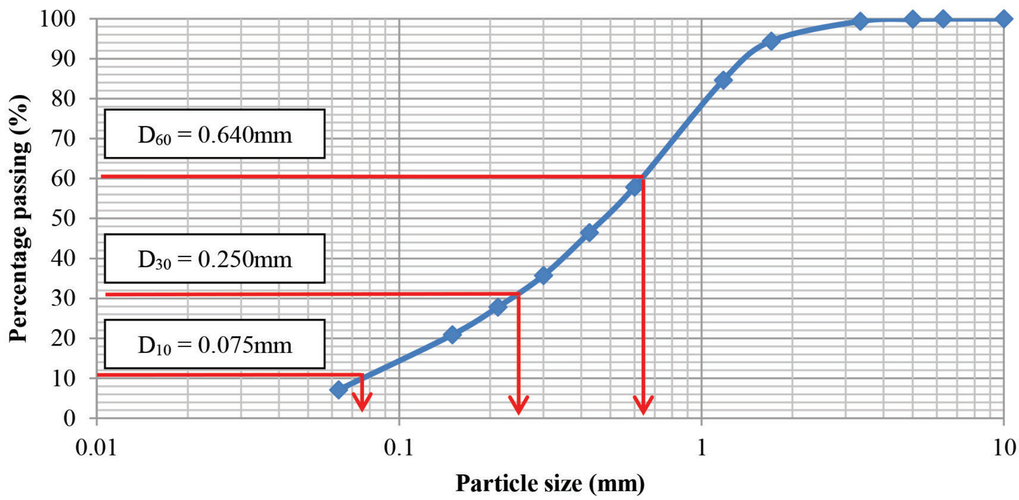

Figure 5: Sieve analysis curve of the peat samples

Figure 6: The GeoCrete® powder (GCP)

The samples were then stabilised with ordinary Portland cement (OPC) and GCP at a constant design mixture of 8% OPC and 2% CGP as presented in Table 3. The mixture was initially applied over clay, silt and sand. Based on their performance in achieving the minimum strength of 2,000 kPa after 28 days of stabilisation, this design mix was therefore applied to be tested on peat. All the specimens were prepared to the optimum moisture content (OMC) and maximum dry density (MDD) with a curing period of 7 days and 28 days (single-batch mixing). In this study, peat and peat-cement mix were also prepared and act as control samples.

Table 3: Design mix for selected soils

Soil	Design Mix
Peat (Pt)	Pt + 8% OPC + 2% GCP
Clay (CH)	CH + 8% OPC + 2% GCP
Silt (MH)	MH + 8% OPC + 2% GCP
Sand (S)	S + 8% OPC + 2% GCP

Results and Discussion

Standard Proctor Test

The standard proctor test was conducted to determine the OMC and MDD of the design mix. Table 4 presents the OMC and MDD results obtained for all selected soils. From the table, peat showed the highest OMC at 65.47% with a very low MDD at 0.67 Mg/m^3. For clay, silt and sand, the OMC values ranged from 10% to 20% with the MDD values ranging from 1.50 Mg/m^3 to 1.90 Mg/m^3.

Unconfined Compressive Strength (UCS) Test

The unconfined compressive strength test was conducted in accordance with BS 1377: Part 7: 1990 which is defined as the load per unit area, where the soil failed in the axial compression test. From the results obtained, GeoCrete® Technology was proven to improve the unconfined compressive strength (q_u) up to more than 200% from 7 days to 28 days of stabilisation using GCP for clay, silt and sand. For peat, even though the results obtained is lower when compared with the three other types of soil, it still showed a significant improvement of the unconfined compressive strength between untreated peat (q_u of 28 kPa) and peat stabilised with GCP (q_u of 72 kPa). The clay sample at Jln Kim San showed a higher increment of compressive strength from 5,750 kPa to 11,530 kPa in 21 days whereas the clay sample at Sungai Anak showed an increment of only 17% from 2,470 kPa to 4,290 kPa for the same period of treatment with GCP. The unconfined compressive strength improvement on silt and sand samples also varied based on location.

Figure 7 summarises the unconfined compressive strength results of selected soil types after stabilisation with GCP for 7 days and 28 days. According to the figure, the unconfined compressive strength of more than 2,000 kPa was reached after 28 days of stabilisation (Djumic, 2010) for all samples. Furthermore, experimental work was carried out on peat treated with GCP. The peat is mixed with 5% OPC and 8% OPC as a control sample. The results are compared and plotted in Figure 8. From observation, the UCS value increased at the curing period of 7 days to 28 days. It can be seen that the strength of peat (q_u) treated with 2% GCP+8% OPC increased up to 72.2 kPa at 28 days when compared with peat treated by 5% OPC (q_u of 37 kPa)

Table 4: Engineering properties of Sarawak soils in various locations

Soil	Location	Optimum Moisture Content (%)	Maximum Dry Density (Mg/m^3)
Peat	Kampung Endap	65.47	0.67
Clay	Sungai Anak	11.50	1.89
	Jalan Kim San	15.50	1.70
	Kampung Mentu	13.20	1.81
Silt	Sungai Mador	19.80	1.51
	Rumah Dawai	16.50	1.72
	Kampung Bengang	16.80	1.72
Sand	Telok Melano	13.70	1.64
	Kampung Hulu Kabong	17.00	1.55
	Institut Aminuddin Baki	10.5	1.65

and 8% OPC (q_u of 44 kPa). This is due to the hydration process caused by the soil particles bonding up together into a rigid mass when GCP reacts with the soil particles, thus producing more crystalline growth, which acts as the filler of pore space. The smaller the pore space, the higher the UCS value. An additional 8% of cement also helped to reduce the pore space between the peat particles. This is because cement also works through a hydration process, a more pozzolanic reaction takes place and the reduction of void in the sample during the curing periods produces high interlocking connectivity which significantly increases the strength.

