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PEAT SOIL BEHAVIOUR STABILISED WITH BY-PRODUCT OF MANUFACTURE OF EDIBLE OILS

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ABSTRACT: Peat settlement is a significant challenge in construction due to its high compressibility, moisture content, poor shear strength, and prolonged settlement behavior under load. Tropical peat soils, in particular, exhibit the highest settlement rates over extended periods, leading to instability in structures built on such soils. These challenges are evident in numerous construction and coastal high-rise projects where peat soil often serves as a foundation material. Despite the critical need, limited research has been conducted on stabilizing peat soils using eco-Processed Pozzolan (EPP). This study investigates peat soil stabilization using EPP through consolidated undrained triaxial tests. The objectives include evaluating the index properties of peat soil, assessing its shear strength under various effective stresses, and analyzing the mechanical properties of EPP-stabilized peat before and after treatment. The results indicate that untreated peat soil recorded shear strength increases of 51.94% at 25 kPa and 186.77% at 50 kPa of effective stress. For EPP-treated peat soil, shear strength improvements were more pronounced. At 25 kPa, T5-25, T10-25, and T15-25 recorded shear strengths of 198.14 kPa, 33.46 kPa, and 21.07 kPa, respectively. At 50 kPa, T5-50, T10-50, and T15-50 exhibited significant increases, with values of 576.77 kPa, 95.72 kPa, and 210.54 kPa, corresponding to percentage increases of 191.09%, 186.07%, and 899.24%, respectively. These findings underscore the potential of EPP in enhancing peat soil properties, offering a sustainable solution for mitigating settlement-related issues.

Keywords: Peat soil, Stabilization, Shear strength, Consolidation behavior

1. INTRODUCTION

In the literature, peat soil is defined as the organic surface layer of a soil consisting of moderately decomposed organic matter, primarily derived from plant material that has formed under conditions of waterlogging, depletion of oxygen, high acidity and depletion of nutrients. Peat soil is encountered in many areas and generally originates from plant/animal remains and is considered partly as decomposed biomass as claimed by [1]. Pursuant to [2], the disintegration of plant in acidic environments without microbial activity generates highly organic matters in peat soil. Moisture and temperature affected the peat formation. Decomposition of plant material by microorganisms is decelerated in heavily saturated anaerobic soils, leading to a high retention of carbon. The decomposition of plant material by microorganisms is decelerated in cold temperatures, leading to rapid peat formation. In lowland and highland areas, peat soils can exist, but highland peat soils are not widespread. Most of the lowland peats have developed along the coast, behind accreting mangrove coastlines on the report of [3].

Prior to the work of [4], latest reports shows that 1,689,171 km^2 is of tropical peatland zones. Intriguingly, the highest deforestation rates were in peat swamp forests with an annualized rate of 2.2 percent, of an overall 1.0 percent annual forest cover drop in Southeast Asia, with the remainder of forest being turned to plantations and secondary vegetation [5]. Malaysia is reported to have about 2.5 million ha of peat soil [6], with Sabah contributing over 4.76 percent of the second biggest peat soil area in Malaysia. Sarawak has the largest peat soil in Malaysia that covers 1.66 million ha, representing 13% of the state area. On the Klias Peninsula and in the Kinabatangan-Segama Valleys, there are two remaining sites that support the largest areas of peat soil in Sabah.

Peat soil is appraised as one of the problematic soils. The bearing capacity of peat soil is very low and apparently controlled by the water table and presence of subsurface woody debris [7][8]. Reduction in the level of groundwater may eventually lead in the deterioration and oxidation of the peat, given the increase in compressibility and permeability likely to result in its humification. As discovered, it is commonly reported that tropical peat soils associated with highest settlement when subjected to a load over long period [9]. Excessive settlement happens when buildings are built on peat soil and thus creates problems of instability, such as local sinking and long-term settlement, even if it is applied to moderate pressure. When provided present existence, many constructions project and coastal high-rise buildings whose bases are often backed by peat soils face complications.

