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YOUNG'S MODULUS OF PEAT SOIL UNDER CYCLIC LOADING

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ABSTRACT: Peat soil classified as high organic content with diverse range of fibers, distinctive intrinsic properties with low shear strength. The behaviour of peat soils under dynamic loading conditions has been studied. Therefore, a series laboratory of cyclic triaxial test on peat soil carried out to determine the effect of cyclic loading to the peat soil behavior after subjecting to cyclic loading is presented. In this study, the frequencies applied for the dynamic testing on the peat soil samples were focused and simulated on traffic vehicle loading frequencies, earthquakes and machine operations. Peat soil sample used from Parit Nipat, Malaysia (PNpt) with natural moisture content, m = 603% and liquid limit of w_l = 231%. A series of undrained cyclic triaxial test were performed on undisturbed peat soil sample under isotropically consolidated specimens. In addition, the strain of amplitude applied is 0.1% to investigate the effectiveness of large strain amplitude response by allowing the generation of cyclic pore pressure and developed stress-strain cycle during cyclic loading. Correspondingly, the undrained Young's modulus of the undrained shear strength subjected to cyclic loading in this study in the range of 60 to 70 for hemic peat soil. The specimen loaded into specific frequency causes in reduction of Young's modulus related to stiffness and more pronounced in softening behaviour. The hysteresis-loops profile with regard to E parameters from 1^{st} cycle to 100^{th} cycles of Young's modulus, E (MPa) for PNpt degrades precisely to an applied effective stress, 0.4 MPa (25 kPa) and 0.4 MPa (50 kPa). Cyclic loading frequencies resulted in decreases of the Young's Modulus of peat soil that related to stiffness and more pronounced in softening behaviour. The result indicates that a reduction effect in the stress-strain cycle occurs in a peat soil from the initial stage of cyclic loading towards the end of 100^{th} cycles due to the repeated loading application.

Keywords: Peat Soil, Cyclic Loading, Young's Modulus, Stress-strain, Stiffness

1. INTRODUCTION

Peats which are formed from the accumulation of organic materials over thousands of years, are characterized by its high-water content, high compressibility, low shear strength and stiffness [1]. Peat classified as high organic content under conditions of almost permanent water saturation in most areas in Malaysia [2][26]. As with mineral soils (silt and clay), the settlement parameters of peats such as the consolidation settlement can be determined from a standard incremental oedometer test [3]. The researcher discovers at the base of the 2 m thick layer with water level at ground level, the effective stress is only about 2 kPa. They compared it with an inorganic soil where the layer is of the same thickness and water level as well, would impose a 20 kPa stress this is almost 10 times greater than the peat soil. This shows that, peats have much lower strength.

Some confusion indicates in peat strength the potential of peats to be treated as a frictional material like sand or cohesive like clay [4]. It is almost the same as the assumptions by [5] where they explain that surficial peats are commonly encountered as submerged surficial deposits. This is because of their low unit weight and submergence, as such deposits develop very low vertical effective stresses for consolidation and the associated peats exhibit high porosities and hydraulic conductivities that are comparable to those of fine sand or silty sand. [4] also states that peats with such materials can be expected to behave like "drained" soils such as sand when subjected to shear loading. On the other hand, soils with consolidation shows a rapid decrease in porosity and hydraulic conductivity becomes comparable to that of clay.

Assessment on the geotechnical properties of peats is made complex by its high-water content and compressibility, as well as its organic composition [6]. Acknowledging the high compressibility of peats and the need to break fibres during sampling makes obtaining high quality samples difficult and disturbed samples may display non-conservative parameters of stability in the assessments especially when it comes to an increased in strength. Researcher in their study stated, the applicability of testing itself depend on peat conditions. On the other hand, [6] affirmed that, all shear strength tests should be performed on undisturbed samples, either consolidated drained or consolidated undrained with measurement of pore water pressure. The increasing need for regional development has led engineers to find safer ways to construct the transportation infrastructures on soft soils.

Soft soil is not able to sustain external loads without having large deformations [29]. In pavement engineering, be it highways or runways, a pavement encompasses three important parts namely traffic load, pavement and sub-grade [30]. Traffic load is generated from tire pressure of vehicles and or airplane wheels on the surface of the pavement. There are two (2) types of traffic loads that needs to be taken into consideration during the designing and analysis stage in pertaining to the problems that generally relates to the static and dynamic loading [31]. The understanding of the static and dynamic behaviour of peats is still embryonic and needs intensive understanding to overcome the issue on peat soils [34].

According to [7] cyclic triaxial testing indicates that the modulus reduction and damping behaviour of peats were significantly influenced by strain amplitude and effective confining pressure and was weakly influenced by loading frequency and over consolidation ratio. Apart from that, [8] elaborated that the type of dynamic loading in soil or the foundation of a structure depends on the nature of the source producing it.

Moreover, dynamic loads vary in their magnitude, direction or position with time. Furthermore, the characteristic of static load differs in accordance to the dynamic loading in which the static loading is produced from the foundation which carried the load in a large amount of a structure in a constant magnitude and direction generated from dead weight of the structures.

