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Design of Industrial Mg-Rich Gypsum Waste with Concrete Waste Aggregate for Compressibility of Problematic Soil

Khairun Najihah Kamarudin[1], Nurmunira Muhammad[1,*], Abdoullah Namdar[2]

1 Faculty of Civil Engineering Technology, Universiti Malaysia Pahang Al-Sultan Abdullah, Kuantan, Malaysia
2 School of Civil Engineering, Iran University of Science and Technology (IUST), Narmak, Tehran, Iran

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ABSTRACT

Peats are often considered as a geotechnically problematic soil due to their poor behaviour and exhibit low soil properties like high compressibility, low shear strength, high fibre content, high moisture content and low bearing capacity values. Chemical stabilization was proven to be an effective method to stabilize the problematic soil. To date many additives like Ordinary Portland Cement, fly ash, lime and other alternatives binder has been applied to improve the compressive strength of the problematic soil. The study describes the effect of compressibility of improved peat soil using waste from industrial such as Mg-rich synthetic gypsum (MRSG) by-product and concrete waste aggregate from institution laboratory waste that can be used to improve the settlement problem of the Gebeng, Malaysia peat soil. The test was conducted at varying percentages of MRSG and concrete waste aggregate additives at 5%, 10%, 15%, and 20% by weight of the soil. The unconfined compression strength (UCS) test was determined to obtain the optimum strength ratio and the data revealed that the optimum ratio of gypsum and concrete waste required to enhance the properties of peat soil were at 5% gypsum, 10% concrete waste, and 10% concrete waste combined with 10% gypsum. Coefficient of consolidation, compression index, and coefficient of volume compressibility were obtained by oedometer test for both untreated and treated peat soil with additives. The compression ratio of the peat soil indicated the peat was very compressible and however, the compression ratio was observed at very slightly compressible once the soil stabilized with the optimum ratio mix. The results indicated that the combination of these two additives improved the compressibility characteristics of peat soil. This research will contribute to the fundamental behaviour of geotechnical problematic soil in Malaysia which results in sustainable approach by recycling the industrial and institutional waste, Mg-rich gypsum and concrete waste aggregate for soil improving instead of implementing soil removal replacing techniques.

Keywords:
Concrete waste aggregate; industrial waste; soil stabilization; peat compressibility

1. Introduction

Peat soils are often considered as geotechnically problematic soil. Peat soil covers around 2.5 million hectares of Malaysia's total land area and almost 219,561 hectares or 9% laid in Pahang [1].

* *Corresponding author.*
E-mail address: muniramuhammad@ump.edu.my

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Especially at east coast area in Pekan and Kuantan districts, Rompin-Endau area and some small areas in Pahang west area [2]. Soil is essential as the foundation of the buildings and infrastructure. Typically, the construction sites are laid on high strength soil. However, the good foundation becomes scarce. Due to the high demands on the construction area, the construction needs to be constructed on any types of soil including the problematic soil where there is suitable area for the development. Gebeng is famously known as an industrial area in Pahang, Malaysia that located in east coast region also been widely covered with peat soil. Since peat is highly compressive in nature, major concern is the compressibility characteristics of peat soil. There is a scarcity of suitable land for development, areas with adverse ground conditions, such as peat soils, are being considered for infrastructure construction. However, construction works on peat lands often cause problems and difficulties. Table 1 shows the physical properties of untreated peat soil.

Table 1
Physical properties of untreated peat soil (source Rahman *et al.,* [15])

Parameters	Results	References
Natural moisture content, MC (%)	77 - 96	Rahman *et al.,* [15]
	119	Ling *et al.,* [28]
	140 - 2200	Zainorabidin et al., [30]
	140 – 200	Wahab *et al.,* [19]
Von Post humification for peat	H4	Rahman *et al.,* [15]
		Kolay P.K. *et al.,* [31]
pH	3.20	Rahman *et al.,* [15]
	4.80	Kazemian *et al.,* [5]
	3.68	Zainorabidin *et al.,* [30]
Specific gravity, Gs	1.30	Rahman *et al.,* [15]
	1.24	Kazemian *et al.,* [5]
	1.21	Kolay P.K. *et al.,* [31]
Loss on ignition, LOI (%)	95.21	Kolay P.K. *et al,* [31]
	44.74 - 85.67	Aminur M.R *et al.,* [29]
Organic content, OC (%)	89.35	Kazemian *et al.,* [5]
	42.53 - 85.10	Aminur M.R *et al.,* [29]
	95.6	Rahman *et al.,* [15]
Liquid Limit, LL	144 - 184	Rahman *et al.,* [15]
	149	Zainorabidin *et al.,* [30]
	75.25	Ling *et al.,* [28]
Maximum dry density, MDD, γd	0.54	Rahman *et al.,* [15]
(g/cm³)	0.56	Kolay P.K. *et al.,* [31]
Optimum moisture content, OMC (%)	86.50	Rahman *et al.,* [15]
	95.17	Kolay P.K. *et al.,* [31]