With the rising need for land for a country's growth, it's becoming increasingly impossible to avoid building on soft peat soil, which can't be used for crop cultivation due to its acidity. As a result, improving the qualities of peat soil is required before any civil buildings may be built on it. Numerous studies have experimented with various building strategies, notably as excavation displacement or replacement, stage loading, and surface reinforcement. These procedures are expensive. Cement, lime, fly ash, and combinations of cement and fly ash, cement and bentonite have all been researched for their ability to stabilize peat soil [27]. In a triaxial consolidated undrained compression test, the effective friction angle of peat is commonly quantified. For highly organic peat, a consolidated undrained test with pore pressure measurement is acceptable for obtaining effective strength characteristics such as effective cohesion (c') and effective angle of shearing resistance (Ø') as stated by [10].

Previous researchers have reported the applications of triaxial method to numerous studies, namely experimental evaluation of the strength of peat stabilized with hydrated lime [11] strength and compressibility characteristics of amorphous tropical peat [12].

Shear strength parameters of cement stabilized amorphous peat of various water additive ratios at different natural moisture contents under consolidated undrained triaxial test [13], application of calcite precipitation method to increase the shear strength of peat soil [14], and comparative study in method of compaction by consolidated drained and direct shear test [15].

Eco Process Pozzolan or known as EPP is a sustainable product recycled from spent bleaching earth (SBE), and recently used as a blended cement as specified by [16]. The removal of pigment or colour, phospholipids and other crude palm oil impurities are by using bleaching earth. It is added in the refinery to process the crude palm oil into refined, whitened, and purified palm oil. SBE absorbed and recovered some oil throughout the process, thus EPP is produced. EPP primarily consists of silica (SiO_2), aluminium oxide (Al_2O_3), and iron oxide (Fe_2O_3). In agreement with [16][30], the combination of the three substances is more 50%, which can be classified as class C pozzolan based on ASTM C618 standard. The rate of methane production and consumption, as well as the capacity of plants and soil to act as a medium that transports the gas to the surface, all affect how much methane is released from peat into the atmosphere [17]. Peat and organic soils are known for their unique geotechnical properties, which present significant challenges for construction activities.

These soils are typically characterized by high compressibility, low shear strength, and high-water content, making them inherently unstable and difficult to build on. In Malaysia, where peatlands are prevalent, particularly in regions like Sarawak, the need for specialized construction practices is critical to ensure the stability and longevity of infrastructure. As can be observed in Table 1, peat soil's specific gravity values for the aforementioned sites typically range from 1.01 to 2.30, respectively.

Table 1: Tabulated of Peat Soil Properties

Location	Researcher	Degree of Humification	Specific Gravity, G_s	Moisture Content (%)	Organic Content (%)	Liquid Limit (%)	pH	Fibre Content (%)
Klias, Beaufort, Sabah	Author (2023)	H5 – H6	1.04	294.84	97.26	169.58	3.3	36.55
Sabah	Mohd and Habib (2023)	H1 - H3	1.47	587.57	96	-	-	69
Sabah	Anis and Habib (2022)	H4	-	580.5	-	-	3.21	-
Sabah	Mohamad (2022)	H4	-	580.5	-	-	3.21	-
Pekan, Pahang	Abdul Wahab et al. (2022)	H5 – H7	-	537.106 – 635.285	95.88 – 98.48	137.638 – 152.540	-	-
Sibu	Syazie et al. (2021)	H5 – H6	1.01 – 1.05	618.72	79.9	125	5.92 – 6.5	42.16
Parit Nipah, Johor & Lumadan, Sabah	Habib et al. (2020)	H5 – H6	1.3 – 1.37	455.51 - 593	95.51 – 95.6	211 - 243	4.0 – 4.3	38.5 - 66
Sarawak	N. Azima et al. (2020)	H5 – H6	-	-	99	-	3.3	
Matang, Kuching, Sarawak	S. N. Aida et al. (2018)	H6	1.13	808.1	-	167.13	-	-
Kampung Meranek, Sarawak	Atikah et al. (2018)	H7 – H8	1.408	1210.497	95.793	458	3.31	32.333

1.04 is significant in stating that these values fall within the acceptable ranges and satisfy the articulation in relation to the KBpt findings in this study. The investigation discovered that there is a substantial association between moisture content and liquid limit, with KBpt having a moisture content of 294.84 and a liquid limit of 169.58, correspondingly.