It increases with increasing magnitude of cyclic shear strain, whereas shear modulus decreases with increasing magnitude of cyclic shear strain. It is also known that dynamic properties of soil are influenced by the plasticity index, void ratio, relative density as well as the number of cycles [9]. The foundation must be safe in both the usual static loads as well for the dynamic loads imposed by earthquakes and therefore the design of either type of foundation needs special considerations compared to static cases [32].

The response of a footing to dynamic loads is affected by the nature and magnitude of dynamic loads, number of pulses and the strain rate response of soil. To account for the effect of its dynamic nature of the load, the bearing capacity factors are determined by using dynamic angles of internal friction which is taken as 2^o less than its static value [10]. Soil behaviour under dynamic loads have attracted the attention of several researchers. Thus, the post-cyclic behavior is measured by the effect of frequencies applied [11].

In their study. [12][27] also stated that the symmetrical loading represents level ground conditions in the free field, where no initial static shear stresses act on the horizontal planes of the soil's elements. In many major projects involving earth dams, embankments or slopes, however, soil elements are subjected to static, driving shear stresses on the horizontal planes before the earthquake loading effect is developed. Strain-controlled tests were preferred instead of stress-controlled tests [13]. 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.

The objective of this study reported herein and suggests that the Cyclic loading frequencies resulted in decreases of the Young's Modulus of peat soil that related to stiffness and more pronounced in softening behaviour. The result indicates that a reduction effect in the stress-strain cycle occurs in a peat soil from the initial stage of cyclic loading towards the end of 100^{th} cycles due to the repeated loading application. Adequate analysis of effect cyclic loading on peat soil behaviour changes contractively so as to gain insight into the response of cyclically loaded of undisturbed peat soil.

2. METHOD AND TESTING

The cyclic test has been conducted by using undisturbed peat soil specimen. The sampling location was located in Parit Nipah, Malaysia and tagged as PNpt. Ground water table was found at the depth of less than 1 meter during the sampling. The soil was excavated to a depth of 0.5 m below the ground surface and numbers of tube sampler with the size of 50mm diameter and 100mm height were pushed slowly into the soil. The undisturbed peat soils were waxed both at the end of the tubes and sealed with the aluminums and plastics to prevent the loss or gain of moisture. Jolting during transport was avoided. Cyclic Triaxial machine or popularly known as Dynamic Triaxial Testing System (ELDYN) with load range 5kN was used in the determination of cyclic loading of PNpt using an electronic controlled system according to ASTMD-5311. The specimens were mounted on the base of the pedestal sealed with a rubber membrane and ends with filter paper and porous stone at each end. Sample placed in highly accurate dynamic electro-mechanical actuator.

All samples were consolidated to 25 kPa and 50 kPa effective confining stress and cyclic tests was performed under different frequencies range of 2.0Hz in order to determine the shear strength by differentiate the cyclic loading and frequencies effects.

Index properties tests conducted on undisturbed specimens. The specimens were subjected to 100 cycles for all specimens with same frequency applied for each sample. The frequencies applied is 2.0 Hz.

The dynamic parameter that has been used by [14] with a depth sample of 0.5 m below ground surface. The researcher explains the significance of choosing the parameters. Effective stress that have been applied represents peat layers from a certain depth where average stress is carried by the soil and simulated to similar on-site condition. For the axial strain, a 20% pressure is set as marginal condition to represent a certain failure percentage or maximum deviator stress happening before yielding.

Peat specimens are sheared at 0.1 mm/min according to [14], as this is due to the material conditions that are very soft and sensitive and related to the coefficient of permeability, thus, the researcher recommends to use 0.1 mm/min as constant strain rate. 100th cycles are used as the effect from the operation of machineries or simulated earthquake motion. In this research, the author has implemented this parameter and applied a dynamic loading by using various frequencies as stated in current study.

The typical test frequency for cyclic triaxial testing referred to the previous study as suggested by [15]. This information becomes a bench mark to determine the ranges of this frequencies applied in this study.

The lowest typical test frequency for wave and wind action loading ranges from 0.1 to 1.0 Hz and earthquakes are about 1.0 Hz, while rail transit is more than 2.0Hz. Thus, this research aims the frequencies of 1.0Hz, 2.0Hz and 3.0Hz to be applied and representative of the mentioned loading type.

It would seem that in this situation, a sustainable development of knowledge that meets the needs of the present engineering design knowledge without compromising the ability of the changes that take place in dynamic behaviour for betterment in geotechnical engineer design need to be done.

By all means, the dynamic loads will affect the soil behaviour and particularly significant in soil shear strength where pertinent parameters have to be observed.

consequence of high strain level, frequency and stress applications a chain reaction from large strain amplitude or deformations. In this research, the frequencies and stress applied are performed on cyclic triaxial test. Triaxial test is a common procedure, as it allows mechanical properties and strength parameters to be determined for many deformable soil materials. The cyclic triaxial and cyclic simple shear test is relevant test apparatuses which can reproduce these kinds of stress conditions accurately [7].

In this context, the internal peat material frequency to simulate the dynamic loading in testing program are difficult to measure. Peat acknowledged with high water content with fibrous condition making it harder to predict. There is still a lack of knowledge in determining the natural frequency of soil [16]. In cyclic triaxial test, the parameter to be taken into account in the analysis of dynamic loading characteristic is the Young's Modulus, *E* (MPa).

