Characterizing the Effects of Pore Pressure Reduction and Voids using X-ray CT Scan towards Physical Changes due to Static Loading

Habib Musa Mohamad, Adnan Zainorabidin, Azura Azhari, Engku Shahrulerizal Engku Ab Rahman

Abstract**:** ***Peat soil is widely known as soil with very low compressive strength and poor in shear strength. When loaded, it is easy to deform and visually witnessed. To understand the vital means to study the characteristic of this rupture soil material, which is of great significance in determination of soil shear strength involving peat soil settlement where pore and voids diminished when loaded especially for embankment prediction. On this basis, static triaxial test has been carried out to simulate the loading phase while pore and void elements inspected through 2D X-ray CT scan. Through the process, peat and the relationship between loading, pore and physical changes are monitored. Measurements were performed on consolidated undrained condition with strain-controlled method under monotonic loading. The 2D X-ray CT scan pattern of the sample deformation was imaged before and after loading process. Sample height is 100 mm and diameter 50 mm in cylindrical shape. Physical changes are visualized, and the data showed that, pore and voids diminished by loading factor, leading pore pressure decrease with increase of effective pressure. Pore pressure developed down-trend characteristic. From the result, there is no volume change are disclosed when loaded. From 2D CT-scan shows that, the pore between peat particles diminished in volume after static loading and parallel to static loading process.***

Keywords **:** ***Peat, pore, X-ray CT scan, static loading.***

I. INTRODUCTION

It is well-known that Malaysia has very precious varieties of natural earth surface even before the formation of the federation of Malaysia itself. Malaysia comprises of the region of Peninsular Malaysia, Sabah and Sarawak. According to United Nations Development Programme [1], nearly 60 per cent of Malaysia or about 19.5 million hectares is covered by forest of one type or another. Malaysia's tropical forest constitutes a significant component especially of peat soil that is naturally available with an estimated 2.7 million hectares and predicted 1.54 million hectares still remaining with the inclusion for more than 70 per cent of these peatland forests are located in Sarawak, while less than 20 per cent of it is available in Peninsular Malaysia and the remainder in Sabah as reported [1].

At present, due to demands and human civilization necessity, large areas of peat soil forests have already been cleared and converted for other uses and purposes. The conversion aims to completely alter the landscapes for future development and to take advantage of the land use in a more productive manner deemed fit for human activities, settlements and industrial properties all in the name of economic development for a greater Malaysia.

The utilization of these peatlands in Malaysia is one out of many options available, however, before compromising these peatlands for construction, there are many economic factors that needs consideration, such as budgets and others. Aside from that, the behaviour of the peat soil itself may result in several major problems in the future after constructions which are highly related to post-construction quality and productivity or involves in failure when peat soil statically loaded.

Peats originate from plants and denotes the various stages in the humification process where the plant structures can be determined [2]. The decaying process of plants under acidic conditions without microbial process will result in the formation of organic matters in the peats. This condition renders the peats extremely soft and can be concluded as problematic soil.

Peats occur as extremely soft, wet and unconsolidated surficial deposits. Peats are geotechnically problematic due to their high compressibility and low shear strength [3]. In a moderate load increment, it lead to large volume changes.

Volume change in drained tests behaves as pore pressure in undrained. Therefore, peats will shows some mode of failure that is different from conventional specimen test and the illustration of peat conditions under triaxial test as compared to conventional tests [4]. For the conventional test failures, the first type is noted as a brittle failure with well-defined shear plane [5],

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the second type is deemed as semi-plastic failure showing shear cones and some lateral bulging while the third is recognized as plastic failure with well-expressed lateral bulging. For peat soils, samples seemed to be compressed in the middle length after undrained compressions as there are some bulging in the multi-lateral bulging and showing shear failure while maximum stressed applied.

Currently, there are only a few study has been carried out in laboratory concerning with the engineering and physical behaviour of hemic peat soil in undrained condition. Thus, this study had been carried out an experimental investigation in order to deal with the ultimate changes in pore pressure and volume change behaviour in peat soil with loading reaction under consolidated –undrained triaxial test. The stress-strain and shear strength relationships of peat are performed. While volume change in drained tests behaves as pore pressure in undrained [4].

Strain-controlled tests were preferred instead of stress-controlled tests [6]. The researcher explained that the reasons in applying strain-controlled tests in prior works on other soil types has shown shear strain to be a more fundamental parameter to control the pore pressure generation and volume change.

Previously, the pore size distribution measured using water retention curves [19]. Time has changed and technology has evolved in determining pore size distribution [17] and method was invented to introduce mercury intrusion and superseded by X-ray computed tomography (CT-scan) technology as introduced to measure pore connectivity [18].