Peat is a term used to describe highly organic soils made primarily of plant remains. Peat soils can be divided into 3 classes which are a) Fibrous, b) Hemic, and c) Sapric. Visually the soil classified from dark brown to black in colour, with a spongy texture and an organic odour [3]. Peat has a spongy texture as when the soil was extruded on squeezing, it was observed that the soil was somewhat pasty and muddy water squeezed out [4]. Peat also contains high organic content, usually more than 75% [5,6]. However, according to Wetlands International (2010) [7], the organic soil containing more than 65% organic matter also known as a peat soil. Due to the peat behaviour like high compressibility, low shear strength, and low permeability, peat-based structures are often unstable. The major problems faced by the engineers are instability, slip failure, localized sinking, and long-term settlement [8]. Due to this event, ground improvement techniques are famously adopted [9]. Soil is essential as the foundation of the buildings and infrastructure.

Soil stabilization is a method of mixing soils with other materials, to improve the engineering properties of soil. Soil stabilization is the process of changing or preserving one or more soil properties to improve the engineering characteristics and performance of a soil [10]. The stabilized soil materials have a far better strength, lower permeability, and lower compressibility than the native soil [11]. Stabilization improves the soil's strength and shrinkage ability, improving the load bearing capacity and overall performance of soils. Soil stabilizations can be classified into two groups: mechanical stabilization and chemical stabilization [12]. Chemical stabilization is a most common category of soil stabilization involving the use of stabilizing agents for initiating reactions within the soil for modification of its geotechnical properties [13]. This study focusing on chemical soil stabilization method to study the compressibility of peat soil by inducing additives from industrial waste and also waste from institution.

The most common additives are Ordinary Portland Cement (OPC), lime, bitumen, and tar [14]. Recently, the cost of these additives has become expensive due to the sharp rise in energy cost. In addition, the carbon footprint of OPC synthesis is very high [12], affecting the nature adversely and not recommended to be used as a sole binder which has opened the door widely for introducing the other kind of soil admixtures that is more sustainable and environmentally friendly such as industrial by-product and institutional waste.

Gypsum as an additive material has better properties than other additives because it does not cause air pollution, cheap, fire resistant, and resistant to deterioration by biological factors and chemicals [14]. Industrial by-product Mg-rich synthetic gypsum (MRSG) waste used in this study was produced by a rare earth-refining plant in Gebeng, Pahang. The industrial gypsum waste can be used as a resource, which gives it economic value and diverts it from landfills to more productive uses. From earlier research, the liquid limit of gypsum stabilized peat soil decreased as the gypsum content increased [15]. Also, it shows that gypsum in addition to other stabilization materials such as cement, fly ash, rice husk, lime, NaCl, tin, jute fibre, bagasse ash etc. produces a better performance in stabilizing soil as compared to gypsum or any other additives as a stand-alone stabilizer [14].

Due to the higher demand in new development, a significant amount of waste generated may also increase [16]. In construction, large amounts of concrete from buildings' demolitions made up 30-40% of total wastes [17]. Moreover, concrete and material laboratories of an institution generally receive extensive amounts of concrete specimens for testing purposes [18]. Hence the excessive amount of waste gathered from the laboratories spark in the environmental issue due to material waste accumulation. The increasing number of waste generation directly has been affected by illegal dumping, and it has been found that this issue becoming depressing in Malaysia [19]. To sustain the environment, it is crucial to prevent waste accumulation and find solutions to deal with waste, pollution, depletion, and degradation resources. As mentioned from previous research, the combination of two or more additives may resulted in better performance than a stand-alone stabilizer. Thus, this study was conducted to investigate the characteristics of peat stabilized using Mg-rich gypsum and concrete waste.

In working towards mitigating these problems, implementation of proper ground improvement method is important. Soil stabilization involves the utilization of stabilizing agents or additives like lime, cement, fly ash, in weak soils to enhance its geotechnical properties like compressibility, strength, and permeability. This study aims to understand the viability of the use new additives as a soil stabilizer using an industrial by-product, Mg-rich gypsum, and a concrete waste aggregate from institution waste for reducing the compressibility of peat soils. In achieving the aim, this research was carried out to understand the physicochemical properties of the untreated soil and assessing the performance of the additives in improving of the peat soils by using consolidation method.

