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INVESTIGATION ON THE SHEAR STRENGTH CHARACTERISTIC AT MALAYSIAN PEAT

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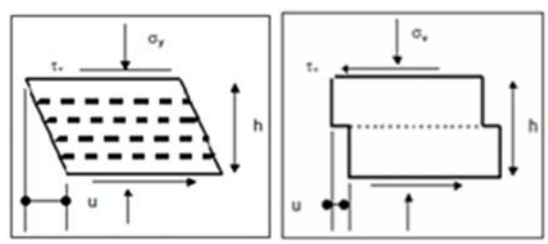
ABSTRACT

Peat is known as a problematic soil because it has low shear strength. This research is to determine the shear strength behaviour of different types of peat. The shear strength of peat is very important for determining the stability of cuts and slope, bearing capacity of foundation and retaining wall. The samples were collected at two different locations, Pontian, Johore and Penor, Pahang, Malaysia. The samples are classified as hemic peat and amorphous peat. The shear strength behaviour of hemic and amorphous can be determined on its cohesion, c and internal friction angle, ϕ. The result shows that there are different shear strength value between hemic peat and amorphous peat. Direct simple shear and direct shear box is used to determine the shear strength of peat. The value of c and ϕ for direct shear box gave higher value than direct simple shear. But it shows that direct simple shear is more suitable to determine the shear strength on peat. Shear strength is very important to know during construction, especially for supporting construction equipment and structures and this paper can help geotechnical engineers understand about the shear strength behaviour on peat.

Keywords: peat, hemic, amorphous, direct simple shear test, direct shear test, shear strength.

INTRODUCTION

Peat soil is a problematic soil because it has low shear strength and the determination of stress strength of peat soil is difficult in geotechnical engineering because of high water content and organic matter. Based on Huat *et al* (2011) discovered that peat contains 100% of pure organic material which have 65% organic matter or less than 35% mineral content. This research is focused at Pontian, Johore and Phenor, Pahang, Malaysia. Shear strength is based on the cohesion, c and internal angel friction, ϕ. The shearing condition of direct simple shear and direct shear box are shown in Figures 1(a) and (b). This research will focus on the challenging of Malaysian peat soil in construction for infrastructure due to the shear strength. Shear strength is very important to know during construction because to determine the support of construction equipment and structures (Huat *et al,* 2011). Shear strength also is needed for determining the bearing capacity of foundation and the stability of cut and slope.



(a) (b)

Figure-1. Conditions of (a) direct simple shear and (b) direct shear box (Hanazawa *et al*, 2010).

Table-1. Summary of differences in shear testing.

Testing	Description	References
Direct Shear Box	Not suitable because of the nonunifomly distribution and mode of deformation	Grognet (2011)
Direct Simple Shear	It has strong anisotropic structure gives it a disposition towards horizontal sliding. Undrained condition is the most appropriate parameter to determine the strengthness for stability assessments	Grognet (2011)

Table-1 above shows the differences between direct shear box and direct simple shear. It is stated that direct simple shear is more suitable to use on peat compare to the direct shear box.

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PEAT

Peat and organic soils are popular as the ultimate soft soils in engineering terms. They are quite difficult to take soil sample and test using the conventional technique. They are the major problematic soils in Malaysia because of their high compressibility and low strength that have total of about 2.7 million hectares of peatland. Among these lands, 6, 300 hectares of peat lands can be found in Pontian, Batu Pahat, and Muar in West Johore (Yulindasari, 2006).

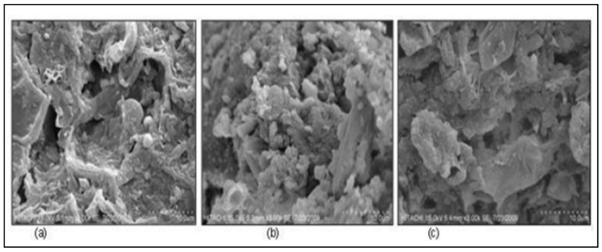

Figure-2. Scanning electron micrograph of peat: (a) fibrous (b) amorphous (c) hemic (Kazemian *et al*., 2011).

According to the American standard that is ASTM standard, there are three classes of peat, such as fibre content, ash content and acidity of soil. Peat in fibre content classification can be divided into three groups based on Figure 2 that shown the electron micrograph of peat that is (a) fibrous (b) amorphous and (c) hemic and Table 2 illustrate the classification of organic soil and peat based on Malaysian standard.