II. TESTING PROGRAMME

A. Peat Soil Properties

The index properties test for peat soil have been carried out in order to describe, classified, and grouped the properties of peat soil from BSpt, PSpt and PNpt. Degree of humification test has been done for BSpt, PNpt and PSpt peat specimens. Degree of humification was done according to visually observed the appearances of physical peat soil on site during sampling. Table I indicates the results for BSpt, PNpt and PSpt by degree of humification observation.

Table I shows the associated specimens BSpt, PNpt and PSpt classified as Hemic peat in different scale respectively. PNpt in the scale of H6 while PSpt in H5 and BSpt in H7 class. PNpt indicates H6 and having a moderate decomposition level compared to PSpt. Generally, the plant structure are recognizable but unclearly understood. This test is based on a visual examination of the colour of the water that is expelled and the soil material remaining in the hand after a saturated sample is squeezed [7].

The water expelled ranges from dark brown to nearly black turbid and up to a third of the sample oozes out between the fingers. BSpt had a special constituents compared to PNpt and PSpt. Sabah Peatlands mainly found in a thick water-logged that made up in decaying plant material. With high water table, it becomes suppler although composed of unidentified fibres. Lowland of peat areas in Sabah are often flooded and swampy. Most of the peat land area covered by mud and transferable organic particle transported by water flood.

In comparison, for Malaysian peat properties from West to East regions, PNpt, PSpt and BSpt specimens goes in line with others peat properties though from different location and physical geography. PNpt and PSpt can be grouped by Malaysian Peninsular peat in Western Johor and BSpt grouped by Borneo Island peat region.

PNpt and PSpt from classified as H6 and H5 in Von Post humification scale. Compared to BSpt classified as H7. Both regions apparently has differ slightly from visual investigation on sampling site. Location and land-use factor seen as a vital factor in this humification process. Despite the fact that, climatic factors have a decisive role in influencing decaying process and peat distributions. Apart from that, water and material forms plants composed are important elements determined humification factors from author observation. Although, some regions in West Johor are marked with H5 [8].

BSpt has special rate of humification and author has observed that H7 represents Beaufort, Sabah and parallel to previous study [9]. On the grounds that, the sampling site surrounded by soft wild plants with grassy area and high water and supplied with water logged naturally accelerates the decaying process, which is bordering forest reserves. Compared to PNpt and PSpt, it is located in palm oil plantation with gross pants abundantly exists. Compared to Peninsular and Sarawak peat, H7 found in Matang, Sarawak [10].

In general, PNpt, PSpt and BSpt are in line with others peat humification characteristic. However, peat classified as Hemic visually rated from H4 to H6, while H7 to H10 classified as Sapric. In this research, classification of Hemic peat is determined from fibre content classification.

Table- I : Von Post Degree of Humification

Criteria	PNpt	PSpt	BSpt
Degree of Humification	H6 (Hemic)	H5 (Hemic)	H7 (Hemic)
Decomposition level	Moderately high	Moderate	Moderately high
Plant structure	Indistinct plant structure	Recognize but vary	Indistinct plant structure
Material squeezing	One-third of the peat escapes between the fingers and very pasty. Dark brownish water	Muddy and water with a very small amount of amorphous granular peat	One-third of the peat escapes between the fingers and very pasty. Dark brownish water
Nature of residue	Very pasty	Very pasty	Very pasty

As seen in Table II, the specific gravity values of the mentioned locations generally range from 1.14 to 1.56 correspondingly for peat soil. In connection with results of BSpt, PSpt and PNpt in this research, it ranges from 1.24 to 1.34 which is relevant to state that this values in the ranges and fulfil the articulation.

The correlation of moisture content and liquid limit have significant value, where the study found the moisture content for BSpt, PNpt and PSpt is approximately 600% to 700% respectively while the liquid limit recorded 149% to 162% respectively. A correlation can be found as it is noted that there is a slight but significant increase in liquid limit with the increase in natural water content [3]. The natural water content of peat in Table II ranges from 140% to 964.50%.

The liquid limit (LL) value is also higher as the sample that contains fibre within 33% to 66% or organic content and thus it has high water absorption capacity [10]. These variations of results are due to climate change that are manifested by changes in temperature, precipitation and rainfall which influences the intensity of soil saturation where, the water table formed in a relatively in horizontal plane and may rise to a level that is greater or less than the elevation of the actual water table.