2. Methodology
2.1 Site Sampling Area

Gebeng industrial estate is located about 25 km from the capital city of Pahang state, Kuantan, Malaysia and strategically located for industrial plant that only 5 km from Kuantan Port. The 8600 hectares industrial area is a world-class chemical and petrochemical zone. Most of the industrial area in Gebeng located close to the body of water and most soil that found near to the sea are organic soil or mainly in peat soil category. The peat soil was collected from Gebeng district, Kuantan, Pahang with the coordinate of (4º00’18.0” N, 103º22’12.2” E) as shown in Figure 1. The area of soil collection was determined by referring to the soil-types map in Pahang and Gebeng is widely covered with the dark brown coloured soil species, peat. Figure 2 proves the rivers or water channel are in dark brown or blackish colour. The lower reaches of the rivers in peat areas are usually brackish and acidic [20].

Fig. 1. Peat sampling location (source: National Soil Maps (EUDASM) Maps Published by Direktorat Pemetaan Negara, Malaysia.1970)

2.2 Site Survey and Sample Method Collection

A manual sampling method was applied for accumulating peat specimens in a range of 0.50 to 1.50 meter depth from ground surface. The tool used for sample collection was the stainless-steel hoe and shovels. The plant structures such as wood and roots were easily recognizable in the peat soil samples. The specimens were stored in an air-tight buckets to avoid any characterization loss, as shown in Figure 2, samples were brought back to the laboratory for analysis. Initially, the soil specimens were air-dried and passed through a 2 mm sieve to separate the coarse sediments, pebbles, roots, plant remains, and other unwanted materials. The natural moisture content of the sample was obtained right after the arrival to the laboratory to prevent the loss or gain of moisture content. As the peat soil is easily disturbed, the test was done quickly to minimize any change in water content of the soil sample.

The industrial by-product Mg-rich gypsum was collected from the rare earth processing industrial plant in Gebeng, Malaysia. The Mg-rich gypsum waste was dried using the oven at 105 °C for 24 hours before crushed into small fragments, by using a sledgehammer, then using LA Abrasion machine following ASTM C535 (2016) [21] which supported by Kianimehr *et al.*, [22]. The concrete waste aggregate was collected from Concrete & Structure Laboratory at Universiti Malaysia Pahang Al-Sultan Abdullah (UMPSA). The concrete waste aggregate was crushed manually by using a steel hammer and sieved to the desired size. The particle size of concrete waste aggregate was consistently prepared in the range between 1 mm to 2 mm size as similar as the size tested by the previous study [23].

Fig. 2. The peat soil samples collection (air-tight bucket)

2.3 Physical Properties Analysis

The physical properties test was conducted in the soil mechanics and geotechnics laboratory, Universiti Malaysia Pahang. All the laboratory tests were following British Standard (BS) 1377. The peat samples were tested for physical properties tests such as moisture content, sieve analysis, specific gravity, and Atterberg limits in accordance with BS 1377: Part 2: 1990. Physicochemical properties such as pH and organic content were conducted following BS 1377: Part 3: 1990. Compaction and unconfined compression strength (UCS) tests were carried out on untreated peat and peat mixed with 5, 10, 15 and 20% by weight of gypsum and concrete waste aggregate using 38 mm diameter mould in accordance with BS 1377: Part 4: 1990 and BS 1377: Part 7: 1990, respectively. The corresponding Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) obtained from the compaction tests for all sample mixtures were used to quantify the materials required prior for UCS test.

The consolidation test was tested for both untreated peat and treated peat soil mixed with the gypsum and concrete waste aggregate additive based on ratio that previously determined from the UCS test. The consolidation test was conducted according to BS 1377: Part 6: 1990 to determine the compressibility behavior of the specimens. This is due to the peat soils' unique organic composition which exhibits distinct characteristics that are particularly important in the context of strength and compressibility. Thus, prior to the consolidation test, the strength analysis was used to determine the optimum ratio of additives. The test set up comprised of 10 kN load frame, with 50 mm sample size width, the GDS Automatic Oedometer System (GDSAOS), pressure and volume controllers and GDS laboratory software. The consolidation pressure (σ) of 5, 10, 20, 40, 80, 160 and 320 kPa was applied to the sample surface and a typical time-compression curve were plotted. The compressibility parameters of peat soil and soil with additives were evaluated to assess the effect of the additives with different mix proportions. The parameters evaluated were: i) compression index (c_c), ii) consolidation coefficient (c_v), and iii) coefficient of volume compressibility (m_v). Table 2 shows the control sample and optimum ratio design additive.