Hemic peat

Hemic peat is known as semi-fibrous peat with intermediate decomposition. It contains 33% -66% of the fibre. It also contains more water content than amorphous. Besides that, hemic hold more water than amorphous peat (Katimon *et al,* 2007). There are only several researches on amorphous peat. Amorphous peat is the most decomposed peat with a fibre content of less than 33%. Figure 3 shows the sample of hemic peat.

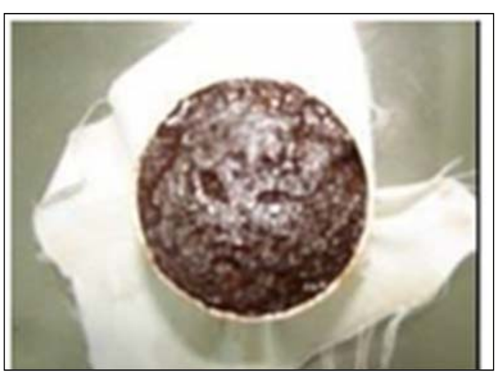

Figure-3. Hemic peat (Katimon *et al,* 2007).

Amorphous peat

Amorphous is very soft, unconsolidated and highly organic content. It is decomposed peat with less fibre content in it. The cell structure of amorphous peat are still visible and the main product of biochemical decomposition. Amorphous peat deposits contain more amount of inorganic matter. It has low shear strength than fibrous peat. Amorphous layer is located in the upper soil layer underlain by hemic and amorphous.

Furthermore, amorphous contained more decomposed material compared to hemic and fibric. Table 2 explained about the differences of peat soil. The bulk density of amorphous is higher than hemic. The organic plan fibres have mostly disappeared. The characteristics of amorphous are very dark gray or black in colour, stable in physical properties and water content less than fibrous and hemic peats. Amorphous peat deposits have lower void ratios and will obtain lower permeability anisotropy, lower friction angle and lower compressibility. The behaviour of hemic peat is at the intermediate rate of fibrous and amorphous peats in terms of the shear strength, compressibility and permeability. Figure-4 shows the sample of amorphous peat.

Figure-4. Amorphous peat (Katimon *et al*, 2007).

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Table-2. Malaysian Soil Classification Systems (MSCS) for organic soil and peat (Zainorabidin *et al*, 2007).

Soil Group	Organic Content	Group Symbol	Degree of Humidific-ation	Subgroup Name	Field Identification
Peat	>75%	Pt	H1 – H3	Fibric or Fibrous Peat	Dark brown to black in colour. The material has low density so seems light. Majority of mass is organic so if fibrous the whole mass will be recognized plant remains. More likely to smell strongly of highly humidified.
			H4 – H6	Hemic or Moderately Decompose d Peat	
			H7 – H10	Sapric or Amorphous peat	

SHEAR STRENGTH

The additional of organic fibre may increase the ultimate strength for drained and undrained condition on peat. This is because the fibre can act as reinforcement. Direct shear test gives higher estimates of strengths than direct simple shear. This happens because of the shearing mechanism that imposed to specimen or due to the size of the specimen and the specimen handling manner. Besides that, shear strength of the peat is increased if the water content is decreased. Small cohesion value has high internal angel friction. This condition is not reflected for high shear strength but will be effected the fibre and modify the shear strength behaviour (Kazemian et. al, 2007). The shear strength is often approximated by Eq. 1:

$$\tau = c + \sigma \tan \phi \qquad (1)$$

τ = shear strength (kPa)
c = cohesion of soil
σ = normal stress (kPa)
ϕ = internal friction angle (°)

Simple shear is in cylindrical shape. It obtained more homogenous distribution to shear and normal stresses, and resulting strains. Besides that, its purpose is to apply the specimen with a simple shear strain deformation (Grognet, 2011). Direct simple shear test can shear a soil to unlimited displacement without creating a substantial non-uniformities in stress and strain distributions. Direct shear test is the simplest, straightforward and the oldest procedure to determine the shear strength of soils. The specimen in the direct shear test is sheared along the horizontal plane and shows that the failure plane is horizontal. The specimen is in square shape. Direct shear box has non-uniformity stress distribution throughout the specimen because of rigid platens that used to confine the specimen (Hanazawa *et al*, 2007).

DIRECT SHEAR BOX

The vertical force act at the top of the box while the lower box is fixed and the specimen inside is sheared. Shearing process can measure the volume of the specimen, shear stress and movement of the specimen. The stress condition of shear box is plane strain condition during shear phase (Ou, 2006). The list below shows the weaknesses of direct shear box, such as:

i. It shear the specimen on horizontal plane, which is usually not the weakest point.
ii. Based on Figure 5, the failure surface is nonuniformly distributed because stress at the edges is greater than in the center.

