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Correlations of The Dynamic Parameters on Malaysia Hemic Peat

Adnan Zainorabidin[1,2,*], Siti Nurul Aini Zolkefle[1,2], Kasbi Basri[1,2], Habib Musa Mohamad[3], Koh An Ang[4], Amirzaki Salikin[1,2], Muhammad Fathur Rouf Hasan[5], Putera Agung Maha Agung[5]

[1] Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia
[2] Research Center for Soft Soil, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia
[3] Faculty of Engineering, Universiti Malaysia Sabah, 88400 Sabah, Malaysia
[4] GDS Instruments Sdn. Bhd., 124, Jalan Kapar, 27/89, Taman Alam Megah, 40400 Shah Alam, Selangor, Malaysia
[5] Departemen of Civil Engineering, Politeknik Negeri Jakarta, 16425, Indonesia

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ABSTRACT

The dynamic behaviour of Hemic peat in Johor, Malaysia is described. The index properties of three different locations in Johor were investigated. Cyclic triaxial test with different frequencies and effective stresses were applied to correlate the characteristics behaviour of Johor peat. By using the Cyclic Triaxial machine located in the Research Centre of Soft Soil, Universiti Tun Hussein Onn Malaysia, the tests conducted referred to the British Standard and ASTM. The result of cyclic shear modulus shows that hemic peat in Johor indicated less than 2MPa and damping ratio in the range of 7.70% to 24.84%. The influences for the cyclic shear modulus correlations in this research are mostly affected by the effects of fibres structures and the natural characteristics of peat. The different behaviour of fibres in peat also significantly influenced the results. These behaviours lead to a different performance of each sample used. The natural characteristics of peat results in varied and scattered behaviour. Through this assessment, the peat characteristic is significantly depending on the well-structured of hemic peat which mostly consists of fibres, water and pores that controls its behaviour during the cyclic loading test.

1. Introduction

The dynamic behaviour of peat in Malaysia has received little attention in the literature. Recently, an empirical model has been proposed to interpret the dynamic properties of organic soil in other countries [1], however, Malaysia peat was variable in characteristics due to the weather changes and its development. Consequently, it is difficult to interpret the characteristics behaviour of peat soil in Malaysia specifically in terms of dynamic loading. Peat soil called as a partially decomposed soil with volumes of plant structures at high moisture content. Malaysia has the thickest peat in Southeast Asia (7m in depth) and the second largest share in volume (10%) [2,3]. This concern has been long

* *Corresponding author.*
E-mail address: adnanz@uthm.edu.my

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minded for the early researchers to encounter and correlate the behaviour of this unique and challenges soil.

Practically, peat is considered as a frictional or non-cohesive material which is due to its fibre content and its orientation [4]. Roads and highways in Malaysia that landed on peats are frequently undergone by severe damages (refer Figure 1) which caused by heavy loadings vehicles and settlements that notify the behaviour of peats with its high compressibility and low shear strength. Talib and Chan [5] once investigated the road constructions in Batu Pahat, Muar and Pontian, and observed that the road was quite bumpy since the area was experienced a surcharge of vertical drainage.

Fig. 1. Bulging along Pontian Road

Early researchers have notified the properties of peat soil in terms of dynamic loading. Moreno and Rodriguez [6] explained that the microstructure of peat influenced the results of the excess pore pressure. Kishida *et al.,* [7] analysed the modulus reduction, damping characteristics and cyclic shear strain amplitude were affected by the types of peat (fibrous and amorphous). Meanwhile, Zainorabidin *et al.,* [8] investigated that the analysis of peat was important in order to reveal the physical properties, particle associations and arrangements. Zainorabidin and Zolkefle [9] examined peat soil in West Johor and discovered that it exhibited higher energy dissipation due to the presence of fibre structures and its inherent composition. Similar finding was obtained by Basri *et al.,* [10] and Basri *et al.,* [11] where the presence of fibre in peat soil causes rapid energy dissipation. Zainorabidin *et al.*, [12] conducted a comparative analysis of dynamic loading characteristics between peat and sand, taking into account their physical properties. They concluded that peat with a greater fiber content exhibits an elevated damping ratio and reduced shear modulus values.

An assessment of the dynamic loading parameters of other countries has been valuated using cyclic direct simple shear and resonant column test [13]. The researchers pointed out that the development of excess pore pressure exhibits dilatant behaviour, as well as nearly flat shear modulus reduction and damping curves at small strains, irrespective of the organic content [13]. This study will correlate the data of cyclic triaxial test parameter, i.e., cyclic shear modulus, damping ratio and pore water pressure of three hemic peats in Malaysia with the early researchers.