Table 2
Control sample and optimum ratio design additive

Specification	Sample
Untreated Peat	Control Sample
Peat = 95%; Gypsum= 5%; Agg. Concrete Waste = 0%	Sample I
Peat = 90%; Gypsum = 0%; Agg. Concrete Waste = 10%	Sample II
Peat = 80%; Gypsum = 10%; Agg. Concrete Waste = 10%	Sample III

3. Results and Discussion
3.1 Physical Characteristics of Untreated Peat

Some preliminary tests, such as moisture content, Atterberg limit, specific gravity, standard proctor, pH, and loss on ignition were performed on natural Gebeng peat soil and the results are presented in Table 3. The natural moisture content of Gebeng peat soil was found to be 138 %. The value was supported by the previous study mentioned that the average moisture content of peat soil ranges is listed in Table 1 by referring to sources [19] and [30]. Figure 3 shows the particle size distribution curve of the peat soil. From the curve, it can be detected that the peat soil consists of 0.99% fines (silt and clay), 70% of sand and 29.01% of gravel. The uniformity coefficient (Cu), is defined as the ratio of D60 to D10, and coefficient of gradation (Cc), as in Eq. (1), were calculated to be 7.95 and 1.13, respectively. The values attributed to the well graded type of soil. The specific gravity of untreated peat soil was determined to be 1.69 Mg/m^3. The values for the Atterberg limits tests are detailed in Table 3 along with the classification of the peat soil based on USCS nomenclatures.

$$C_c = \frac{D30^2}{D60xD10} \qquad (1)$$

Table 3
Physical properties of Gebeng peat soil

Parameters	Results
Moisture content (%)	138
Organic content (%)	57.63
Liquid limit (%)	112.98
Plastic Limit (%)	88.38
Plasticity Index	24.60
Specific gravity (Mg/m^3)	1.69
Maximum Dry Density (g/cm^3)	0.69
Optimum Moisture Content (%)	60.78
pH	3.59
USCS classification	SW

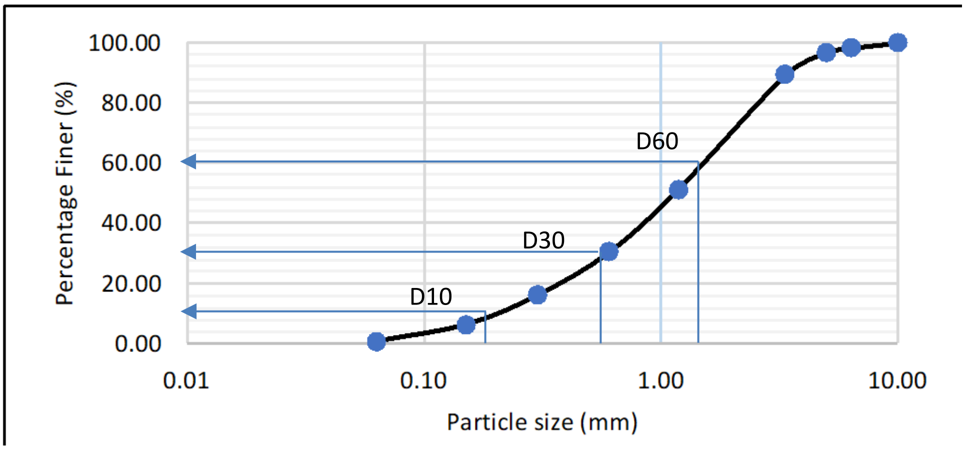

Fig. 3. Particle size distribution curve of Gebeng peat soil

3.2 Acidity/Alkalinity

The peat soil and peat mixed with 5% gypsum, 10% concrete waste and 10% of both additives were investigated for their pH. Table 4 shows the results. It was observed that the pH value for untreated peat soil was about 3.59 which indicated that the peat soil was strongly acidic. Soils with pH less than 5.5 are considered as strongly acidic [24]. Similar value obtained from the previous studied, the pH value of peat in West Peninsular Malaysia is 3.51 [9]. The pH value of gypsum and concrete waste aggregate were 9.47 and 7.36 respectively, which indicated that the Mg-rich gypsum and concrete waste aggregate were alkaline. After stabilization of peat mixed with 5% gypsum, and 10% concrete waste aggregate, the pH shifted to less acidic values. This implies that the peat soil still dominantly observed in stabilization process in additional of 5% gypsum, and 10% concrete waste aggregate. Meanwhile, the pH mixture of peat with 10% gypsum and 10% concrete waste aggregate was observed at 6.28. This confirmed that the gypsum and concrete waste aggregate have actively reacted with the peat soil due to changes of pH value from acidic condition of peat and highly alkaline of gypsum has shifted the mixture to less acidic and neutral environment. The gypsum released hydroxide ions (OH^-) and calcium ions (Ca^{2+}) into the peat soil which increased the pH of the soil mixture. These released ions have the capacity to neutralize acidic compounds. Additionally, the admixtures interacting with the low-pH soil constituents are able to create new compounds and alter the soil's mineral composition, improving its strength and microstructure. The measured pH values were found to be between 6 and 7, which are acceptable values in environmental regulations [25].