Table- II: Peat Soil Properties

Location	BSpt	PNpt	PSpt
Degree of Humification	H7	H6	H5
Specific Gravity, G_s	1.34	1.33	1.12
Moisture Content (%)	713.35	676.30	637.00
Organic Content (%)	68.21	80.32	87.49
Liquid Limit (%)	170	149	155
pH	4.5	3.68	3.77
Fibre Content (%)	37.72	40.51	53.23

B. X-ray CT Scan Imaging Analysis

The purpose of this analysis is was to carry out a non-destructive testing on peat soil to visualize the inner structural characteristic on its physical changes when subjected to monotonic loading using X-ray Computer assisted Tomography. A testing procedure has been developed using a custom-built digital radiography and computer aided tomography (CT) scanner [16].

The peat soil materials are uniformly-sizes soils manufactured to test the resolution of the CT scanner and consisted of similarly-sized particles from undisturbed peat soil sample that affected from monotonic loading. Soil structure characteristics quantified and visualized using CT scanning procedures in 2D, and the results are compared to initial and loaded samples.

50 mm diameter and 100 mm height wore with membrane used to hold the undisturbed soil samples during the CT scan process in vertical position. Sample were scanned before static test in undisturbed peat core and scanned again after statically loaded. The instrumentation characteristics and methods of visualization and quantification of 2D CT images in the analyses of peat soil structure that were used in this research by penetrating rays from a 160kV/10mA industrial X-ray machine and a bank of Linear Array Detectors (LAD). This study was carried out at Malaysia Nuclear Agency.

This scan spacing scheme is shown diagrammatically in Figure 1. Test were performed within the vertical section of the sample and each scan consisted of one individual sectional scan with 360o rotation angle. The x-ray images are compiled into a quality two dimensional view of the interior of the scanned specimens as a reconstruction image process.

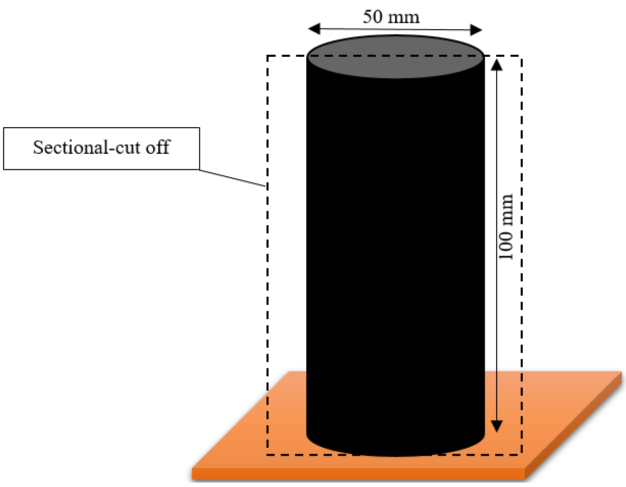


Fig. 1. Diagram of the clustered scan spacing scheme

Beaufort, Sabah peat (BSpt), Parit Nipah, Johor peat (PNpt) and Parit Sulong, Johor, peat (PSpt) specimens under monotonic loading with an axial strain rate 20% with loading rate of 0.1 mm/min. This test are carried out to establish the stress-strain relationships as well as to obtain the particulars of maximum deviator stress at required effective stress applied.

B. Static Undrained Triaxial Test

This section presents a static parameters. A series of static undrained triaxial test were performed on undisturbed specimens of normally consolidated peat soil, 50 mm diameter by 100 mm height. All tests were done until the strain limit of 20%. The specimens were sheared to large strains to obtain steady-state conditions. The steady-state is reached when the pore pressure remains constant under continued shearing [11].

C. Stress-strain Behaviour

Stress-strain behaviour within specimens is crucial under undrained triaxial conditions. Thus in this research, both deviator stress and pore pressure in undrained triaxial test were determined and measured. In this particular test, graphs plotted the deviator stress (σ_d) versus axial strain (σ_a) for all samples.

Figure 2 shows typical deviator stresses versus axial strain response for PSpt. Stress-strain relationships obtained during the static undrained triaxial test. Specimens was consolidated under various effective stresses from 25 kPa, 50 kPa and 100 kPa as shown in Figure 2 where, it shows increasing trend with hardening behaviour parallel with stresses applied. The stronger the stresses or effective pressure applied, the higher the deviator stress or strength.

A typical trend of stress-strain as a function of the shear strength benchmark viewed as typical trend for BSpt, PSpt and PNpt.

To examine in detail so as to determine the nature or tendencies of peat soil on the stress-strain curves behaviour, Figure 2 shows a pronounced peak is conspicuous, is ascending against the axial strain, εa. It is efficiently mobilized forcing through strain applied. These condition is maintained right up to the end of test and tends to hardening behaviour.