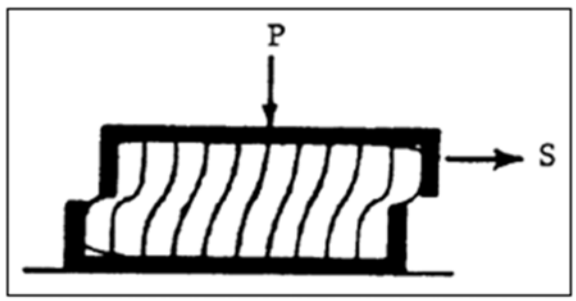

Figure-5. Nonuniform distribution of shear strains in direct shear box (Lai, 2004).

iii. It is difficult to control the drainage condition when shearing because the specimen is not covered with rubber membrane.

DIRECT SIMPLE SHEAR

Direct shear box test has many weaknesses especially it is unable to apply to clayey soils. The direct simple shear is in cylindrical shape and confined with stacked of rings to prevent it from lateral deformation. Shear is acted at the top of specimen without lateral deformation and in the state of plane strain that is shown in Figure 6. Direct simple shear can overcome all the weaknesses of direct shear box that has been forced to fail on horizontal plane and uneven distribution of stresses (Ou, 2006). Direct simple shear test is widely used in America and Europe.

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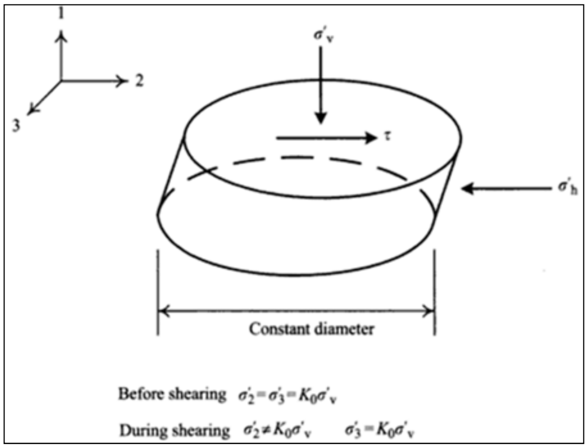


Figure-6. The shearing diagram of direct simple shear test (Ou, 2006).

EXPERIMENTAL INVESTIGATION

Direct simple shear

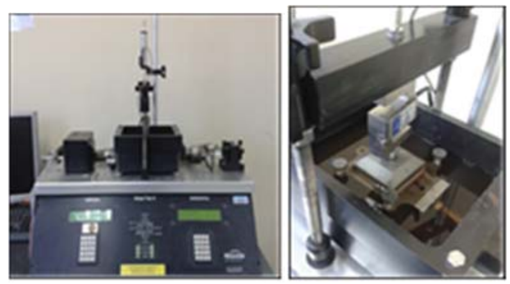
The normal stresses that have been carried out on undisturbed specimens for direct simple shear and direct shear box test are 12.5 kPa, 25 kPa, 50 kPa and 100 kPa. The shear rate is 0.1mm/min. The specimen was thoroughly saturated with water bath for 24 hours before run the test and applicable to field situation. The direct simple shear test apparatus used in this research is shown in Figure-3(a) and (b). It was conducted on a cylindrical specimen that retained inside a series of thin rings. A soil specimen surrounded by a stack of rings. The size of the specimen is 63 mm in diameter with 30 mm height as illustrated in Figure-7. The specimen is consolidated anisotropically under a vertical stress and deformation by application of shear stress. The specimen is then sheared from top platen with constant normal stress.

(a) (b)

Figure-7. (a) Simple shear test (b) Specimen in simple shear (Mansor *et al,* 2014).

Direct shear box

The peat specimen of the shear box test was prepared properly based on BS standard 1377:1990 (Part 7). As shown in Figure 8 (a) and (b), the specimen was in square with the size of 60mm x 60mm x 25mm. The test equipment consists of a metal box which a soil specimen is placed. Porous stones were placed at the bottom and the top of the specimen. Normal stress is applied through a metal plate. The box is split horizontally into two halves during shear.



(a) (b)

Figure-8. (a) Direct shear test (b) Specimen in direct shear (Mansor *et al*, 2014).