The parameters obtained from dynamic loading behaviour with the aids of the stress-strain loops, it's clearly understood that the cyclic triaxial is the slope from the extreme points of the hysteresis loop from the deviator stress versus the axial strain graph gives the value for the modulus of elasticity or Young's modulus (E) as in the Equation 1. Unfortunately, it's requires the knowledge of poisons ratio (μ). According to [34], at low strain amplitudes, the shear modulus is high, but it decreases as the strain amplitude increases.

$$E = \frac{Cyclic\ deviator\ stress, \sigma_c}{Cyclic\ axial\ strain, \varepsilon_c} \tag{1}$$

3. RESULTS AND DISCUSSIONS

Study was carried out in Batu Pahat, Malaysia. As seen in Table 1, the index properties of PNpt fairly significant that natural moisture content for PNpt is 603%. The natural water content of peat in Malaysia ranges from 200 % to 700 % and with organic content in the range of 50 % to 95 % [17]. Therefore, the recorded values for PNpt fulfill this statement. Specific gravity recorded 1.3 were within the range as reported by [17]. In addition to basic characterization tests, the Parit Nipah peat identified as Hemic.

Figure 1 shows the GDS Enterprise Level Dynamic Triaxial Testing System (ELDYN) apparatus with system connected to the dynamic data logging. The electro-mechanical actuator controlled from computer system by using GDS data. Cell pressure injected through air pressure controller (ADVDPC) up to the maximum capacity of cell pressure to 2 MPa. Sampling setup tools and systems showed in Figure 1. Figure 2 shows the position of peat, membrane and rubber O-Rings embraced in bottom pedestal.

Figure 3 shows typical cyclic behaviour of peat soil (PNpt) at an effective stress 50 kPa with frequency applied of 2 Hz, where normalized deviator stress plotted and stress-strain relationships obtained in the course of the undrained cyclic loading on PNpt. The normalized deviator stress (i.e. deviator stress divided by two times consolidation stress or known effective stress).

Table 1 Index properties of Parit Nipah peat soil (PNpt)

Properties	PNpt
Natural moisture content *m*, %	603
Liquid limit w_l, %	231
Specific Gravity, G_s	1.3
pH test	4.0
Organic Content, %	95.6
Fiber Content, %	32

Axial strain versus time is monitored during undrained cyclic loading as shown in Figure 3 to confirm the appropriate behaviour of cyclic loading. As suggested by [18], the determination of cyclic behaviour, following the end of undrained cyclic loading, the drain valve remained closed and undrained cyclic loading was observed as a function of time.

Confirming that the undrained cyclic behaviour in strain-controlled method with one-way loading occurred in this research is similar to the proposed data by [18]. This is showed that, these findings are in line with valid method of application of dynamic loading condition. Put in other words, it reads thus, which methodological testing is appropriate for this research on dynamic formations to study the effects to post-cyclic shear strength.

Identically, Figure 3a shows the frequency 2 Hz with the normalized deviator stress. 2 Hz has reached an equilibrium at the early stage of loading phase until the end of test at 100th sec. or completed 100th cycles. At this stage, there is no any changes towards normalized deviator stress against time (s) noticed. It is uniformly loaded up to the end of test. As comparison, 1Hz and 3Hz frequencies was applied as shown in Figure 3a. On the contrary, it has been observed and more pronounced at larger frequency,

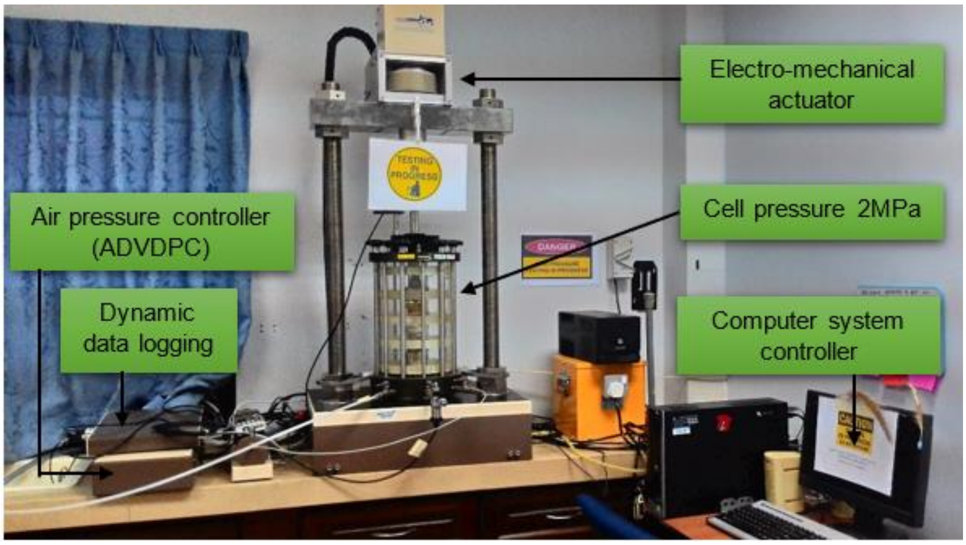


Fig.1 GDS Enterprise Level Dynamic Triaxial Testing System (ELDYN)