Guidelines for Construction on Peat and Organic Soils in Malaysia [27] have been developed to address these challenges. These guidelines provide a framework for engineers, developers, and contractors to assess, design, and implement construction projects in these difficult environments. The guidelines cover various aspects, including site investigation, soil stabilization techniques, foundation design, and environmental considerations.

A key reference in these guidelines is Geoguide 6: Site Investigation for Organic Soils and Peats [28], which provides detailed procedures for the investigation of peat and organic soils. Geoguide 6 is essential for understanding the subsurface conditions, assessing the risks, and designing appropriate construction strategies. It covers techniques such as sampling, in-situ testing, and laboratory analysis, ensuring that the unique properties of peat and organic soils are accurately characterized. For current study regarding peat soil stabilization, the bearing capacity of slabs with bamboo micropiles was close to that of concrete micropiles, or about 0.92 times the bearing capacity of concrete micropiles [32]. A minimum CBR value of 5% for subgrade soil was achieved with 6% marble ash content and a soil layer thickness of approximately 20–30 cm. CBR values exceeding 5% are suitable for use as a subgrade in road construction [33].

2. RESEARCH SIGNIFICANCE

The use of by-products from the edible oil manufacturing industry in stabilizing peat soil presents a sustainable approach to waste management. By recycling these by-products, the study promotes a circular economy, reducing the environmental footprint of both the edible oil and construction industries. Stabilized peat soils can be more effectively used for construction and agricultural purposes, reducing the need to convert other types of land, thus preserving natural habitats and biodiversity. Stabilizing peat soils can reduce risks associated with soil subsidence and infrastructure failure, enhancing the safety and resilience of communities living in areas with extensive peatlands.

3. ECO-PROCESSED POZZOLAN (EPP)

Eco-Processed Pozzolan (EPP) is a solid waste produced from spent bleaching earth (SBE) after the residual oil extraction process has been completed.

Spent whitening earth (SBE) is an industrial waste created mainly from the processing of edible oil. World production in the edible oil and fat industries currently exceeds 65 million tonnes and SBE production is estimated at 650,000 tonnes worldwide according to [18]. Reported that forthcoming, the disposal of SBE to landfill may be restricted by strict environmental regulations.

EPP has been used as blended cement recently. Research on EPP as a pozzolanic material from previous studies is minimal. Waste products with pozzolanic properties are used for cement replacement in concrete, thus reducing the use of cement. The use of pozzolanic material for cement replacement could reduce the cement industry's release of carbon dioxide (CO) because cement production contributes to 5%-7% of global CO emissions in keeping with [19]. The original EPP was visually found to be mostly coarser and porous in nature, as shown in Figure 1. As shown in Figure 2, the Scanning Electron Microscope (SEM) image of the EPP shows that it has an irregular, sharp, uneven, and porous structure.

Fig. 1 Eco Processed Pozzolan (EPP)

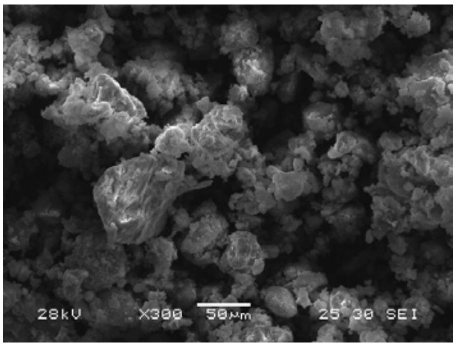

Fig. 2 Micrograph image of EPP

3.1 Physical and Chemical Properties of EPP

Using X-ray fluorescence (XRF), X-ray diffraction (XRD), and scanning electron microscope (SEM), respectively, the chemical oxides, mineralogical and microstructural characteristics of EPP have been analysed.