RESULT AND DISCUSSIONS

The shear strength obtained from direct simple shear and direct shear box are shown in Figure 9 and 11. The different linear lines are based on different type of peat fibre. Normal stresses are 12.5kPa, 25kPa, 50kPa and 100kPa. As can be seen in this Figure 9 and 11, hemic has higher shear strength than amorphous. The different shear strength value of hemic and amorphous can be seen in Table 4 and 6. The shear stress increased with normal stress. The test involved a change of normal stress to define the stress obtained from the shear box and presented in Figure-9 and Figure-11. It shows that the shear stress is increasing continuously based on the increment of the normal stresses. But, there are differences of the internal angle of friction between amorphous peat and hemic peat. It may cause from the pattern or arrangement of fibre and void ratio. As illustrated in this figure the shear strength increased, probably because of the peat fibre and normal stress that respond on the tested peat. The sources of shear strength are based on cohesion and frictional resistance between particles as shown in Tables 3 and 5.

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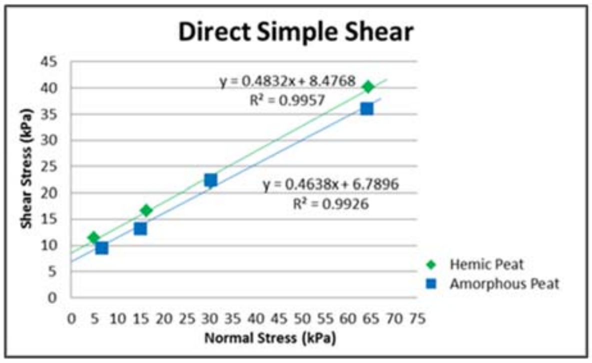

Figure-9. The relationship of shear strength on peat between shear stress and normal stress with different normal stress of 12.5kPa, 25kPa, 50kPa and 100kPa after direct simple shear test.

Table-3. Cohesion, c and internal friction angle, ϕ of Pontian, Johor (amorphous) and Phenor, Pahang (hemic) after direct simple shear test.

	Hemic	Amorphous
c	8.259	6.79
ϕ	22.6	21

Table-4. Shear strength of Pontian, Johor (amorphous) and Phenor, Pahang (hemic) after direct simple shear test.

Normal stress	Shear strength (kPa)	
	Hemic	Amorphous
12.5kPa	11.527	9.015
25kPa	14.562	11.241
50kPa	20.631	15.692
100kPa	32.771	24.594

The Figure-10 shows the specimen that was taken out after direct simple shear test created a zone failure can be seen in the figure, proved the applicability of direct simple shear test. It is in the formed diagonal shape. Usually cohesive soil has the connection with shear failure. The complete soil failure can happen along one zone or sliding surface and create soil displacement.

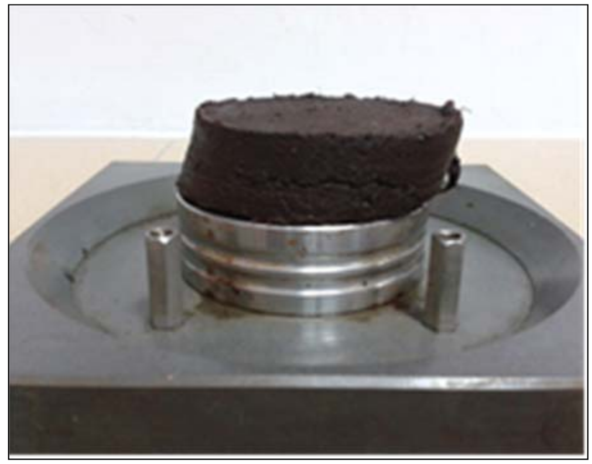

Figure-10. Peat soil taken out from the stack of rings after test (Hajar *et al,* 2014).

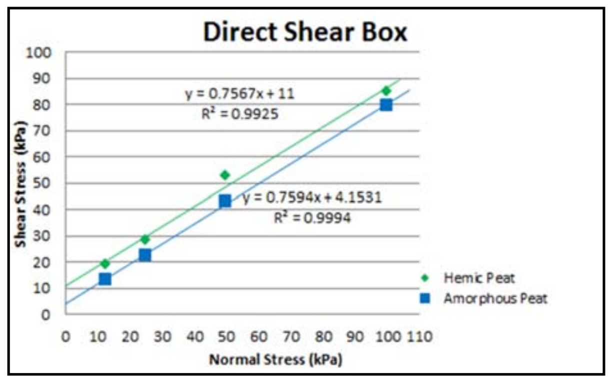

Figure-11. The relationship of shear strength on peat between shear stress and normal stress with different normal stress of 12.5kPa, 25kPa, 50kPa and 100kPa after shear box.

Table-5. Cohesion, c and internal angle of friction ϕ of Pontian, Johor (amorphous) and Phenor, Pahang (hemic) after direct shear box test.