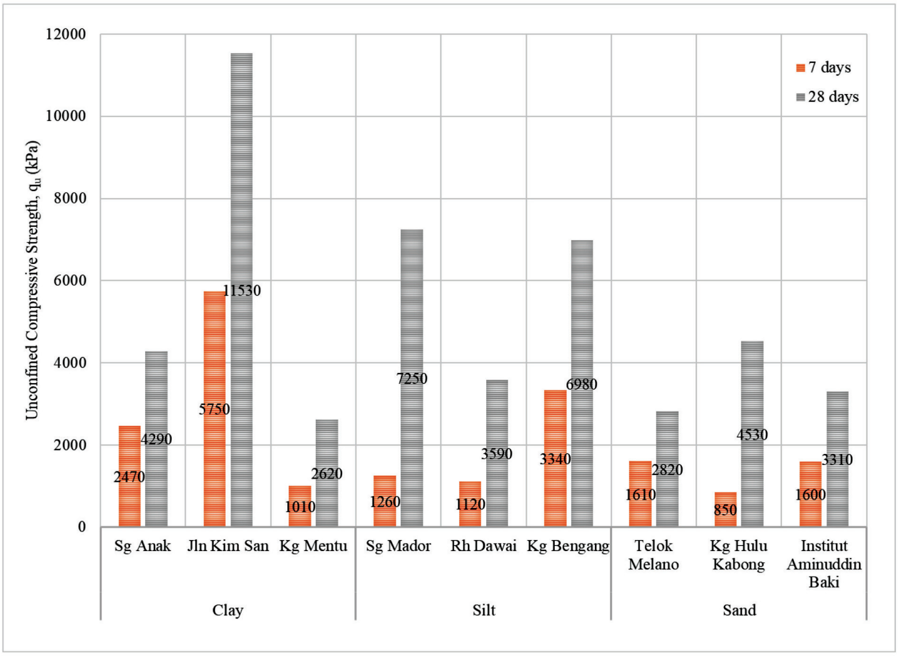

Figure 7: Unconfined compressive strength of selected Sarawak soils stabilised using GCP

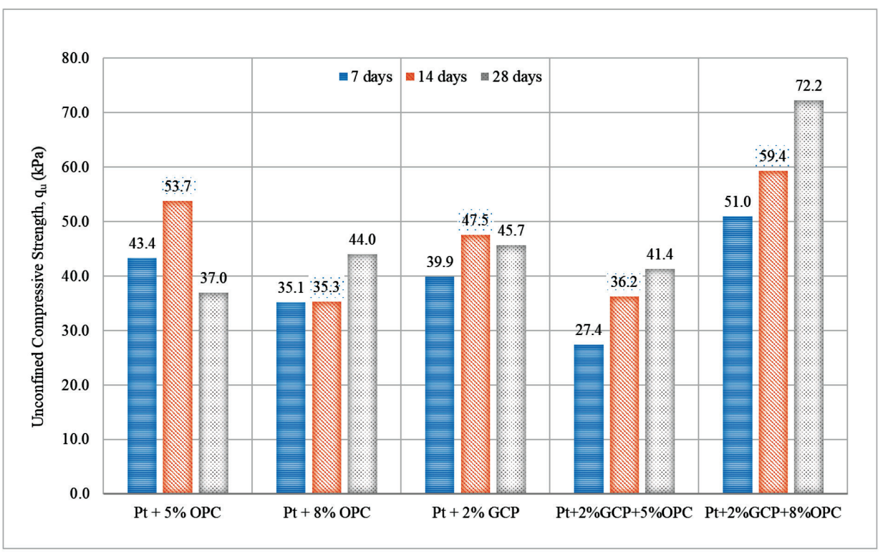

Figure 8: Unconfined compressive strength of peat stabilised with GCP

A further comparison with other published literature on the strength increment of stabilised peat shows an agreement or similar behaviour with the current study. A study by Romali *et al.* (2021) using 10% to 20% fly ash for peat stabilisation shows that the strength increases up to 122 kN/m^2 and most of the samples recorded strength improvements after 28 days of curing. Also, a study by Boobathiraja *et al.* (2014) indicates that the strength of peat stabilised with lime increased from 0 to 113.57 kN/m^2 with 50% lime added to the peat. Based on the current results, it can be seen that an improvement in strength for peat stabilised with GCP has the potential to be explored and used for future development such as road embankment construction.

Conclusion

This section summarises the physical properties of Sarawak soils tested in the investigation into the performance of unconfined compressive strength after being treated with OPC and GCP. Based on the laboratory results obtained, the following conclusions were made:

- The results of physical properties obtained from the laboratory tests show that sapric peat has the highest moisture content at 495% when compared with clay (15%-21%), silt (17%-33%) and sand (3%-21%).
- The unconfined compressive strengths of clay, silt and sand samples after being treated using GeoCrete® Technology show a greater improvement to more than 200% after 28 days of stabilisation.
- Peat stabilised with 2% GCP and 8% OPC shows the highest strength value when compared with untreated peat after 28 days of stabilisation.

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