The physical properties of EPP and OPC are outlined in Table 2. The mean particle size of d50 was 29.3 and 27.4 µm, respectively, for EPP and OPC. The EPP and OPC particle sizes, d90, were 80.42 and 94.36 µm respectively. Based on the results, the specific gravity was 1.93 and 3.27, respectively, for EPP and OPC. There is a lower specific gravity for the EPP than the OPC. The chemical oxides of EPP and OPC are revealed in Table 3. The XRF outcome indicates that the total value of SiO2, aluminium oxide (Al2O3) and iron oxide (Fe2O3) was 68.98 percent of the EPP consisting of SiO2 at 47.6 percent. As per the ASTM C618 standard, the value is less than 70 percent. Nonetheless, in class C pozzolan, it is more than 50 percent that the EPP can be graded. There is a high percentage of SiO2 in the EPP. The mineralogical analysis indicates that the EPP consists of various minerals, either in the crystalline phase or in the amorphous phase, as it has SiO2. The pozzolanic reactivity of the material can be more dependent than other properties of the material on the occurrence of its amorphous level.

Table 2: Physical Properties of EPP.

Physical Properties	d_{10}, (µm)	d_{50}, (µm)	d_{90}, (µm)	Specific Gravity
OPC	3.37	27.4	94.36	3.27
EPP	7.04	29.3	80.42	1.93

Table 3: Chemical Properties of EPP

Chemical Properties (%)	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	LOI
OPC	14.4	3.6	3.2	72.3	1.7	5.78
EPP	47.6	11.6	9.8	12.5	6.2	3.3

4. METHODOLOGY

The aim of the present research is to study the index properties of Klias, Beaufort's peat soil, to evaluate the stress-strain behaviour of peat soil under consolidated undrained triaxial test and to determine the effect of EPP on the shear strength behaviour of peat soil. The shear strength behaviour of peat soil was studied utilizing the consolidated undrained triaxial test with two different applied effective pressure of 25kPa and 50kPa on untreated and treated peat soil with EPP for a period of time.

The researcher covered data and test findings from lab experiments in this domain. One of the experiments the author has conducted is this one. Included tests are those for moisture content, liquid limit, organic content, pH, specific gravity, and fibre content. The University Malaysia Sabah's Faculty of Engineering Laboratory (Geotechnic) provides the setting where the experiments are being performed.

The process of mixing peat with eco processed pozzolan begins with assessing the peat soil's characteristics, such as depth, moisture, and organic content. After clearing and leveling the site, a suitable eco processed pozzolan with passing 63 micron is selected based on its chemical and physical properties. The optimal mix ratio, typically 5%, 10% and 15% pozzolan by weight, is determined through triaxial tests. The pozzolan is then spread evenly over the peat surface and mechanically mixed using rotary tillers or deep soil mixers to ensure its equally mixed. As the materials are blended, a pozzolanic reaction occurs between the pozzolan and the moisture in the peat, forming cementitious compounds that enhance soil strength. This mixture is allowed to cure for a period ranging from a few days to several weeks, during which the shear strength of the soil increases. Following the curing period, the mixed soil is compacted to 4 segments with 4.5kg free drop hammer to achieve the desired density [31]. Quality control tests, such as unconfined compressive strength and vane shear tests, are conducted to ensure the soil meets design specifications.

The triaxial test for peat involves preparing a cylindrical sample of the peat soil, which is then encased in a rubber membrane and placed in a triaxial testing apparatus. The sample is subjected to confining pressure within a chamber filled with water, simulating the in-situ conditions. Axial stress is applied to the sample through a loading piston to replicate the stress conditions the soil would experience in the field. During the test, both the axial and radial stresses are controlled and measured, and the sample's deformation is monitored to determine its strength and deformation characteristics. This test carried out under consolidated undrained condition.

5. RESULTS AND DISCUSSION

The ramifications of this study are examined in this section within the context of the main research findings. The peat soil qualities in Malaysia and other nations are summarised in Table 4.8 and were taken from the index properties of earlier studies conducted by various scholars. Therefore, the primary goal of this study is to evaluate the integration of data from earlier research. In order to meet the ranges of results produced, the results from this study are compared to the available data to assess the characteristics of KBpt. Table 4.8 shows the natural water content of peat, which varies from 12% to 1210.497%.