2. Research Strategy

The undisturbed peat samples were taken from Pontian (POpt), Parit Nipah (PNpt) and Parit Sulong (PSpt). Index properties tests like moisture content test, degree of humification, fibre content test and organic content test were tested for each sample before conducting the cyclic triaxial. Tests were referred according to the British Standard, BS1377 [14] and American Society for Testing and Materials, ASTM [15].

Differences in the loading frequency had been implemented in this research. The cyclic triaxial test of 0.1Hz, 1Hz and 3Hz loading frequencies with the effective stresses of 25kPa, 50kPa and 100kPa were set up. Figure 2 shows the cyclic triaxial test machine used in this research for all samples. The sample should be prepared cautiously in order to get the best and accurate results. Minimum disturbances of peat in preparing the sample and assembled it on the triaxial cell cannot be avoided, however the disturbances should be minimised since it is one of the difficulties in preparing for the dynamic loading test. The triaxial cell was then assembled into position after enclosed the sample with rubber membrane. The loading piston was slowly pushed down until it made contact with the surface of the top cap. The connection of the cell pressure and back pressures supplied on the base of the cell were tightened to avoid any leakage. Then, the specimen was ready to be pressurized. The test procedure is practically referred to the GDSLAB software input data stage by stage.

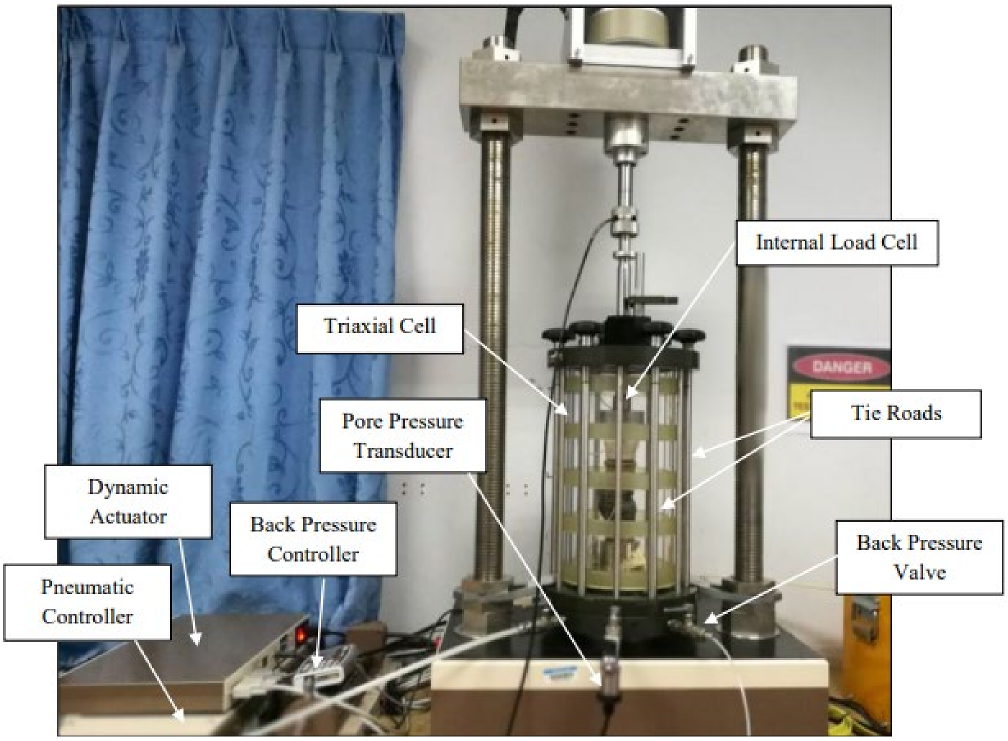

Fig. 2. Cyclic Triaxial Test Machine

Figure 3 shows the cyclic loading stage screen. One-way loading with the strain-controlled method is applied during the cyclic triaxial test. The strain amplitude on dynamic stage was set as the same values as input data from the conventional triaxial test which is the half of maximum axial displacement for every sample. The cyclic stage was stopped when hen the test reached the target of the amplitude and number of cycles.

3. Peat Characteristics Behaviour

The importance of index properties test was to evaluate the physical and natural characteristics of peat, thus providing basic knowledge in describing peat's behaviour. Table 1 indicates the results of index properties test for PNpt, POpt and PSpt. Different groups of the degree of humification show in the results of PNpt, POpt and PSpt in this study, however, it was indicated the same types of peat which are Hemic peat. This is proved that all peat samples are semi-fibrous with moderately decomposed soil, recognizable some of the plant structures, strongly pasty residue and muddy dark water and some peat when squeezing by hand.