Table 4
Results of pH test

Type of samples	pH values
Untreated Peat	3.59
Gypsum	9.47
Concrete waste aggregate	7.36
Peat + 5% Gypsum	4.77
Peat + 10% Concrete waste aggregate	4.44
Peat + 10% Gypsum + 10% Concrete waste aggregate	6.28

3.3 Atterberg Limit

The Atterberg limit test was conducted for both untreated and treated peat sample. The liquid limit was examined for Gebeng peat soil at about 112.98%. Meanwhile, the plastic limit was observed at 88.38%. Thus, the plasticity index (PI) of untreated peat soil in Gebeng was 24.60%. The research findings lead to the conclusion that, according to the Unified Soil Classification System (USCS) as depicted in Figure 4, the sample falls into the category of silts and high-plasticity organic soil, situated below the A-line in the MH zone. Figure 5 presents the impact of various proportions of additives on the liquid limit (LL) and plastic index (PI) of stabilized peat soils. Specifically, the combination of 10% Gypsum (G) + 10% Concrete Waste Aggregate (CW) exhibited the lowest plasticity index at 12.24% and a liquid limit of 63.80%. These findings indicate that the soil treated with a combination of gypsum, concrete waste, and both additives displayed lower liquid limit values compared to untreated peat.

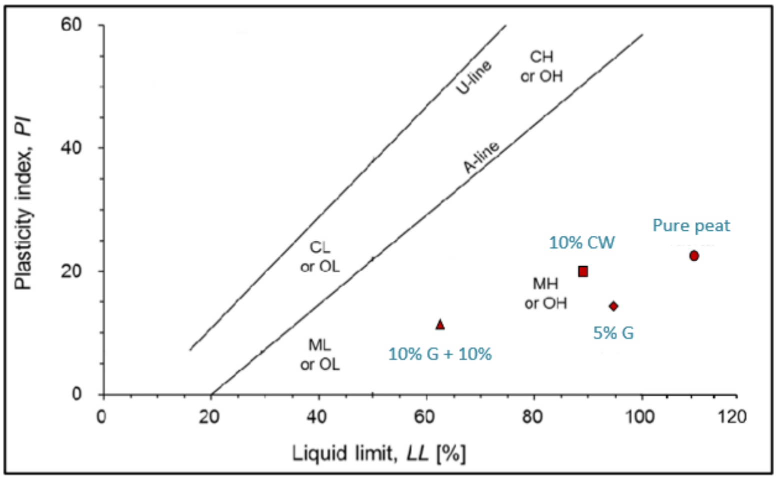

Fig. 4. Atterberg limits (USCS chart)

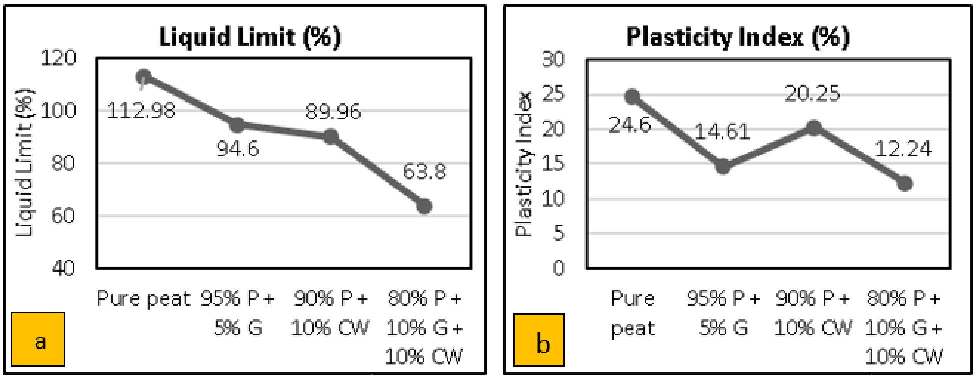

Fig. 5. Atterberg limit results (a) liquid limit versus different mixture (b) plasticity index versus different mixtures

3.4 Compaction/Standard Proctor

The compaction test was conducted for untreated and treated peat mixtures to determine the maximum dry density (MDD) ρd (g/cm^3) and optimum moisture content (OMC). The unit weight of untreated peat soil increased with increasing water content until an optimum value was reached. Beyond the optimum moisture content, the unit weight decreased with increase in moisture content. Figure 6 shows the results of compaction test. The MDD observed for Gebeng peat was 0.69 g/cm^3 which is almost consistent with previous study from Muhammad Aishat Sani *et al.,* [14]. The OMC was observed to be 60.78% for the untreated peat soil in Gebeng. Similarly, the moisture content of the treated peat soil was influenced by the addition gypsum and concrete waste aggregate. The mixture of peat with 10% gypsum and 10% concrete waste recorded the highest MDD and lowest OMC with 1.08 g/cm³ and 40.17%, respectively. The results indicated that the additives able to improve the dry density and reducing the amount of optimum moisture content of the peat soil. Several previous studies also mentioned a similar trend of the influence of gypsum, as it avoids the ability of water to absorb into the soil, which presents to the lowering of the OMC and increasing of the MDD [12,15]. Typically, the values of dry density of soil foundation within the range of 1.0 – 1.6 g/cm³.