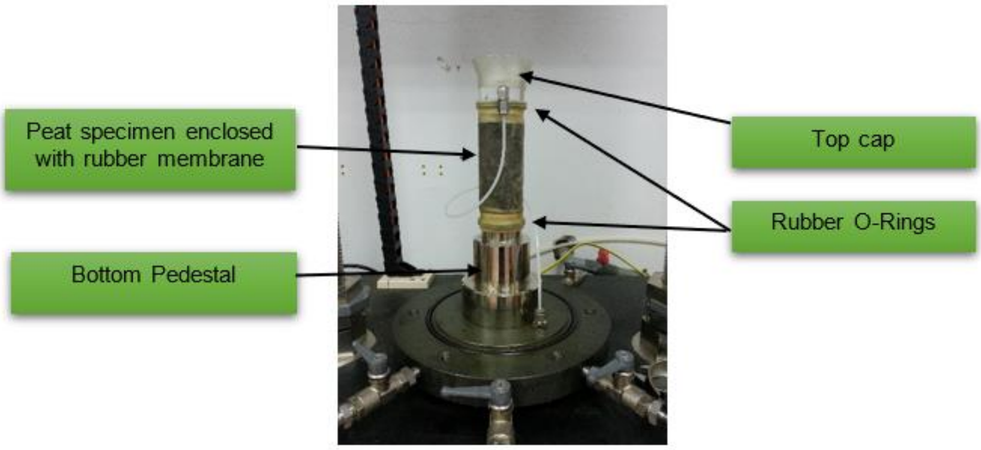


Fig.2 Dynamic triaxial specimen setup

the more disorderly and inconsistent cyclic behaviour notched. In short, the higher frequency applied, the more irregular behaviour occurs especially for frequency more than 2 Hz to 3 Hz. Undoubtedly, at 2 Hz frequency (Figure 3a) the peat soil specimen observed closely and found that the sample reached a stable condition and an equilibrium at 35 sec or precisely at 70th cycles (section B-B).

With these means, during the loading and unloading process, dilative behaviour observably happened and dilation continues into the extension loading phase to the contractionary phase and reached an equilibrium. In addition, these conditions are noticeable to the 3 Hz loading phase, the equilibrium of loading phase uniformly achieved on section A-A at 30 sec of loading time or at 90th cycles. In this study, on 2Hz will be considered for post-cyclic study.

Loading time is significantly reacted differently, the higher frequency applied, the maximum loading rate reached quickly. At the meantime, axial strain applied and the deviator stress reduced. In a like manner, these findings are in line with other previous studies.

When the dynamic test is commenced after half shear or reaches datum, the dynamic stress induces an additional axial stress on the specimen. This statement is in line with finding that observed by [16].

Taking into account, as described by [18] and to rephrase it, at this stage [19] states that, cyclic shear strains would lead to strain softening, particle structure breakdown and a rapid deterioration of stress-strain-shear strength characteristics up to the plastic threshold.