According to Ratna et al. (2020), Yulindasari et al. (2019), and Johari et al. (2016), the moisture content ranged from 389.48% to 640.09% in Malaysia and 236.532% to 294.300% in Indonesia. The sample has a higher liquid limit (LL) value because it has a high capacity to absorb water and contains fibre with an organic content ranging from 33% to 66%. These variations in outcomes are caused by climate change, which is reflected in changes in temperature, precipitation, and rainfall that have an impact on the level of soil saturation. The water table, which formed in a relatively horizontal plane, may rise to a level that is higher or lower than the elevation of the actual water table.

Figure 1 shows the stress-strain behaviour of untreated peat soil indicated by U25, and treated peat soil with different percentage of EPP, specifically 5%, 10% and 15%, denoted by T5-25 T10-25 and T15-25. For U25, when applied the effective stress of 25kPa, the axial strain recorded was 20.00% and the maximum deviator stress. Meanwhile, the organic and fibre contents of the KBpt material used in this investigation were determined to be 97.26% and 36.55%, respectively.

The results make it evident that the result falls within the range shown in Table 4.8, where Malaysia's organic content ranges from 78.76% to 99% and its peat's fibre content ranges from 11.51% to 90%. It is clear that ongoing agricultural activities played a role in the development of ground fibre made from living and dead plants or crops. The stress-strain behaviour had been discussed of peat from the perspective of geotechnical engineering based on consolidated undrained triaxial laboratory test. Effective stresses applied for the samples are 25kPa and 50kPa, both under consolidated undrained condition. Figure 1 shows the stress-strain behaviour of untreated peat soil indicated by U25, and treated peat soil with different percentage of EPP, specifically 5%, 10% and 15%, denoted by T5-25 T10-25 and T15-25. For U25, when applied the effective stress of 25kPa, the axial strain recorded was 20.00% and the maximum deviator stress recorded correspond to 51.94kPa.

Meanwhile, for T5-25 at the effective stress of 25kpa, the maximum deviator stress recorded was 198.14kPa with the value of axial strain of 20.00%. The results for T5 increases significantly with 281.48% of increment compared to the U25. Contrarily, for T10-25, the maximum deviator stress recorded was 33.46kPa at 20.00% of axial strain. The graph shows a decrease of 83.11% from T5-25 to T10-25. The lowest maximum deviator stress recorded was for T15-25, showed value of 21.07kPa corresponds to 19.43% in axial strain, shows 37.03% of decrease in percentage compared to T10-25. On the question of stress strain curve, [20] found that at effective stress of 25kPa, the axial strain and deviator stress recorded was 21% and 49kPa respectively. This finding is consistent with [21] whereas it is recorded that for effective stress of 25kPa, the axial strain was 18.83% and maximum deviator stress recorded was 40.81kPa for undisturbed peat. For reconstituted peat, [21] reported that for axial strain of 17.40%, the maximum deviator stress recorded was 106.71 kPa. For U25, the value recorded was 51.95kPa for maximum deviator stress with 20.00% axial strain, [20] reported for undisturbed peat, the maximum deviator stress recorded was 49.00kpa with axial strain of 21.00%.

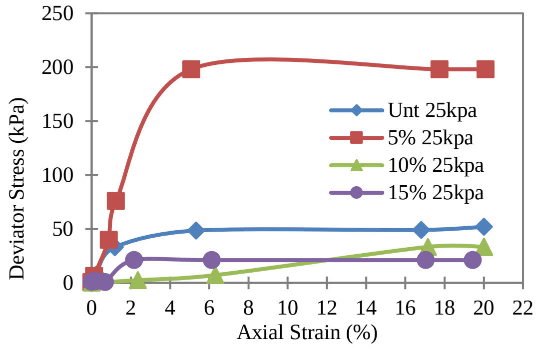

Fig. 3 Stress-strain curve of peat soil for 25kpa

Moreover, [21] recorded a value of 40.81kPa for maximum deviator stress with 18.83% of axial strain. From the author observations, the differences recorded in the value above are due to several aspects. First, soil sample collected are from various locations, such as Sabah, China and Johor respectively. Another difference is in the index properties, specifically fibre content of the respective peat soil. As for U25, the fibre content recorded was 36.55%-hemic peat while [21] recorded fibre content of 66.56%-fibric peat.