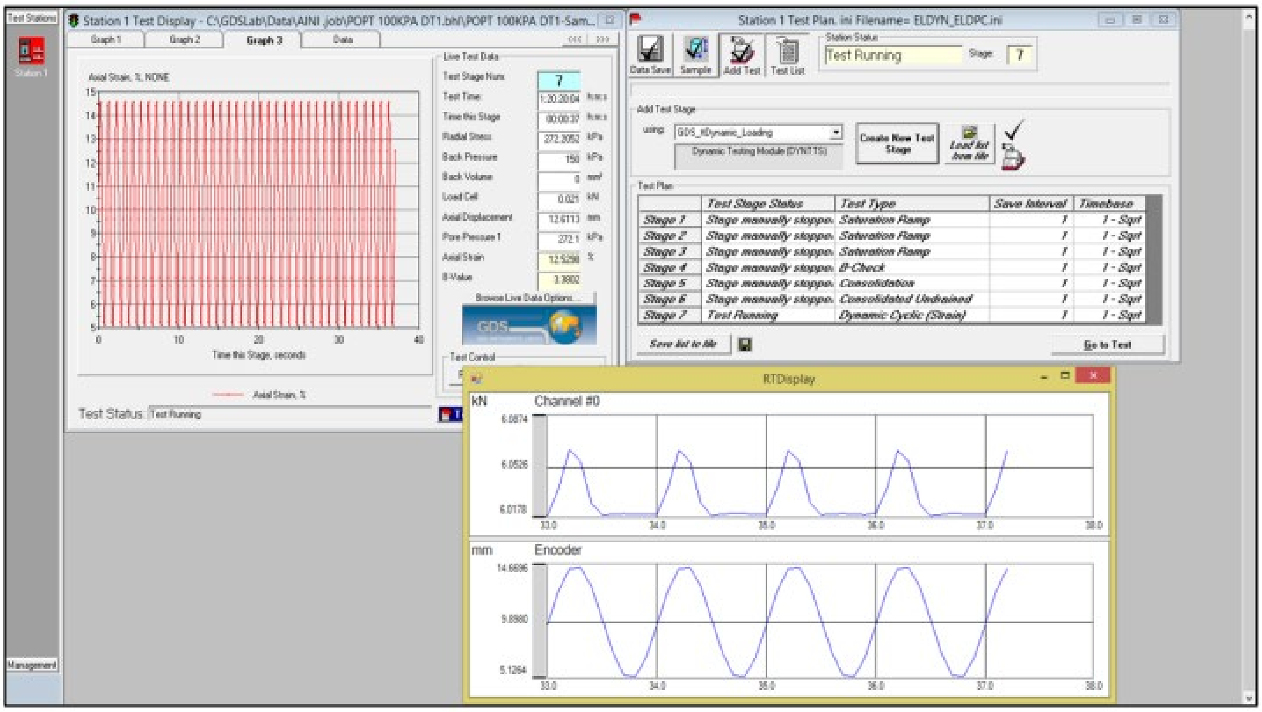

Fig. 3. Cyclic Loading Stage Screen

Table 1
Index Properties Test Results

	PNpt	POpt	PSpt
Degree of Humification	H6 (Hemic)	H5 (Hemic)	H6 (Hemic)
Moisture Content (%)	662.312	753.845	515.861
Organic Content (%)	96.491	98.262	87.656
Fibre Content (%)	43.491	50.169	35.586

The moisture content of peat is a significant geotechnical characteristic as it was directly linked to the initial void ratio of peat. The percentages of moisture content are pointed more than 500% for all peat with the highest was pointed at 662.312% for PNpt compared to PSpt which pointed the lowest percentage at 515.861%. These results are agreed with prior researchers and lies between the ranges [12,16,17]. The reason may due to the level of ground water level during the sampling process and may affect by the climate changes [18].

Meanwhile, the organic content test of all peat samples is indicated a higher percentage of organic. POpt shows almost 100% and PSpt indicated the lowest compared to all at 87.656%. These results, taken from previous studies, also fall within the range of 84% to 99% [17,19,20].

All peats is classified as a hemic peat during the fibre content test in this study. POpt shows the highest percentage of fibres compared to both PNpt and PSpt. These results proved that peat samples were accommodated the high amount of moisture and organic content. Fibres in each peat locations also marked at in the range of hemic peat fibres (33% to 66%). The condition of the surrounding area during sampling, environmental changes and plants grow in each location signifies the decomposition degree that influenced the fibre content results [16,18].