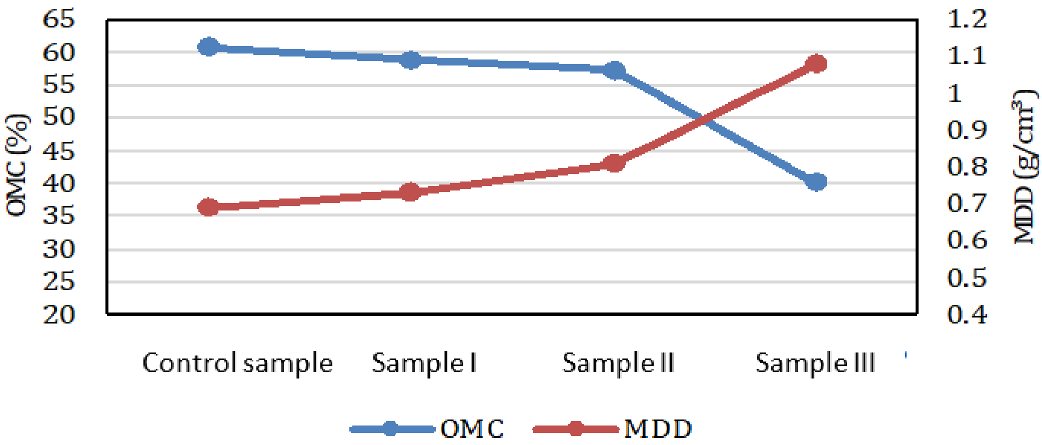

Fig. 6. Results of compaction test for untreated and treated peat

3.5 Unconfined Compression Strength (UCS)

The untreated peat samples with 5, 10, 15, and 20 % of gypsum and concrete waste aggregate were tested to obtain the highest unconfined compressive strength for determining the optimum ratio mix design of additives between the gypsum, concrete waste, and both. The unconfined compressive strength for untreated peat was recorded at 36 kPa. Table 5 below shows the result of UCS test for various ratio of treated peat. The optimum design additives were chosen based on the unconfined compressive strength, qu obtained from the UCS test. The compressive strength at 5% of gypsum was at the highest strength value obtained which was 59 kPa for peat-gypsum mixture. The mixture of peat-concrete waste aggregate recorded the highest strength at 10% concrete waste aggregate which was 93 kPa. Meanwhile, the mixture of peat-gypsum-concrete waste aggregate recorded the highest strength achieved at 10% gypsum and 10% concrete waste aggregate, which was 144 kPa. Thus, the mixture of 5% gypsum, 10% concrete waste, and 10% of both additives were chosen as the optimum ratio design of peat soil. As mentioned before, strength and compressibility are main characteristics for peat soil. Figure 7 shows the scanning electron micrograph (SEM) of untreated peat, and peat treated with both additives (10% G and 10% CW). The morphological analysis showed that the untreated peat appears to have many cavities with high void, high porosity, and rounded shape particles. However, it is clearly can be seen that in the treated peat, there is not much visible cavities anymore and the peat soil particles flocculate together which resulted into a solid structure when it is added with 10% gypsum and 10% CW.

Table 5
Results of UCS test

Type of samples	Average strength (kPa)		
	5%	10%	15%
Peat + Gypsum	59	56	55
Peat + CW	55	93	82
Peat + Gypsum + CW	129	144	100

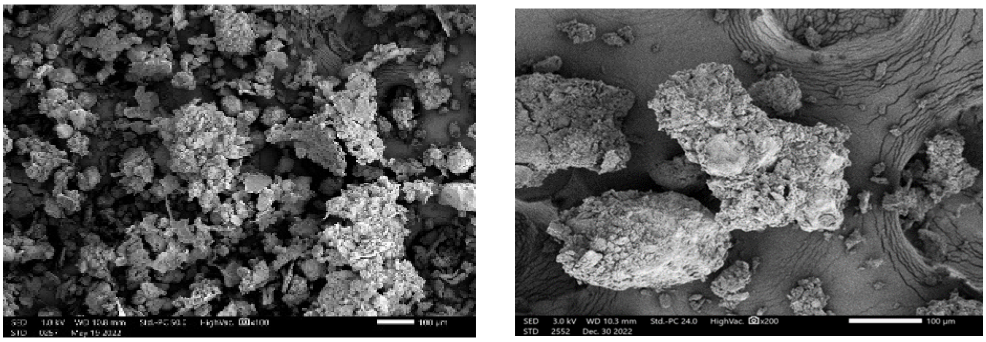

Fig. 7. Scanning electron micrograph (SEM) for untreated peat and peat treated with 10% gypsum and 10% concrete waste aggregate

3.6 Consolidation/Oedometer Test

The consolidation test was done on both untreated peat and treated peat mixed at the optimum ratio design additive.