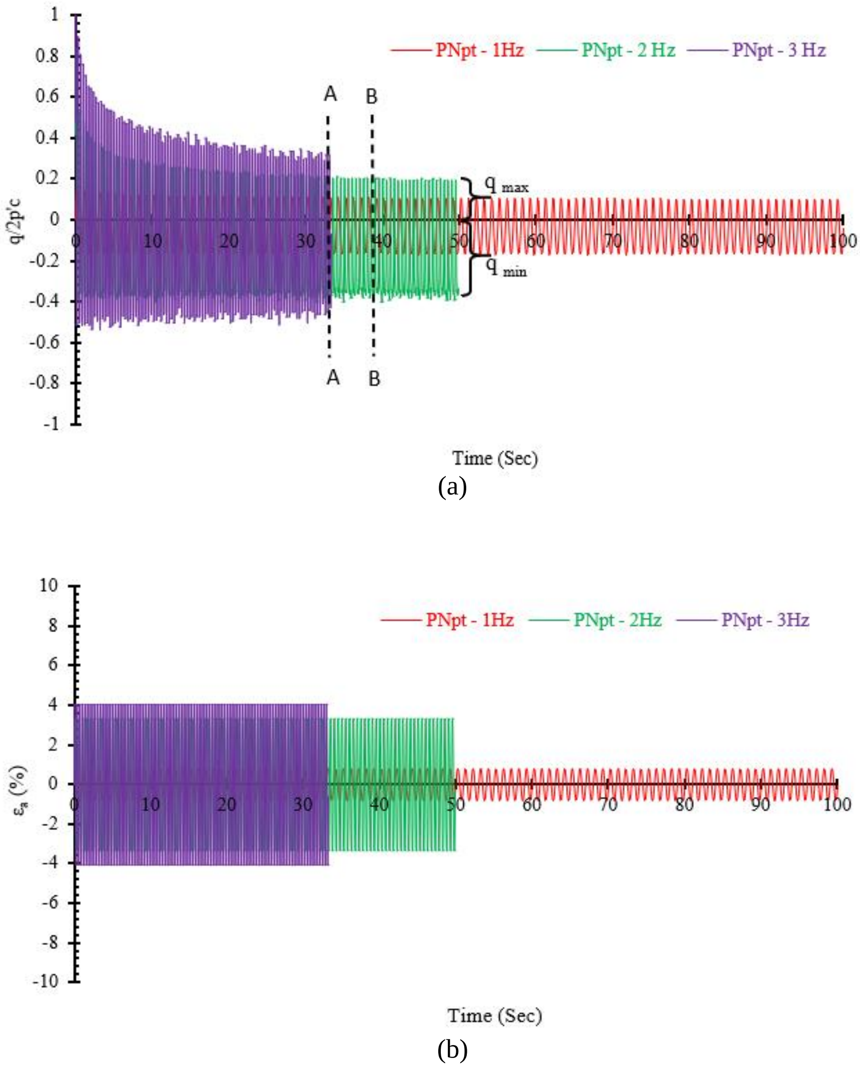


Fig.3 Typical Cyclic behavior of peat soil (PNpt) 50 kPa Effective Stress with various frequencies. (a) q/2p'c Vs. Time and (b) ε_a Vs. Time.

The transformation phase point at section A-A and section B-B in Figure 3a defined herein is similar to that defined by [18]. Section A-A and section B-B defined as steady state condition as defined by [20]. The time between loading and unloading in cyclic phase, the response becomes dwindle and contractive at 2 Hz and 3 Hz.

After 70 and 90 cycles, the behaviour of peat soil samples reaches a steady state condition as previously explains or called alternate phase by [20]. Clarification on this matter had explained by [20] and states that, dilation and contraction are develop and move as a main part of alternate phase. Dilation happened during loading and contraction occurring during unloading process.

Furthermore, adopts this approach to Figure 3a and Figure 3b, distinctive profile of deviator stress during cyclic loading were identified and axial strain against time. Figure 3b shows a constant axial strain which no alteration between positive and negative axial strain and immediately, the deviator stress reduced (Figure 3a). Evidently, this phenomenon was identifiably associated with stiffness or modulus elasticity, *E* and degradation of dynamic shear modulus.

Although, [18] has discovered these circumstances and states that, this phenomenon affects the soil stiffness and degrades as evidenced to the reduction in the shear stress to achieve the uniform strain amplitude. To the end that, from these findings and qualitative viewpoint the stress-strain behaviour of peat soil in this research is comparable to past studies, there is no liquefaction observed in this research, since in peat soil, liquefaction does not happen. This result is consistent with the general knowledge that liquefaction does not take place in peat [33].

In order to investigate post-cyclic shear strength degradation, this research has carried out testing to inspect the relationships between dynamic characteristic to the degradation behaviour of post-cyclic for peat soil. A typical stress-strain result plots of peat soil represented by PNpt specimens showed in Figure 4 and Figure 5. As expected, the initial yield locus is plotted to be in elliptic as presented by [21] in their research on dynamic behaviour of peat soil.

An elliptical shape of dynamic behaviour drawn based on maximum deviator stress over preconsolidation pressure. The elliptical profiles are similar to the shape which are commonly observed in hemic peat presented by [21] and [22].

Compared to clay soil, these elliptical loops profiles of peat soil surprisingly exist as irregular eclipse shape. In fact, it is a different parent material. Peat formed from humus, plants and decaying process and accumulation of nature activities. Significantly, fibrosity, spongy, and inconsistent of properties explains the occurrence of irregular shape.

However, in order to investigate the inter-cycle strength degradation, Figure 4 and Figure 5 illustrates the normalized deviator stress versus axial strain at various effective stress to draw a hysteresis-loops of peat soil for PNpt. Figure 4 and Figure 5 represents effective stress at 25 kPa as comparison to 50 kPa. Figures 4 and 5 drawn for all 100 cycles of stress-strain behaviour, while Figures 4b and 5b for 1st cycle and Figures 4c and 5c drawn for 100th cycles of stress-strain hysteresis-loops.

This is done to investigate of what is going on from start to finish the cyclic loading and to evaluate the parameters involved which is contributes to the reduction of post-cyclic shear strength. In the event that, hysteresis-loops are measured to confirm that there are contraction and dilatation which is suspected as the main cause.

Seeing that, the analysis of hysteresis-loop leads to determination of Young's modulus, *E* (MPa) and dynamic shear modulus, *G* (MPa) for PNpt, for this study, only Young's modulus, *E* will be studied. In line with [23] which inspected the deformation modulus (*E*) of soil before and after application of resin.

The elliptical profiles of hysteresis-loop illustrated in Figure 4 and Figure 5 shows rapid expansion to from size in general. In the hope that, analysis of hysteresis-loop contributes to the understanding of dynamic behaviour on peat soil expressly, the elliptical profile develops outgrow towards frequencies applied from lower to higher.

Significantly, growth in parallel with increasing of effective stress. Specifically, the hysteresis-loop developed in disorderly and unsymmetrical form. The higher effective stress applied; the more pronounced disorderly profile formed. Overall, the hysteresis-loop is still in elliptical profile that allows *E*, analysis can be determined accordingly same with [19] observation.