4. Conventional Triaxial Test Result

Conventional Triaxial test result in this research shown in Figure 4. Early researchers' data were compared to the result in this research and it shown within the ranges of the previous research. The degree of decomposition for all peats is shown in the same group of hemic peat type except for Azhar *et al.,* [21]. The maximum value of deviator stress was noted at approximately 110kPa Cola and Cortellazo [22] and Yang *et al.,* [23] which indicated at σ'=100kPa. The differences could vary due to the origin of the peat samples and the effect of the fibres from the soil particles. Chen *et al.,* [24] justified that peat could obtain high effective friction angles in CIU triaxial test which attributed to the effect of the peat fibres.

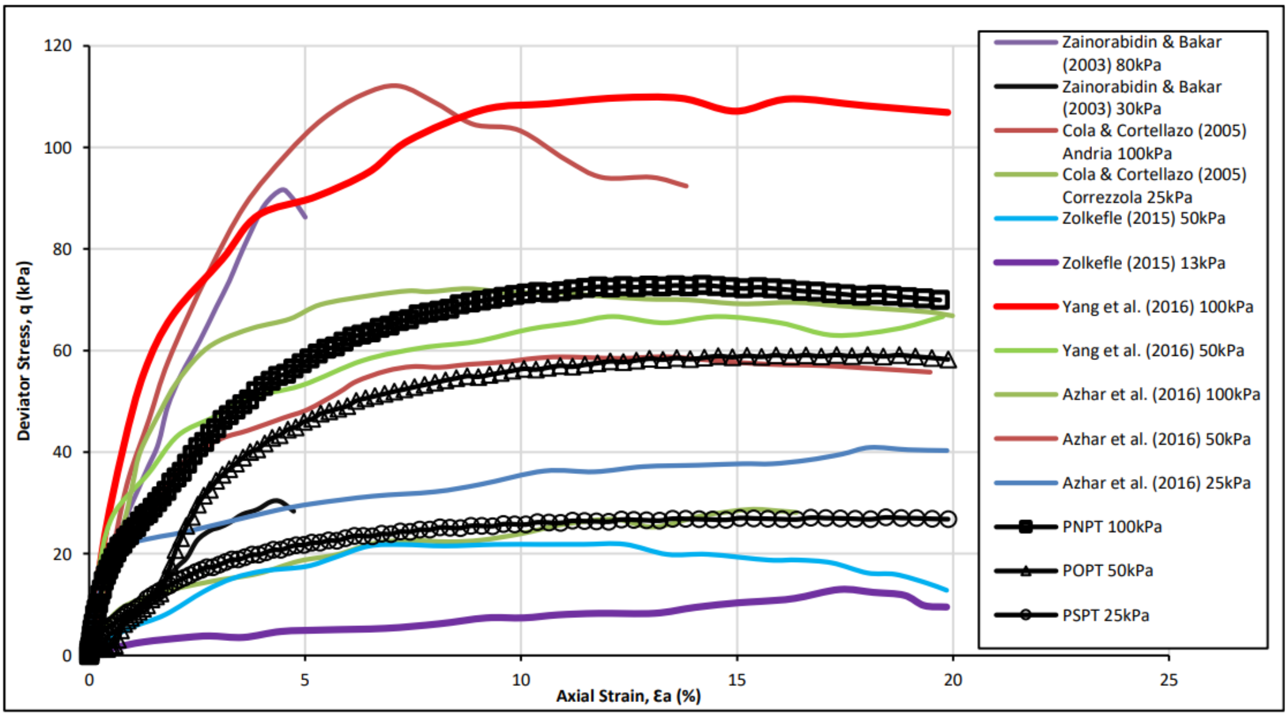

Fig. 4. Deviator stress vs axial strain

Figure 5 pointed out the comparisons of the pore water pressure behaviour of hemic peat and selected prior researchers. Cola and Cortellazo [22] (for both Andria peat and Correzzola peat) and Yang *et al.,* [23] pore water pressure results are compared thoroughly.

The results pointed within the range of prior researchers. PNpt, POpt and PSpt indicated low in range compared to previous researchers. Cola and Cortellazo [22] mentioned that the presence of fibres influenced the development of significant excess pore water pressure leading to failure. Yang *et al.,* [23] additionally demonstrated that the typical pore water pressure results were a consequence of the reinforcing impact of fibres in peat. Hendry *et al.,* [25] asserted that the outcomes of the CIU triaxial tests validated the cross-anisotropic nature of peat when fibres were oriented perpendicular to the direction of axial compressive stress. Guzman and Alfaro [26] also agreed which mentioned that the responses of results were due to the fibre's overriding each other. These varied results proved that its fibre sizes mainly influenced the pore water pressure of hemic peat in peat which varied depending on their behaviours.