At various effective stresses applied, the stress-strain curves is noticeable remains ascended to the end of 20% axial strain applied.

To examine in such a manner as to ascertain the elements or nature of the thing examined, specimens still does not showed signs of failure at any parts and it's still aren't happening. At this stage, a maximum of deviator stress at 20% of axial strain determined as maximum shear strength of peat, $\sigma_{d\ max}$. The shear strength inclines to the maximum axial strain associated with increases pore pressure during static loading. The shear strength of peat soil at 25 kPa slightly near to constant value due to the low stress applied which the shear strength recorded at 20% is 26.78 kPa.

Conversely at higher effective stress, the shear strength increase dramatically at 50 kPa and 100 kPa where, the shear strength tangibly at 39.97 kPa and 57.78 kPa respectively. This is show that, pressurizing of peat soil will increase its shear strength, which is often reflected in a higher effective stress. The higher the effective stress, the higher shear strength. So greater effective stress and therefore greater deviator stress.

The following stress-strain data indicates same results and behaviour for BSpt and PNpt as recorded in Table III. The typical behaviour apparently demonstrates same stress-strain properties of peat soil from disparate locations which is distinguishes by its shear strength. However, distinctive features of shear strength belong to various peat soils specimens in this research seems to be due to difference in particle size, degree of humification, circumstances of land-used activities and lack of equality or recognizably different in nature characteristics known as peat soil properties.

These conditions has been reported where, the undrained triaxial shear strength test on undisturbed of peat soil sample [12]. In particular way, there it's hard to establish maximum shear strength of peat soil evidently, with this in mind for this research, the final condition at maximum 20% of axial strain are referred to as a pseudo-critical condition. This condition stated influenced by the breakage and slippage of fibers [12] and continues change of pore water pressure and also happened at greater than 20% of axial strain.

Moreover, the increase in resistance seems to be higher for PNpt, compared to BSpt and PSpt. In essence, PNpt has the lowest liquid limit compared to BSpt and PSpt indicating perfectly plastic behaviour. For specimens with lower fibre content (BSpt = 37.72%) shows amidst shear strength compared to higher fibre content like PSpt at 53.23% notched lowest shear strength at an effective pressure of 100 kPa as shown in Table II.

These uncertain situations describes the origin properties of peat soil, which is they had concluded peat soil has peculiar properties from strong acidity and deficiency in both macro- and micro-nutrients with low bulk density associated with large shrinkage by desiccation [13]. However, there was no significant difference in static undrained shear strength pronounced in shape of stress-strain curves throughout the BSpt, PSpt and PNpt specimens.

In other words, as it were incline steadily against axial strain, the deviator stress also plots the stress-strain curves with the function of concave down. Furthermore, the curve plots describes situation with a grows quantity at toe to the knee point, then levels out to limiting value at 20% of axial strain where, these curves behaviour pronounces an exponential decay with increasing form as a result.

At the same time, it has been observed that none of specimens from PNpt, PSpt and BSpt exhibited quasi-steady state while during loading, the deviator stress kept increasing. Based on Figure 2, the slope of a straight-line stress-strain curve, one with a constant slope, has constantly notched a great difference between the results.

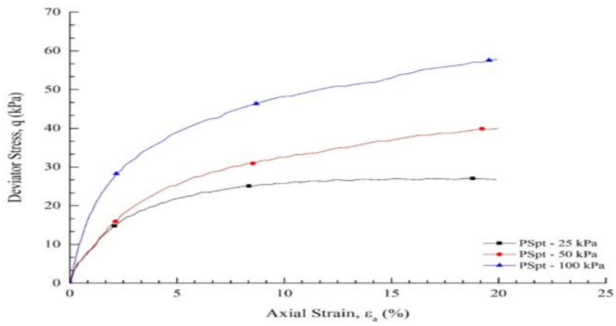


Fig. 2. Typical deviator stresses versus axial strain response for PSpt.

From the resulting elements of the stress-strain behaviour in static test tabulated in a consequential for the use of author in dynamic loading. Table III shows the demographic characteristics that indicates the maximum deviator stress for each specimen that had been carried out in this research.

These results indicates quite clearly that, PNpt at maximum deviator stresses, σd max, 25kPa, 50 kPa and 100 kPa were lying between ranges of 39.51 kPa, 61.83 kPa and 72.84 kPa respectively. PNpt has the highest undrained shear strength compared to PSpt and BSpt. From the author's observation, this occurred due to difference in fibre content and degree of humiciation of each specimen itself.