Another key point to the dynamic behaviour of peat soil in this research is, the hysteresis-loop sizes are observably reducing from 1st cycle to the 100th cycles. Under those circumstances, this phenomenon seen tend to the transformation phase or steady state condition as mentioned in previous section. On the other hand, in the 1st cycle of hysteresis-loop, it more pronounced where the shape is more vertical or in other words, directed to the "northeast" condition different from 100th cycles where the profiles seen moving tends to horizontal or noticeable directed to the "east-west" looped especially for bigger frequency applied. From observation from the testing that was carried out, the higher frequency or 2 Hz or more need a minimum duration to ensure the radial equilibrium to the sample as identified at 70 sec and 90 sec respectively.

Notwithstanding, the shape changes observed in hysteresis-loops is also related to the equilibrium of specimens. [20] states that, this phenomenon attributed to deformation within the first load cycle and gradual strain-hardened.

This means that, the deformation or hysteresis-loops size reduction is related to the dilatation and contraction during loading and unloading phase where at the end of cycle load it tends to gradually transformed to strain-hardening characteristic. On this side, [24] observed that, the applied strain exceeds the degradation cyclic threshold and relates to the equilibration at start of cyclic loading [20].

Apart from that, all Figures 4 and 5 has develops similar hysteresis-loops behaviour which is tends to positive and negative saturation side profile. In the foreground, the residual magnetism seen surpasses positive and negative lines in axial strain to develop space and with varying sizes from coercive forces.

In the first place, peat soil characteristics and index properties are often seen as conclusive causes to the disparity's behaviour of dynamic loading. At different point, as has been noted which is from 1st cycle to 100th cycles, the coercive forces make the sizes become smaller.

Equally important and significant, the diminution of hysteresis-loop size leads to the reduction of Young's modulus, *E* and dynamic shear modulus, *G*. Upon achieving stress equilibrium, had been notice that decrease in stress-strain plots (Figures 4c and 5c). This implies that the frequencies and effective stress had significant influence on the normalized deviator stress and axial strain.

With this intention, for each of the specimens tabulated in the first column on Table 2 for 1st cycle and 100th cycles together, all the effects hitherto observed have the same sign and profile for all samples of PNpt. Table 2 represents the relationship of Young's modulus, *E* (MPa) for all samples. The formulae been used for extending the parameters obtained from dynamic loading behaviour in Table 2 as described in Equation 1 and Figure 4. In This case, Table 2 represents the quantity tabulated with Equation 1. The parameters of the Young's modulus computed and tabulated in an arithmetic for the use of author's further analysis. Another, significant factor in Young's modulus determination is Poisson's ratio, μ = 0.5 used for saturated undrained peat.

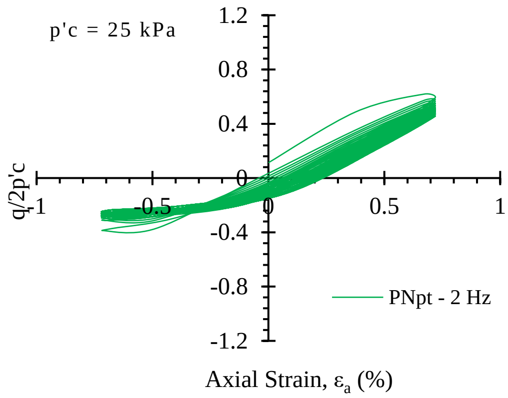
The results for each condition of specimens and frequencies states are tabulated. Given, the hysteresis-loops profile with regard to E parameters from 1st cycle to 100th cycles, it is quite surprising that, Young's modulus, *E* (MPa) for PNpt degrades inconsistently, somewhat important where, 1st cycle for PNpt specimen at 2 Hz, degrades precisely to an applied effective stress, 0.4 MPa (25 kPa) and 0.4 MPa (50 kPa).

It is important to note however, in the same regime of PNpt at a frequency applied 2 Hz, the Young's modulus of peat decreases accordingly to the effective stress applied. The sentiment expressed in the Table 2, embodies the view that, the Young's modulus decreases with effective stress. Continuing its downtrend, the decrease is most marked as distraction and fibre breakage approaches. This point is also sustained by the work of cyclic loading that leads to the strain softening as analysed in previous section.

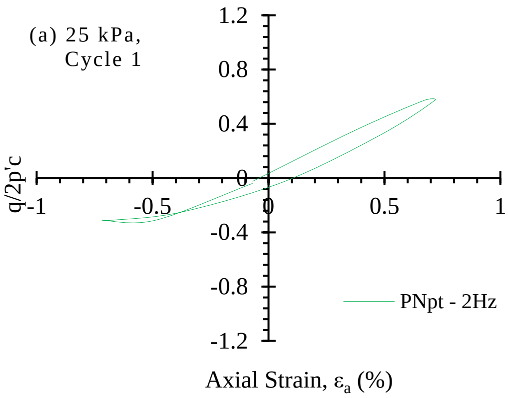
There is also, however, a further point to be considered in 100th cycles. To be able to understand, as a function of hysteresis-loops analysis, and as discussed in Figures 4 and 5, the comparison had been made between 1st cycle to 100th cycles.