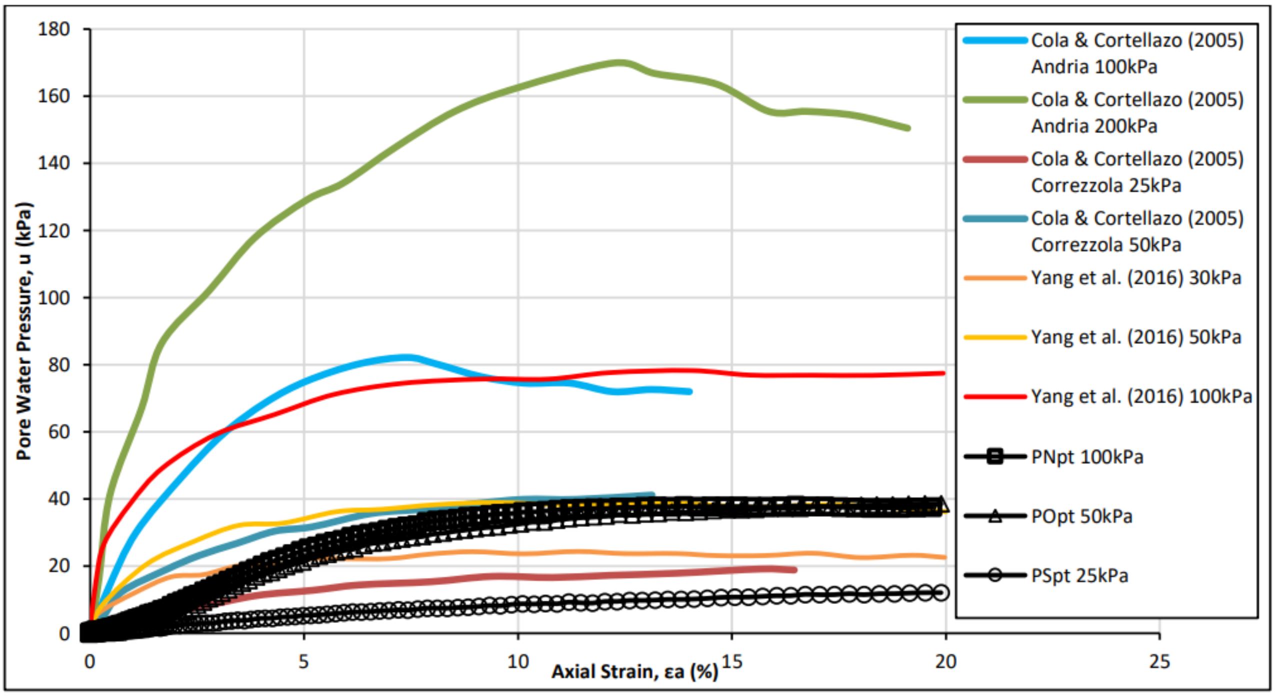

Fig. 5. Pore Water Pressure Behaviour

5. Cyclic Shear Modulus (G) Correlations

The result of cyclic shear modulus in this research clearly shows that hemic peat in Johor indicated less than 2MPa. The highest value pointed at 1.56MPa (PNpt-3Hz-100kPa) and the lowest pointed at 0.11MPa (POpt-0.1Hz-25kPa). The influence is reflected by its effective stresses and frequencies applied. This agreed by prior researchers Boulanger *et al.*, [27] who proved that peat from Sherman Island was affected by the loading frequencies. Kishida *et al.*, [28] stated that the cyclic shear modulus for all percentages of organic content laid in the range of 0 to 9 MPa. Zolkefle [29] also mentioned that the peat in Johor pointed very small behaviour of G which was less than 2MPa. Figure 6 illustrated the comparisons of G with early researchers on peat.

Based on the figure, G behaved in increasing trend for all researchers when the effective stress increased except for Zainorabidin [30]. Hemic peat indicated within the range of G for past researchers except for Wehling *et al.*, [31] and Kishida *et al.*, [28]. The behaviours show that it is due to the different method used in performing the cyclic triaxial test. This research used a strain-controlled test from a high strain test. Meanwhile, Wehling *et al.*, [31] and Kishida *et al.*, [28] used a small strain test for a cyclic triaxial test. Besides, the physical characteristics of peat for Wehling *et al.*, [31] and Kishida *et al.*, [28] also different compared to Zainorabidin [30], Zolkefle [29] and this research. Early researchers stated that the properties of peat from temperate and arctic peats are in contrast with the tropical peat [32].