Table- III: Static Loading Properties

Soil Location	Effective Pressure σ' (kPa)	Maximum Axial Strain $\varepsilon_{a\ max}$ (%)	Maximum Deviator Stress, $\sigma_{d\ max}$ (kPa)	Average Deviator Stress, $0.5\sigma_{d\ max}$ (kPa)
PNpt	25	19.7784	39.5179	19.7589
	50	19.7077	61.8357	30.9179
	100	19.6914	72.8469	36.4235
PSpt	25	19.8885	26.7828	13.3914
	50	19.9667	39.9734	19.9867
	100	19.9329	57.7804	28.8902
BSpt	25	19.9189	27.2953	13.6477
	50	19.6503	50.1984	25.0992
	100	19.6421	59.0868	29.5434

D. Excess Pore Water Pressure

The stresses applied to peat soils for all specimens has generated pore pressure when running a triaxial test and displayed in Figure 3, typical pore pressure versus axial strain response for PSpt. The graph plotted shows excess pore water pressure, u against axial strain, ε_a. Results in Figure 3 shows general view of typical pore pressure versus axial strain response for PSpt plot 25 kPa, 50 kPa and 100 kPa during shearing loading in isotropic assembly.

Pore pressure is one of the formation properties that have a direct impact on shearing loading. Curves in Figure 3 shows the pore pressures for PSpt increased with increasing effective stress consistent with Figure 3 for BSpt typically.

The higher deviator stress, the higher pore pressure generated. Therefore, the effective stress is conventionally defined to be the subtraction of pore pressure. Meanwhile, for PNpt and BSpt specimens also notched higher deviator stress than PRpt and generated same patterns for pore pressures, PNpt seems like higher than PRpt accordingly. This same pattern has appeared in past studies [12].

The pore pressure parameters response for PNpt, PSpt and BSpt. As a matter of fact, the undrained shear strength of peat soil in trixial test proportionally increases with effective stress levels that applied as pore pressure does. The same history was discovered [12] and described the failure criterion as a linear relationship in stress-path.

As shown in Figure 3 typical pore pressure for PSpt, it can be clearly seen that curves are positively sloped associated with deviator stress. Under those circumstances, deviator stress and generation of pore pressure component is interrelated to one and another. Obviously, the deviator stress reflects the pore pressure behaviour.

Air and water-filled is easily trapped among hemic components as it is among peat structure. In that case, saturation of specimens observably is easier, this phenomenon have discouraged research on the research on effect of shear strength to the fibre distortion induced with loading for peat soil. Figure 3 examines the excess pore pressure response of peat typically for all specimens at 20% axial strain. Unsurprisingly, peat pore pressure behaves like other peat soil, and the peak of pore pressure pronounced at an axial strain of about 20% as summarized in Table IV. As has been noted, all specimens are generally same. Most compelling evidence, Figure 3 shows pore pressure versus axial strain for the undrained test is similar to the idea [12].

Table- IV: Pore Water Pressure Parameters Response for Peat

Soil Location	Effective Pressure, σ□ (κΠα)	Maximum Axial Strain εα μαξ (%)	Maximum Pore Water Pressure, u_{max} (kPa)
PNpt	25	19.7784	9.3
	50	19.7077	26.745
	100	19.6914	37.5
PSpt	25	19.8885	26.7828
	50	19.9667	39.9734
	100	19.9329	57.7804
BSpt	25	19.9189	9.5
	50	19.6503	24
	100	19.6421	38.29

The results showed that all undrained static shear strength tests are able to produce a pore pressure gradient where the delineation of pore pressure related to effective stress applied. Excess pore water pressure increased with stress applied. It has been observed during the test that, loading process take into account the excess pore pressure from undrained yielding of peat, which traditionally has change the pore pressure when peat is loaded to failure.

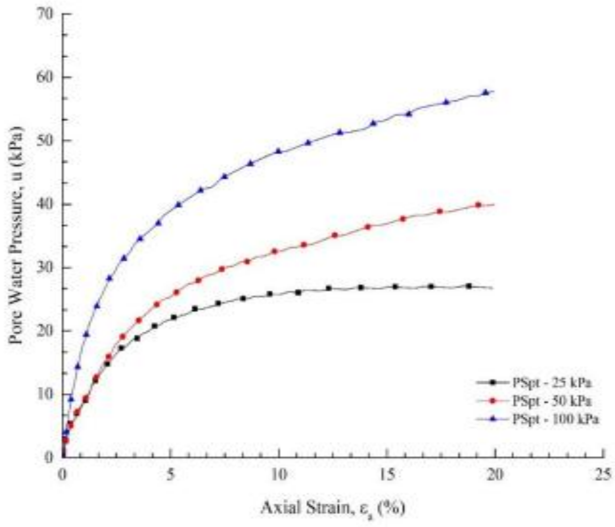


Fig. 3. Typical pore pressure versus axial strain response for PSpt.