According to [22], the soil's increasing fibre content will have an immediate impact on the moisture content and void ratio as well as the soil's shear strength. For the T5-25, the value recorded was 198.14kPa for maximum deviator stress and 20.09% for axial strain with effective stress of 25kPa.

Meanwhile, [21] recorded 106.71kPa for maximum deviator stress and 17.40% for axial strain with effective stress of 25kPa. T5-25 is a remoulded sample, added with EPP as stabilizer while [21] used reconstituted sample with no additional stabilizer. EPP has the ability to help peat soil achieve stable settlement.

Peat soil treated with additional materials has the potential to be stabilised, according to [23]. T10-25 and T15-25 exhibit decreasing value trend as both recorded axial strain of 20.00% and 19.43%, and maximum deviator stress of 33.46kPa and 21.07kPa, respectively. This shows that the optimum percentage of EPP needed as stabilizer is peak at 5%. As a conclusion, EPP has shown a potential to stabilised peat soil and reacts to the peat soil structure thus significantly increase the shear strength. Figure 3 shows graph for axial strain versus total stress ratio for effective stress of 25kPa. From the graph, U25 recorded the value of 0.37 for maximum total stress ratio and 20.00% for maximum axial strain.

Alternately, T5-25 recorded the highest value of total stress ratio with 0.75 at 20.09% axial strain. T5-25 increases 102.7 in percent compared to U25, thus the graph grows exponentially. On the other hand, T10-25 recorded value of 0.20 for maximum total stress ratio at 20.00% axial strain. T10-25 decrease of 73.33 percent compared to T5-25.

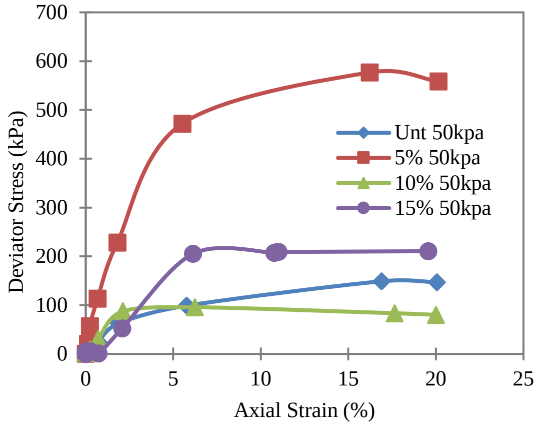

Fig. 4 Stress-strain curve of peat soil for 50 kPa

T10-25 slowly stepped up until reaching the maximum total stress ratio. Meanwhile, T15-25 recorded value of 0.25 for maximum total stress ratio at 19.43% of axial strain. T15-25 shows similar trend as T10-25, where slowly rose to maximum total stress ratio. T15-25 shows and increase from T10-25 of 25%, yet a decrease from T5-25 of 32.43%. Figure 4 shows graph for axial strain versus total stress ratio for effective stress of 50kPa.

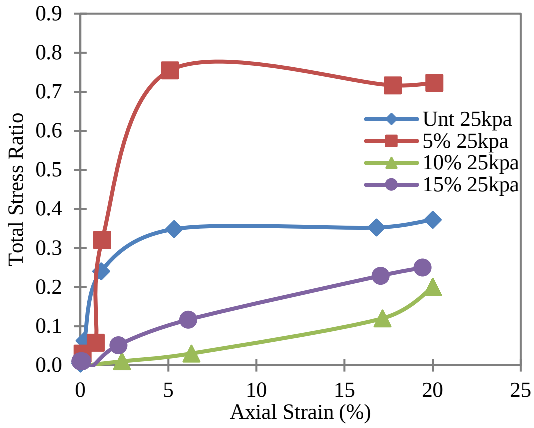

Fig. 5 Total stress ratio of peat soil for 25 kPa

From the graph, U50 recorded the value of 0.60 for maximum total stress ratio and 20.06% for maximum axial strain. Alternately, T5-50 recorded the highest value of total stress ratio with 1.75 at 20.15% axial strain. T5-50 increases 191.67 in percent compared to U50, thus the graph grows exponentially. On the other hand, T10-50 recorded value of 0.50 for maximum total stress ratio at 20.01% axial strain. T10-50 decreased 71.43 percent compared to T5-50. T10-50 slowly stepped up until reaching the maximum total stress ratio then continuing to slightly drop.