Whilst the discussion in the preceding paragraph, where the hysteresis-loops profile diminishes, the initial hypothesis of this phenomenon discussed previously and author suggested that the course of events is the following: 1st cycle to the 100th cycles of dynamic loading resulting in reduced hysteresis-loops profile size.

The specimen loaded into specific frequency causes in reduction of Young's modulus related to stiffness and more pronounced in softening behaviour. The softening tends to split the cycles from uniform in the beginning and reduced the sizes to an end 100th cycles. Proposed method of calculating the residual deformations of granular materials by cyclic loading [25] but has not been adapted for peat soil in this study. Undoubtedly, Young's modulus act as an elastic soil parameter and a measure of soil stiffness. Under those circumstances, in this research of peat soil from PNpt observed that, from the computed elastic parameter, there appears then to be a deceleration in the growth of Young's modulus that leads to deficiency of stiffness and of elastic behaviour in the range of this research's peat soil. This study had observed that, load and stresses applied to peat specimens tends to change size and shape as strains occur. The reduction of hysteresis-loops profile size and shape is related to this where it happens due to changes of stress and strain.



(a)



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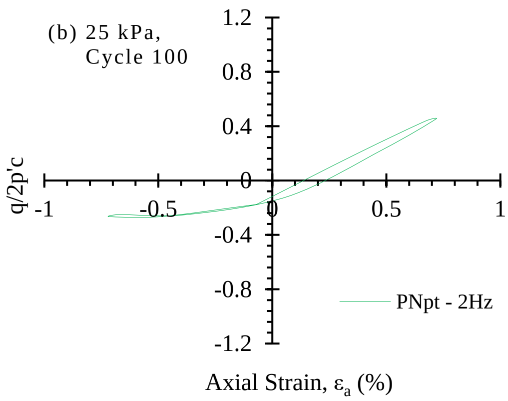
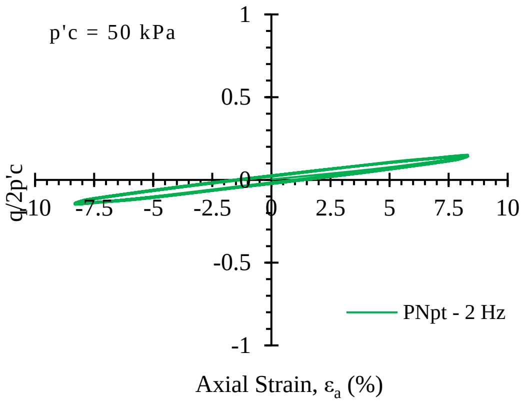
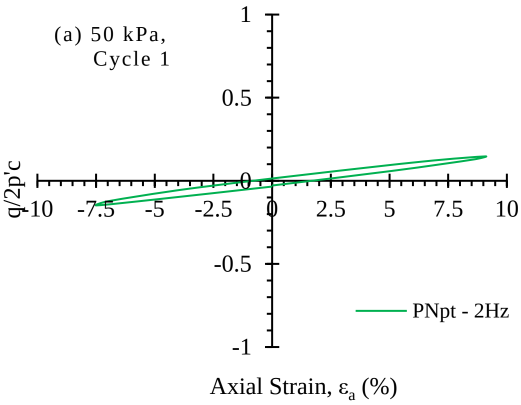


(c)

Fig. 4 Typical Stress-strain plots for PNpt of (a) Stress-strain cycle, (b) Stress-strain cycle 1st and (c) stress-strain cycle 100th at an effective stress 25 kPa.



(a)



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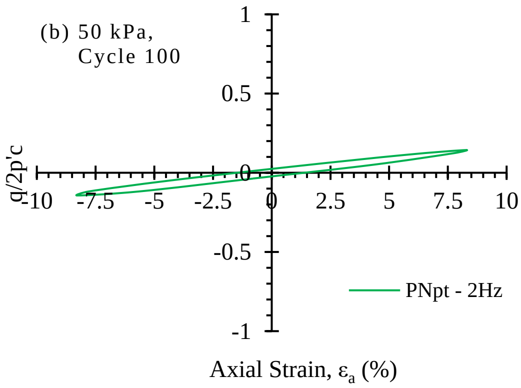

(c)

Fig. 5 Typical Stress-strain plots for PNpt of (a) Stress-strain cycle, (b) Stress-strain cycle 1st and (c) stress-strain cycle 100th at an effective stress 50 kPa.

Table 2. Relationship Young's Modulus, *E* (MPa) for PNpt.

Sample	σ' (kPa)	*E* (MPa)	
		Cycle 1	Cycle 100
		2 Hz	2 Hz
PNpt	25	0.79	0.63
	50	0.81	0.77

In case when dynamic loading imposed to the peat soil, the effect of stress-stain behaviour to the Young's modulus relationship, it is significant that the Young's modulus relatively decreases against effective stress. There has been a significant decrease in E, so stiffness parameters are degrading. Figure 6 shows the relationship between Young's modulus, *E* and effective stress, σ' at various frequencies applied for PNpt. These conditions related to the uncertainty peat behaviour of peat soil.

In general, a Young's modulus value decreases to the effective stress and frequency that applied. In like manner, the Young modulus for 1st cycle compared to the 100th cycles and it states a significant difference.