E. Physical Changes of Specimen

In the course of undrained static loading, it has been anticipated that sample generates and build up pore pressure while indicating its shear strength and there is a change in sample shape occurred simultaneously. Under those circumstances, this changes of shape is monitored to ensure this triaxial test on peat soil is in consonance with earlier studies [4]. In relation to this research, mode of failure of peat soil observed closely and describes the important relevance between loading and changes occurred.

As a result, due to the load imposed on the peat specimen, it experiences physical changes. Physical changes are changes affecting the form of cylindrical shape of undisturbed peat specimen during static loading. A physical changes which is said in this research is intended in physical change involves a change in physical size and transformation of shape. In this case, peat specimen identically bulging after 20% axial strain reached or at maximum deviator stress achieved.

The diameter of sample increase while its height decreased due to encumbrances from loading process. This mode of failure are observed for all samples from PNpt, PSpt and BSpt unsurprisingly, it's an analogous to triaxial pattern on peat soil and similar to all samples.

This mode of failure categorized in the third category and recognized as plastic failure with well-expressed lateral bulging [5] failure classification type. Figure 3 showed the failure mode of peat soil in this research. The Figure 4 shows that peat behaves radically in static. After static loading test, the cylindrical shape of peat specimen changed to the plastic failure [12].

This is happened due to the load that imposed to the specimen in shearing test for the strength testing. This condition clearly showed that, restructuring of peat fibre structure occurs significantly that makes changes in pore pressure, reinforcement and affected to the deviator stress and volume changes [15]. The shape observed more round and bulbous. It has been observed that, static loading giving more impression and stress to the peat soil.

As has been noted, from

this changes also can be explained that, peat soil imposed with loading responded by showing changes to the restructuring fibre and soil physical.

F. Restructuring and diameter change

Physical changes are discussed in this section specifically to the displacement, volume change, area and diameter changes in peat specimens. On the other hand, with the initial hypothesis which is discussed previously where restructuring of peat fibre caused by loading action from static and dynamic activities, this research alternatively observed the changes towards loading on peat soil.

(a) PNpt-100 kPa-1.0Hz before Shearing

(b) PNpt-100 kPa-1.0Hz after Shearing

Fig. 4. Failure Condition of Peat Soil.

Physically, the changes in peat shape after loading contributes in restructuring peat fibre and degradation of shear strength are discussed in this section. Figure 5 shows typical axial displacement (mm) and deviator stress (kPa) versus Axial Strain (%) for peat sample PNpt - 100 kPa. The specimens had initial diameter of about 50 mm and height is 100 mm. Final measurement of peat diameter appeared increased to the increment of axial strain. As regard to all samples of PNpt, PSpt and BSpt, this is happened due to the load that imposed to the specimen in shearing test for the strength testing.

Figure 5 shows the typical current area change, Δ_A (mm2) and Diameter Change, $\Delta\varnothing$ (mm) versus Axial Strain, ε_a (%)for peat sample PNpt - 100 kPa. Table V expresses, in absolute and relative terms, the summary of physical changes of soil sample for entire specimens from PNpt, PSpt and BSpt. PNpt recorded additional diameter almost 5.1 mm for both effective stress makes the final sample bulging to 55.1 mm.

BSpt at 50 kPa showed slightly rudiment were almost 5.71 mm additional diameter makes final shaped transformed to 55.71 mm transformed as shown in Figure 4. The cylindrical shape of peat specimen changed to the plastic failure [4]. From Figure 5, it can be seen that displacement of sample 19.7 mm nearly or equal to 20% of axial strain applied for each sample. Aligned with that, the development of deviator stress is parallel with increment of axial strain.

The deviator stress observed reach maximum peak 72 kPa at 14.20% axial strain and concave down to softening behaviour expressing failure characteristic. This means that, change clearly occurred and more pronounced on physical changes when specimen loaded and changed due to compression of loading.

Consequently, the initial area, A_0, 1963.50 mm2 expanding 435.36 mm2 making it bigger to 2398.86 mm2. This area expansion is related to bulging phenomenon as discussed in previous section and depicted in Figure 4. With attention to volume change, this research has carried out in undrained triaxial condition. Refer to Figure 6, there is no volume change occurs. This is explained due to it drained condition where, no valve open during static loading and water is not dissipated from specimens to make it remained unchanged and no volume change measured. In essence, no volume change occurred during undrained static triaxial test.