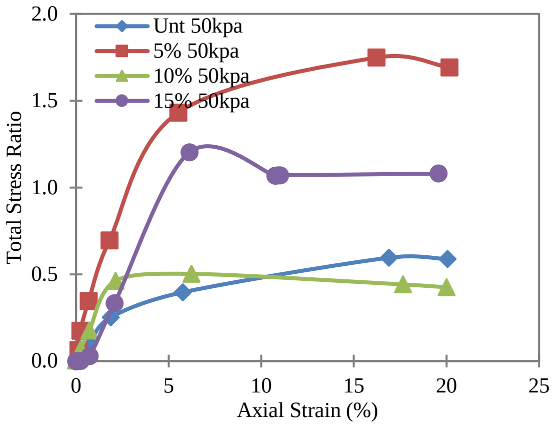

Fig. 6 Total stress ratio of peat soil for 25 kPa

Meanwhile, T15-50 recorded value of 1.20 for maximum total stress ratio at 19.43% of axial strain. T15-50 shows similar trend as T5-50, where sharply rose to maximum total stress ratio, then drop gradually before it remained constant. T15-50 shows and increase from T10-50 of 140%, yet a decrease from T5-25 of 31.43%. The total stress ratio increases significantly from effective stress of 25kPa to 50kPa. According to Pongpipat and C. Roth (2018), when silt concentration increases, the stress ratio curves rise faster and reach greater peak values. This suggests that silt-clay soils have increased shear resistance due to inter-particle friction as silt content increases. In this setting, EPP-stabilized peat soil modifies the physical and chemical properties of untreated peat soil, indicating better shear resistance.

Figure 5 shows the graph of mean effective stress versus shear strain for effective stress of 25kPa. For sample U25, the maximum mean effective stress and maximum shear strain recorded was 19.31kPa and 5.76% respectively. As can be seen, U25 depicted the lowest value for both mean effective stress and shear strain.

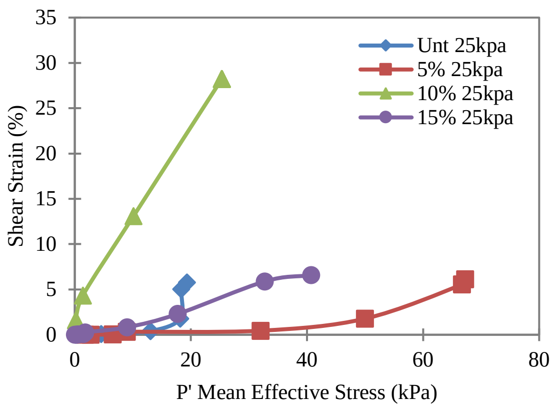

Fig. 7 Mean effective stress for 25 kPa

Different from U25, T5-25 showing increase in value for mean effective stress, noted 67.27kPa corresponds to 6.13% for maximum shear strain. T5-25 increase for 248.37% from U25 in terms of mean effective stress. T5-25 graph seems almost constant initially, but gradually increase in shear strain and mean effective stress.

T10-25 shows sharp increase in terms of shear strain, reporting value of 28.22%, corresponds to 25.33kPa maximum mean effective stress. T10-25 shows decrement of 62.35% from T5-25. Lastly, T15-25 recorded value of 40.74kPa and 6.58% for maximum mean effective stress and maximum axial strain respectively.

T15-25 shows decrease in percent of 39.44% from T5-25, and an increase in percent of 60.84% from T10-25. Figure 6, 7 and 8 shows the graph of mean effective stress versus shear strain for effective stress of 50kPa. For sample U50, the maximum mean effective stress and maximum shear strain recorded was 53.93kPa and 6.07% respectively.