The results of G shown in the figure are variable, however, it results in less than 5MPa. The influences are mainly reflected by the effects of fibres structures and the natural characteristics of peat. The results were also influenced by alterations in the percentage and size of the fibres, as well as their volume. According to Boulanger *et al.*, [27], the behaviour of peat was impacted by its pronounced cross-anisotropy, characterized by factors such as a high fibre content, significant compressibility, and scale effects. Besides that, prior researcher Kramer [33] also mentioned that the cyclic loading behaviours of peat were influenced by its properties of variable nature. Veloo *et al.*, [32] pointed out, temperate and arctic peatlands are frequently characterized by the dominance of land plants and shrubs. In contrast, tropical peatlands exhibit a greater diversity of tree species with roots penetrating to depths of several meters.

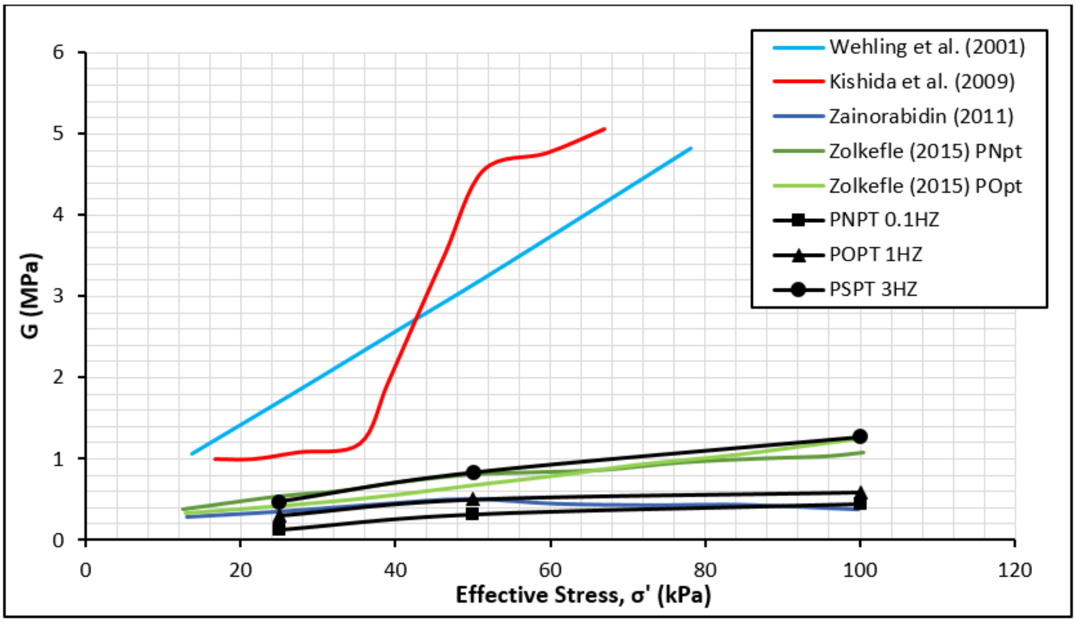

Fig. 6. Correlations behaviour of G

6. Damping Ratio (D) Correlations

The results of maximum value of damping ratio pointed out in the range of 7.70% to 24.84%, approximately. Different behaviours of maximum damping ratio appeared at every peat sample. The highest value of was noted at 24.84% (POpt-3Hz-25kPa). Meanwhile, the lowest value was noted at 7.09% (PSpt-0.1Hz-100kPa). Figure 7 compared the results of D with early researchers.