Volume change does not occurred in undrained monotonic test. In a moderate load increment, it may lead to large volume changes that shows high compressibility [15]. Eventually, physical changes happened continuously up to the maximum axial strain applied. Table V presents physical changes of peat soil sample, evaluated for all samples from PNpt, PSpt and BSpt. Diameter change increased dramatically up to the end of 20% axial strain. Parallel with diameter changes, followed with current area change climb up gradually. On the whole, loading process gives impact to the physical changes and restructuring peat specimens.

Table V summarized the associated parameter changes governed by loading action on the peat specimen. The initial height of specimen are uniformly prepared at 100 mm. Affected to loading process, the height of sample decreased gradually nearly to 20% likely the axial strain. In general, displacement of peat brought to decrement from 18.6 mm (PNpt – 50 kPa) minium to the 19.5 mm (BSpt – 50 kPa). In brief, displacement takes various differences due to its internal friction of fibre and index properties.

Table - V: Physical Changes of Soil Sample

Sample / Effective pressure	Initial Height, H_0 (mm)	Displacement Change, Δ_H (mm)	Diameter Change, $\Delta ø$ (mm)	Maximum Current Area Change, Δ_{Amax} (mm^2)
PNpt – 25 kPa	100	18.7252	4.3364	2256.686
PNpt – 50 kPa		18.6503	5.4487	2190.048
PNpt – 100 kPa		18.7253	5.5099	2210.905
PSpt – 25 kPa		19.4387	5.7302	2341.344
PSpt – 50 kPa		19.0803	5.6286	2240.354
PSpt – 100 kPa		18.7532	5.5221	2164.170
BSpt – 25 kPa		18.0253	5.3150	2007.868
BSpt – 50 kPa		19.4387	5.7177	2391.332
BSpt – 100 kPa		18.9999	5.3224	2230.278

G. Computed Tomography (CT-scan) analysis

This research enhanced with Computed Tomography (CT-scan) analysis to discover the existence of void spaces that governed peat shear strength. Figure 7 shows CT-scan images diagnostic where the initial prepared peat or undisturbed specimen represented PNpt sample (Figure 7a) without loading effect before triaxial testing conducted have been scanned in CT-scan apparatus and PNpt sample subjected to static monotonic triaxial test is scanned (Figure 7b) in 2D images.

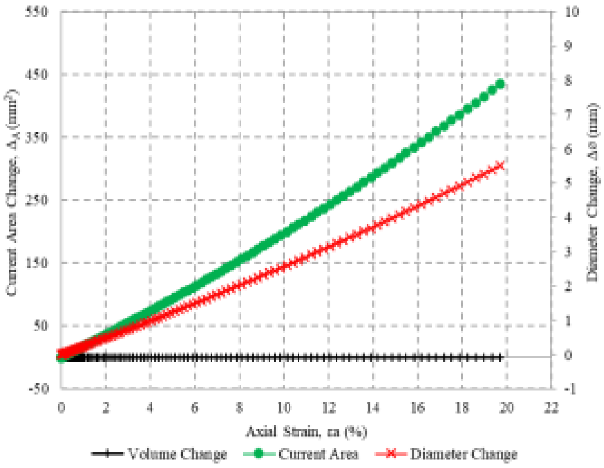


Fig. 5. Typical Axial Displacement (mm) and Deviator Stress (kPa) versus Axial Strain (%) (PNpt - 100 kPa)

On the subject of void and pore spaces existence in peat specimen, it clearly can be seen that initial scanned specimen as shown in Figure 7a indicates more voids spaces in undisturbed sample through vertical cross section imaging process attached with rubber membrane. The pore and void spaces showed in different image density where, darker images in sample is formed by air or voids and pore spaces and brighter images in membrane rubber indicates high density that formed solid material or identified as peat.