3.6.1 Compression index (c_c)

The c_c is defined by the slope of the final part of the void ratio versus logarithmic of consolidation pressure (log σ) curve. Based on Figure 8, the c_c values calculated from the consolidation test results for untreated peat, sample I, sample II, and sample III were 0.292, 0.146, 0.166, and 0.103 respectively. The addition of additive significantly reduces the compression index of the peat soil either the soil stabilizes with gypsum, concrete waste aggregate or both. In addition, the combination of the additives subsequently reduces the compressive index up to 65%. c_c was correlatively related to the liquid limit and bulk density [26].

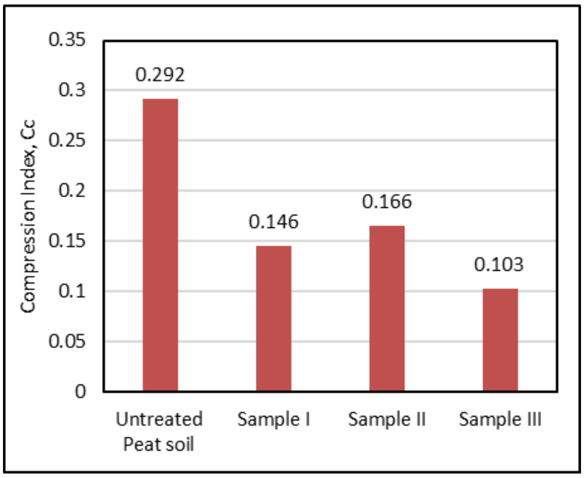

Fig. 8. c_c versus optimum ratio

3.6.2 Coefficient of consolidation (c_v)

There is a significant decrease in the c_v of the untreated samples with an increase in the consolidation pressure. For treated peat (Figure 9) indicate that the c_v decreases upon increasing the σ. Under range of consolidation pressure from 5-320 kPa, c_v for untreated peat varied between 16.54 to 4 m²/year. Untreated peat recorded the lowest c_v value, lower c_v is more evidence in specimen with higher organic content [27]. Sample II (10% CW) varied between 23 to 8.29 m²/year under the same consolidation pressure, higher c_v could be due to the additives content in replacement of organic content.

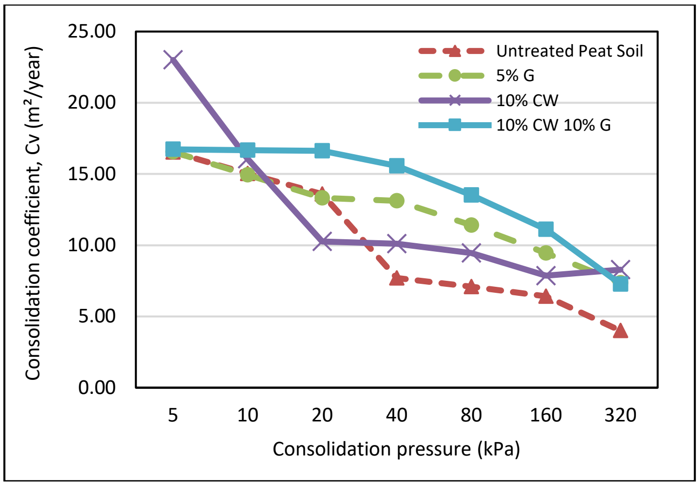

Fig. 9. c_v versus consolidation pressure

3.6.3 Coefficient of volume compressibility (m_v)

This parameter is very useful in estimating the value of the primary consolidation settlement. The void ratio, e against applied pressure, log σ is used to obtain c_c and σ_c. It is observed that the average m_v of each mixture in Figure 10, for untreated soil, the m_v gradually decreases upon increased in the pressure. The m_v for all mixture of 5% gypsum, 10% concrete waste and 10% CW 10% G significantly decreased compared to untreated soil. It was observed that m_v declined from 1.05 m²/MN for untreated peat soil to 0.12 m²/MN for peat soil added with 10% gypsum and 10% concrete waste aggregate. The mixture that is highly decreased in coefficient of volume compressibility (m_v) was 10% gypsum with 10% concrete waste aggregate. Because of the hardened peat-cement matrix formed by cement particles bonding with adjacent soil particles in the presence of water in its pores, the compressibility characteristics of soils are improved as similar as previous study [32].