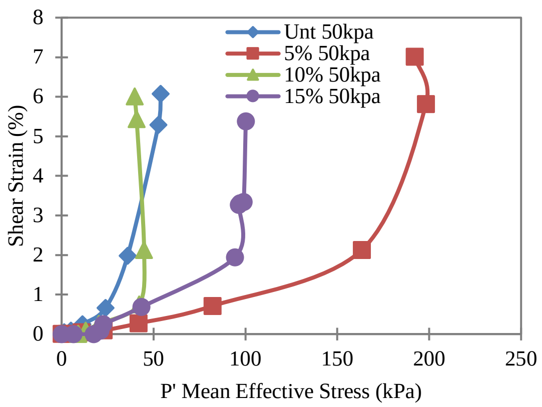

Fig. 8 Mean effective stress `for 50 kPa

As can be seen from the graph, U50 grow sharply before remained constant at the maximum mean effective stress and maximum shear strain. Different from U50, T5-50 showing increase in value for mean effective stress, noted 198.26kPa corresponds to 7.01% for maximum shear strain. T5-50 shows an increase for 267.62% from U50 in terms of mean effective stress.

T5-50 rise rapidly compares to all other samples. T10-50 similarly shows sharp increase, reporting value of 6.01% for maximum shear strain, corresponds to 44.30kPa of maximum mean effective stress. T10-50 shows decrement of 77.66% from T5-50.

Lastly, T15-50 recorded value of 100.19kPa and 5.38% for maximum mean effective stress and maximum axial strain respectively. T15-50 shows decrease in percent of 49.47% from T5-50, and an increase in percent of 126.16% from T10-50. In the consolidated undrained condition, shear strength and accompanying deformation parameters were developed. The maximal deviator stress is determined by compressing the specimen in the axial direction with a deviator stress.

Maximum deviator stress is defined as the difference between the major and minor stresses in the maximum condition. The shear strength parameters of peat soil are calculated using the deviator stress curve against a 20% axial strain average.

The peak deviator stress, peak effective principal stress ratio, constant stress and excess pore pressure or volume change observations, or simply a certain value of axial strain was reached, or the test was discontinued at 20% of axial strain.

As discussed before, shear strength is directly proportional to effective stress. For effective stress of 25kPa, U25 recorded shear strength of 51.94% while for effective stress of 50kPa, U50 recorded shear strength of 148.95kPa, showing an increase for 186.77%. In the same manner, for treated peat soil with EPP, when applied effective stress of 25kPa, T5-25, T10-25 and T15-25 recorded value for shear strength are 198.14kPa, 33.46kPa and 21.07kPa respectively.

Whereas when 50kPa of effective stress is applied, T5-50, T10-50 and T15-50, shear strength increases to 576.77kPa, 95.72kPa and 210.54kPa, thus showing an increase in percentage of 191.09%, 186.07% and 899.24% subsequently. Comparable with [32] where peat soil strength improved accordingly.

The liquid limit, plastic limit, bulk density, dry density, natural moisture content, and plasticity index were all substantially linked with shear strength parameters. It was not, however, significantly linked with soil specific gravity or the liquidity index.

The evidence from this study suggests that peat soil coupled with EPP will significantly improve the soil shear strength. The major finding was that the mixture of peat soil with optimum percentage of 5% EPP will stabilizes the soil sample and increase the shear strength of peat soil. Thus, this study strengthens the idea that adding EPP to peat soil can enhance the properties of soft peat soil and sustain the strength over loading for a period of time accordingly.

6. CONCLUSION

The by-products effectively increase the load-bearing capacity and stability of peat soils. Improvements in shear strength, compressibility, and moisture retention were observed, indicating that these by-products can transform the challenging characteristics of peat soil into more manageable and reliable substrates for construction. The improved properties of stabilized peat soil open up new possibilities for infrastructure development in areas previously deemed unsuitable due to poor soil conditions. This can lead to enhanced land use and development opportunities, particularly in regions with extensive peatland coverage. Standard tests that include undrained triaxial testing with pore water pressure monitoring do not require more than 50% axial strain to fail. However, when only 20% of axial strain is applied, testing can be conducted out and results interpreted to produce similarly high effective stress levels. Peats' geotechnical qualities, according to [44] are complicated by their high-water content and compressibility, as well as their organic makeup.

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