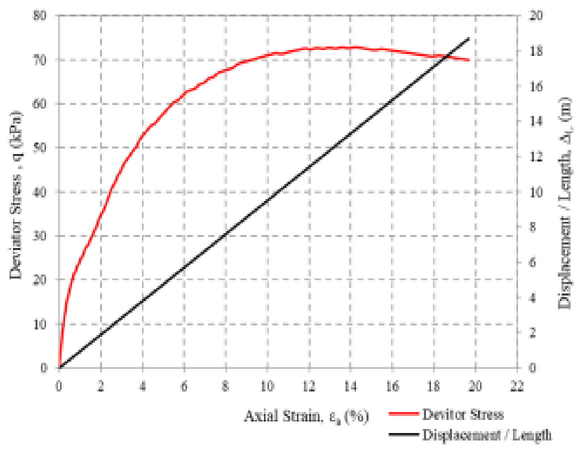
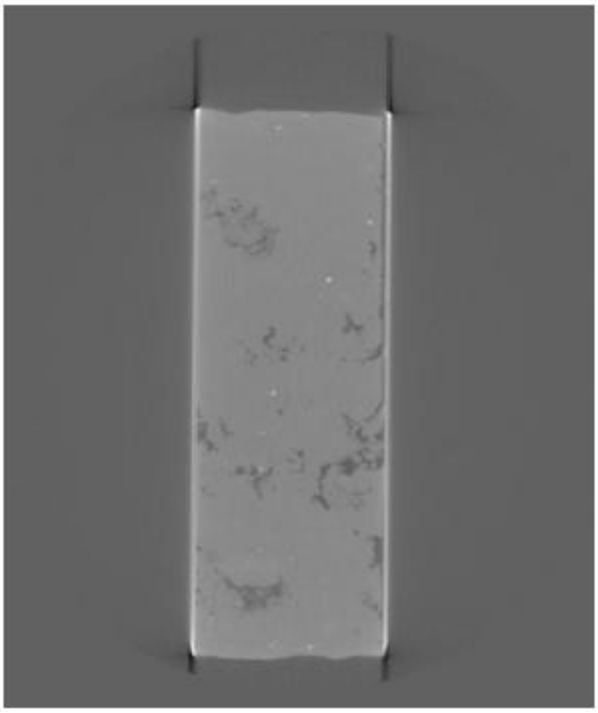
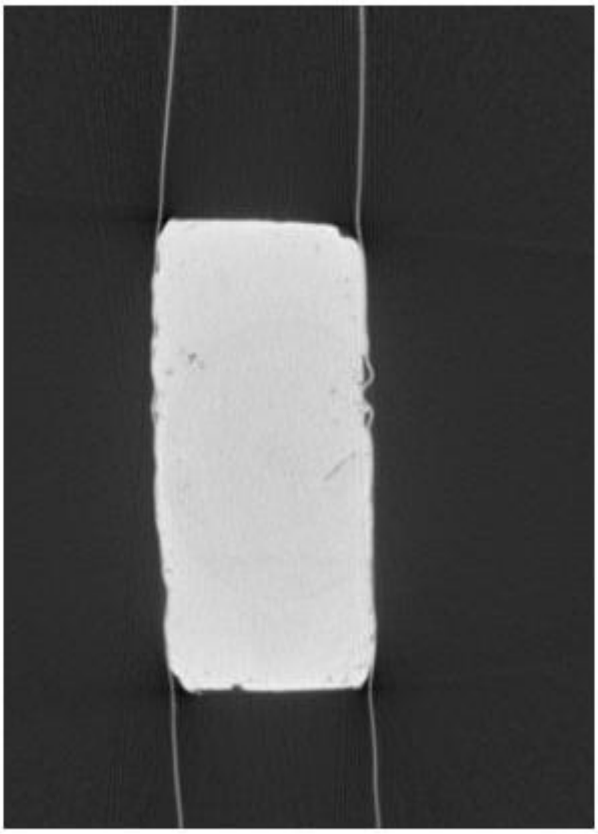


Fig. 6. Typical Current Area Change, Δ_A (mm^2) and Diameter Change, $\Delta ø$ (mm) versus Axial Strain, ε_a (%) for peat sample PNpt - 100 kPa.

As a result, due to static loading, it has gives significant impacts to the peat soil specimen. Figure 7b shows pore and void spaces removed gradually and peat specimen as though to compaction process. No shear plane was discovered in this image and sample experience reshaping from cylindrical shape to plastic failure shape.



(a) Initial prepared PNpt sample for triaxial test



(b) PNpt sample after static.

Fig. 7. CT-scan images diagnostic

IV. CONCLUSION

The findings presented in this research demonstrates the potential for loading in influencing the static shear strength in peat soil. Apart from that, the static monotonic triaxial test are carried out to establish the stress-strain relationships as well as to obtain the particulars of maximum deviator stress at required effective stress applied for the static loading uses and established static parameters. At various effective stresses applied, the stress-strain curves is noticeable remains ascended to the end of 20% axial strain applied. Consequently, datum and amplitude determined accordingly from stress-strain curve.

On the whole, loading process gives impact to the physical changes and restructuring peat specimens. Pore pressure

An increase in effective stress, affected pore pressure decrease in result. During shearing process, there is no volume change are disclosed. However, result from 2D CT-scan shows the pore between peat particles diminished in volume after static loading. This is show that, pore pressure behaviour are parallel to diminish process during static loading.

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