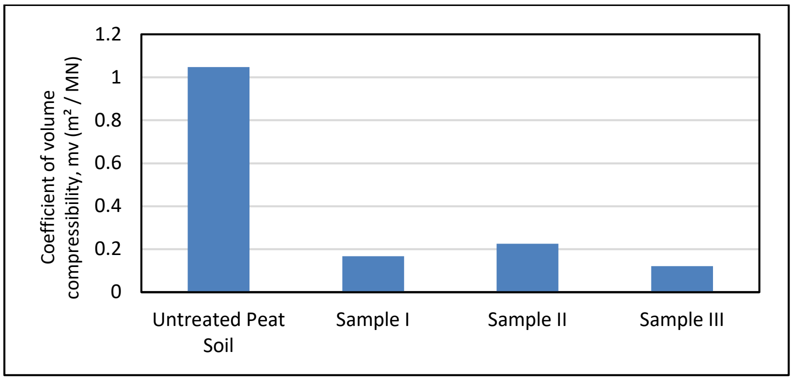

Fig. 10. m_v versus σ with optimum ratio

3.6.4 Compression Ratio

The compressibility of a soil is classified by its compression ratio. For peat soil, compression ratio can be classified as 'very compressible', 'moderately compressible', 'slightly compressible', and 'very slightly compressible' based on previously adopted in study from [32]. The parameter of compression ratio was defined by $C_c/1 + e_0$. Figure 11 shows the specimens compression ratio, the compression ratio for untreated sample, sample I, II, and III were 0.214, 0.079, 0.09, and 0.056 respectively. Combination of gypsum and concrete waste aggregate as additives in peat soil reduced the value of compression ratio hence varied compression ratio categorization from very compressible to slightly compressible. The dominant factors controlling the compressibility characteristics of peat are fiber content, natural moisture content, void ratio, nature and arrangement of soil particles, and inter-particle chemical bonding in some of the soils [33]. As can be seen from Figure 7, the SEM test revealed that the microstructure of the treated sample with both additives was more compacted and solid bonding, indicating a reduction in voids when compared to the untreated sample. Thus, generally, stronger bonds may contribute to a more stable structure with lower compressibility, while weaker bonds or decomposition may lead to a less stable structure and higher compressibility.

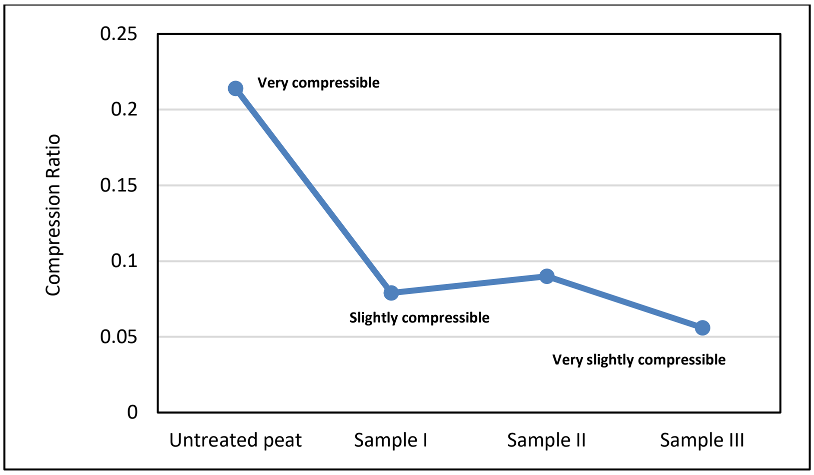

Fig. 11. Compression ratio versus optimum ratio design additive

4. Conclusions

This research is highly significant because it provides engineers with the soil consolidation parameters to be used in the design of structures and roads on Gebeng peat soil. Based on the observation from consolidation test on both untreated and gypsum-concrete waste aggregate stabilized peat soil of optimum ratio design described in this paper, the following conclusion were made:

i. The peat soil was discovered from the physical properties' tests and the ensuing soil classification that the peat soil is unsuitable for supporting infrastructures in its natural state.
ii. UCS tests were carried out after mixing 5, 10, 15 & 20% of gypsum and concrete waste aggregate to the soil and optimum ratio design were obtained with 5% G, 10% CW and 10% G+10% CW addition.

iii. The cc from GDS consolidation test results for untreated peat, sample I, II, and III were 0.292, 0.146, 0.166, and 0.103 respectively. It shows that the combination of two additives resulted in better performance where cc decreased about 65%.
iv. The cv untreated peat soil is decreasing upon increase in consolidation pressure and gypsum-concrete waste aggregate ratio.
v. Combination of gypsum and concrete waste aggregate as additives in peat soil reduced the value of compression ratio hence varied compression ratio classification from very compressible to slightly compressible.
vi. The SEM test revealed that the microstructure of the treated sample with both additives was more compacted and solid bonding, indicating a reduction in voids when compared to the untreated sample.
vii. Generally, stronger bonds may contribute to a more stable structure with lower compressibility, while weaker bonds or decomposition may lead to a less stable structure and higher compressibility.
viii. Overall, a better understanding of peat soil and the method of stabilization was achieved through this study.

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