	Hemic	Amorphous
c’	11	4.153
ϕ'	37.1	37.2º

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Table-6. Shear strength of Pontian, Johor (amorphous) and Phenor, Pahang (hemic) after direct shear box test.

Normal shear	Shear Strength (kPa)	
	Hemic	Amorphous
12.5kPa	18.154	11.358
25kPa	25.307	18.563
50kPa	39.614	32.974
100kPa	68.229	61.795

Figure-12 shows a peat specimen that is done after direct shear box test is sheared at the center of the specimen on horizontal plane. This is because of the relative displacement of the two halves of the box.

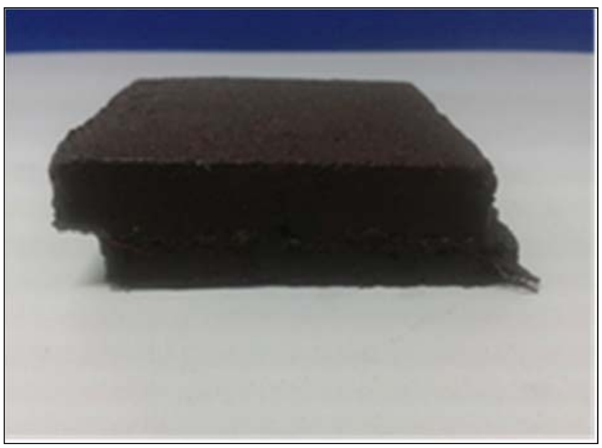

Figure-12. Peat soil taken out from shear box test (Hajar *et al*, 2014).

Based on Figure 13 and 14, direct shear box has the highest shear strength than direct simple shear test. This happens because DSB shear failure is on the horizontal plane as it might not be the weakest point. DSS shearing plane is in diagonal shape of every layer of the specimen and shear failure happened on plane strain of the specimen.

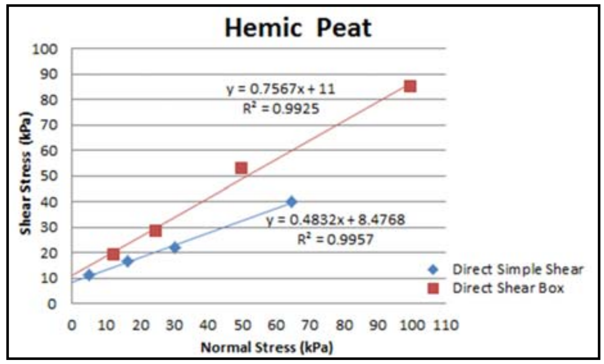

Figure-13. The shear parameter of hemic peat between direct simple shear and direct shear box.

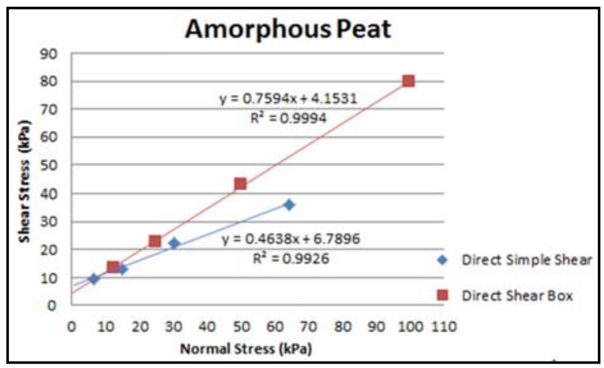

Figure-14. The shear parameter of amorphous peat between direct simple shear and direct shear box.

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CONCLUSIONS

The shear strength behaviour between direct simple shear test and direct shear box test are based on the behavior of peat that is largely based on its fibrosity and anisotropic. Both tests are increasing continuously during normal stress. Hemic gives higher shear strength than amorphous. There are differences of cohesion and internal angle of friction between direct simple shear test and direct shear box test for hemic and amorphous. Direct simple shear has smaller shear strength than a direct shear box. This is because the shear stress homogeneity is increased inside the simple shear specimen. Besides that, normal stresses applied might have been influenced the

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peat homogeneity during shearing. Based on the results, direct shear box test gives higher estimates of shear strength than direct simple shear based on the shearing mechanism or due to the size of the specimen and the specimen handling manner. For direct shear box, the fibre in the middle of the specimen will much affect than the entire area of the specimen. Even though the direct shear box gives higher value of c and ϕ, it is not quite accurate because the shearing mechanism of direct shear is only acting at the center of a specimen only, while direct simple shear can sheared around the surface of a specimen. So, direct simple shear is more suitable to use on soft soil (peat) rather than a direct shear box.

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