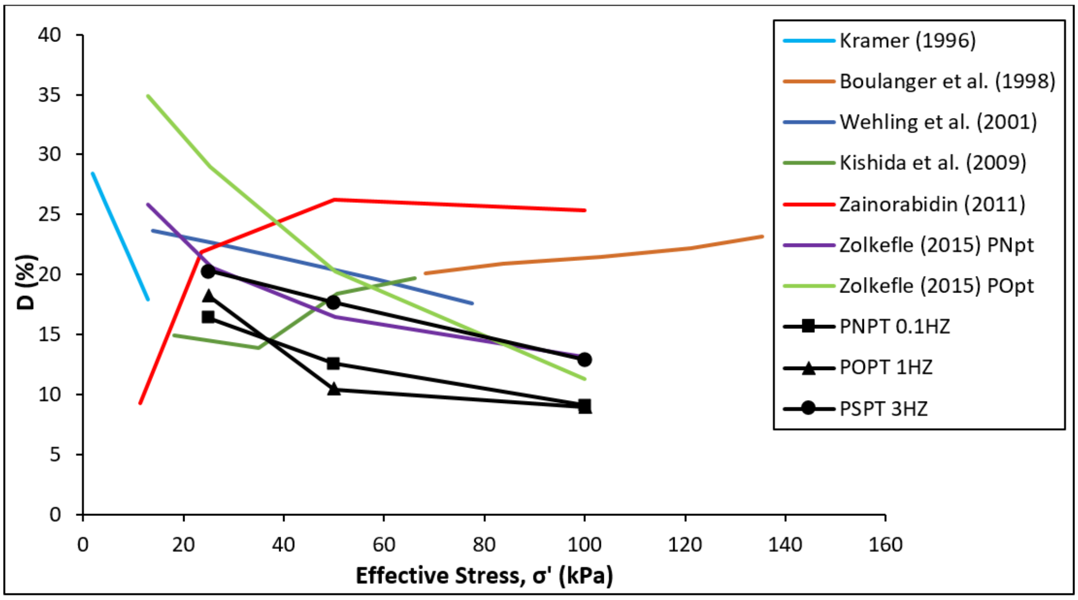

Fig. 7. Correlations behaviour of D

The behaviour of D indicated variation, but mostly the results are decreasing with the increase of effective stresses except for Zainorabidin [30], Kishida *et al.*, [28] and Boulanger *et al.,* [27] pointed increasing results. These results are varied and could be reflected by the degree of decomposition of the peat sample used. In fact, the method used when performing the cyclic triaxial test also different like the small strain method and the stress-controlled method. The types of peat such as temperate peat and tropical peat also altered different behaviours of damping ratio.

The correlations of D in the Figure indicated within the range of 7% to 35% at below σ'=140kPa. The percentage of D in this research also pointed out between the range of past researchers. These behaviours are mostly due to the effect of frequencies and effective stresses applied. Zainorabidin [30] and Wehling *et al.,* [31] agreed to this. Besides, the different behaviour of fibres in peat also significantly influenced the results. Kishida *et al*., [28] stated that the inherent anisotropy of peat might have affected the results of damping characteristics. Early researchers, Kumar *et al*., [34] noted that the damping ratios at higher strain levels mostly displayed nonlinear effect compared to low strain level. These correlations lead to a different performance of each peat sample used. Besides, the natural characteristics of peat results in different and scattered behaviour. The characteristic is significantly depending on the well-structured of hemic peat which mostly consists of fibres, water and pores that controls its response during the cyclic loading test. Ozcan *et al*., [35] explicitly mentioned that the organic fibres present in peat behaved like reinforcement materials which influenced the results of cyclic shear modulus and damping ratio.

7. Pore Pressure Ratio (r_u) Correlations

Hemic peat in Johor indicated that the pore pressure ratio is less than 1%. The highest value noted at POpt-3Hz-100kPa (0.99) and the lowest value noted at 0.18 (POpt-0.1Hz-50kPa and POpt-1Hz-25kPa). The correlations of the r_u results in this study has been made with early researchers. Figure 8 indicated the behaviours of peat based on the number of cycles and Figure 9 indicated the results of r_u by the means of effective stress. The results of r_u indicated within the range of early researchers. Figure 8 shown increasing results until the hundredth cycle. These results are compared with Moreno & Rodriguez [36] and Zolkefle [29] which displayed the same results as in this research.