The Young modulus of peat soil has decreased. On the other hand, increasing the number of cycles causes the decrease of the Young modulus. This has to do with the fact that cyclic loading causes to dissipate and without dissipation pore pressure and stiffness changes. These changes reflect the restructuring of all peat soil fibers and discovered new compression phases due cyclic loading. As a result of stresses from cyclic loading, hysterical-loops downsizing occurs. For PNpt at first cycle, with an effective stress 25 kPa and 2 Hz of frequency the Young modulus (0.79 MPa) decreased slightly to 0.75 MPa in 100 kPa of effective stress at same frequency applied.

In similar fashion, for 100th cycles the Young modulus decreased from 0.63 MPa to 0.58 MPa. Cyclic loading pressure causes the origin sample size changed, which is contributes to the changes of the origin Young's modulus to a lower one at the end of the cyclic loading process. Unfortunately, in 50 kPa of effective stress applied, the value of Young modulus increased uncertainty. This condition states the peculiarity of peat even it in the same category. Comparatively, [22] has states this condition which is the author had discovered same peculiarity behaviour of Young's modulus despite sample in the same category.

By the same token, according to the [25] the Young modulus, *E* for fibrous peat soil is within the range of 20 to 80 in undrained shear strength. In the first place, [26] have been concluded that, the distinctive of fibrous peat in undrained Young's modulus exceptionally low values. A lower Young's modulus viewed in higher effective stress and frequency. [22] found that, the Young modulus value decreased significantly to the stress more than 50 kPa. As has been noted, the Young modulus of PNpt decreased significantly to the stress applied after 50 kPa.

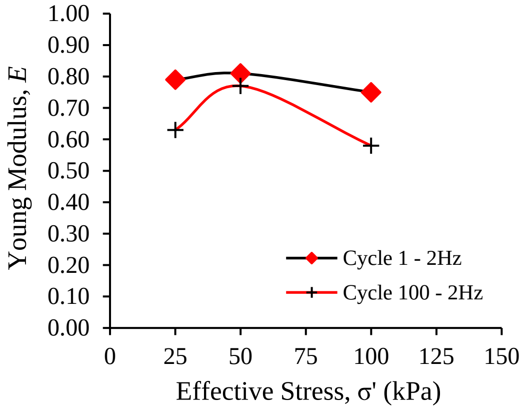

Fig. 6 Relationship between Young's Modulus, *E* (MPa) and Effective Stress, σ' at frequency of 2 Hz.

Figure 7 shows the comparison of Young's Modulus, *E* (MPa) with previous study. In this study, the Young's modulus discovered within the range as suggested by [23] which are in the range 20 to 70 as shown in Figure 7. This is show that this range are comparable and in line with the previous study which is in the same undrained condition. To the end that, [27] stated that, the major causes governed Malaysia's peat dynamic behaviour are percentage of fibre and its sizes that contained in peat sample. Peat is considered as weak foundation soil as they have low shear strength, high compressibility and high moisture content [28].

Comparatively [19] has stated that this condition which is the author had discovered same peculiarity behaviour of Young's modulus despite sample in the same category. [19] found that, the Young modulus value decreased significantly to the stress more than 50 kPa.

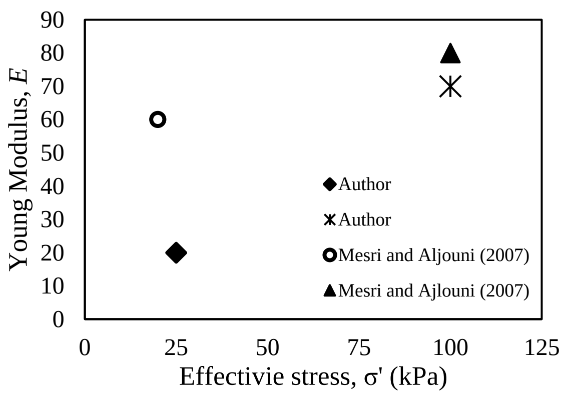

Fig. 7 Comparison of Young's Modulus, *E* (MPa) with previous study.

4. CONCLUSIONS

The cyclic loading test which simulates traffic loading frequency behaviour showed that the dynamic behaviour has a significant effect on cyclic loading properties of peat soil. It has been observed that, at larger frequency, the more disorderly and inconsistent cyclic behaviour notched. In short, the higher frequency applied, the more irregular behaviour occurs especially for frequency more than 2 Hz. Significantly, the Young's modulus has decreased against frequency and effective stress applied.

The Young modulus for 1st cycle compared to the 100th cycles and it states a significant difference. The Young modulus of peat soil has decreased. On the other hand, increasing the number of cycles causes the decrease of the Young modulus. When the effective stress applied was increased, the dynamic shear modulus decreased slightly. The undrained behaviour of peat soil subjected to cyclic loading significantly show the correlation of static and dynamic loading behaviour of undisturbed soil sample. The following results have been observed and obtained. Destruction of fibre in peat soil confiscated of peat stiffness.

Correspondingly, the undrained Young's modulus of the undrained shear strength subjected to cyclic loading in this study in the range of 60 to 70 for hemic peat soil. The specimen loaded into specific frequency causes in reduction of Young's modulus related to stiffness and more pronounced in softening behaviour.

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