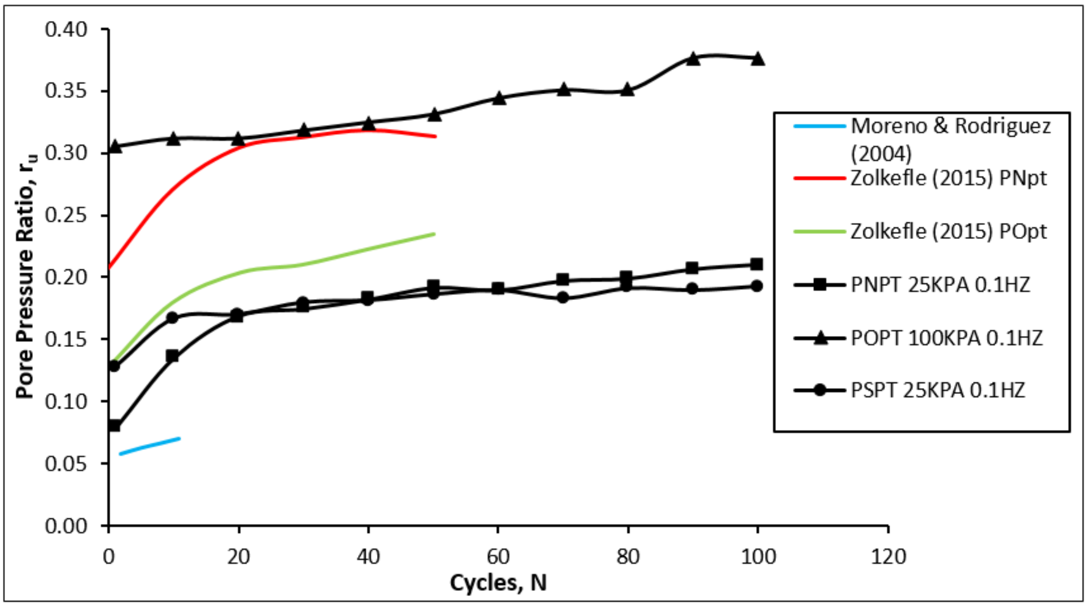

Fig. 8. Pore pressure ratio correlations vs number of cycles

Meanwhile, Figure 9 clearly pointed increasing data when the effective stress increased. Similar finding was obtained by Latib *et al.,* [36] where the pore pressure increases significantly with effective stresss. Moreno & Rodriguez [37] and Zainorabidin *et al.*, [38] stated that the excess pore pressures were mainly depending on the strain level reached and the results happened may be due to the microstructure of peat. Furthermore, Zainorabidin and Wijeyesekera [39] also noted that the slight increase in pore pressure response during the cyclic test was influenced by varying geographical locations in distinct climates, leading to the emergence of distinct and unique peat properties.

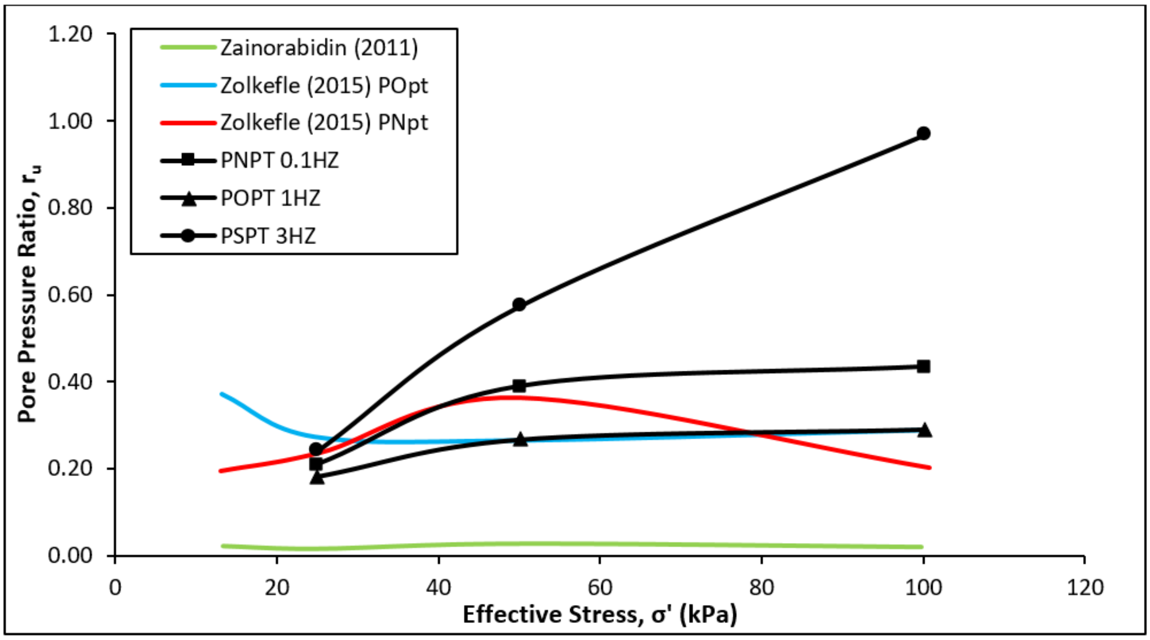

Fig. 9. Pore pressure ratio correlations vs effective stress

8. Conclusions

The factors predominantly affecting the correlations of cyclic shear modulus in this study are primarily influenced by the structural characteristics of fibres and the inherent properties of peat. The outcomes were also altered by variations in both the percentage and size of fibres. Meanwhile, the behaviours of damping ratio in this research are mostly due to the effect of frequencies and effective stresses applied. The different behaviour of fibres in peat also significantly influenced the results. These behaviours lead to a different performance of each sample used. The inherent attributes of peat lead to diverse and dispersed behaviour. This characteristic is significantly depending on the well-structured of hemic peat which mostly consists of fibres, water and pores that controls its behaviour during the cyclic loading test. In the other hand, the behaviours of r_u mainly depend on the strain level reached and the results happened were due to the microstructure of peat. The small increment of r_u during the cyclic test could possibly influenced by the different location's condition which leads to different and unique properties of peat.

Further study needs to conquer deep knowledge and information on the influence and correlations of cyclic shear modulus and damping ratio in Malaysia peat compared to the other countries.

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