# Dynamic Characteristics of Penor Peat Using MASW Method

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**Abstract.** The dynamic behaviour of soil affected the mechanical properties of soil such as shear wave velocity, shear modulus, damping ratio and poisson's ratio [1] which is becoming important aspect need to be considered for structures influences by dynamic movement. This study is to determine the dynamic behaviour of Penor peat such as shear wave velocity using MASW and estimation its shear modulus. Peat soils are very problematic soils since it's have high compressibility, low shear strength, high moisture content and low bearing capacity which is very not suitable materials to construct any foundation structures. Shear wave velocity ranges between 32.94 – 95.89 m/s and shear modulus are ranging between 0.93 – 8.01 MPa. The differences of both dynamic properties are due to the changes of peat density and affected by the fibre content, organic content, degree of degradation and moisture content.

**Keywords:** Peat, shear wave velocity, shear modulus, MASW.

## 1. Introduction

The dynamic behaviour of soil affected the mechanical properties of soil such as shear wave velocity, shear modulus, damping ratio and poisson's ratio [1] which is becoming important aspect need to be considered for structures influences by dynamic movement. This study is to determine the dynamic behaviour of Penor peat such as shear wave velocity using MASW method and estimation its shear modulus.

The knowledge of the dynamic response of the soil-structure are required for dynamic structural analysis of the superstructures [1] and relies on dynamic soil properties. Soils tend to behave differently and very complex under dynamic loading such as earthquake, moving traffic, machineries and bomb blasting. The loadings will contribute to an accumulation of shear strains, and when the threshold shear strain has been exceeded, the shear modulus will be reduced [2]. Dynamic loading is distinguished by the magnitude of the loading fluctuating with time and the deformations of the soil consist of both recoverable and permanent displacement [3]. In many researches of soil properties, there are three typical dynamic properties of field test and laboratory test such as shear modulus, shear wave velocity and damping ratio. Researcher Shafiee et al., [4] also claimed that the dynamic properties of peat that typically investigated in prior work with cyclic shear strain are the differences of shear modulus and damping ratio [4].

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Peat soils are very problematic soils since it's have high compressibility, low shear strength, high moisture content and low bearing capacity which is very not suitable materials to construct any foundation structures. This problem often faced by the engineers when attempted to construct roads for rural area or foundations which covered by very vast peat soil area and have difficulty to maintain the completed structures life span as peat continued to have settlement for long term period.

## 2. Properties of Peat

Peat is formed by the accumulation of organic material undergoing partially decomposition process with proper condition. Peat is a combination of fragmented organic and animal matter and formed in wetland under appropriate anaerobic conditions for long periods [5,6]. Peat soil is an organic with content more than 75 % [7] which caused a lot of problems for construction due to unpredictable behaviour of its properties. At the study location, the peat is known as hemic peat with fibre content 33.7 % [8] where, according to ASTM D 1997-91 [9] hemic has fibre content between 33% and 67 %. Hemic peat has moisture content 472 – 554 %, organic content 92 -96 %, and von post classification is H5 – H6 [6].

## 3. Multi-channel Analysis of Surface Wave (MASW)

Multi-channel Analysis of Surface Wave methods are used to determine shear wave velocity on the field for subsurface characterization by measuring the phase velocity of surface wave using an active source to create seismic waves at specified location along linear direction with spread length [10] then recorded the propagation of surface wave to generate shear wave velocities through Fourier transform and inversion dispersion curve of phase velocities in the frequency domain. The shear velocity, soil profile can determine when measure the phase velocity of Rayleigh waves of different frequencies [11].

This method is ideal to for effective identification and isolation of seismic noise such as body waves, scattered, and non – source generated surface waves and higher mode of surface waves according to distinctive trace to trace comparison of coherency in arrival time and amplitude. The MASW method can take out accurate phase velocities of Rayleigh wave ground roll [12].

## 4. Geological Setting

Study location actually near at Penor which located about 26 km north from Pekan town where the area is covered with natural tree and did not have any human activities. This research location has 1.5 meters depth of peat soil that observed through peat soil profiling using peat sampler. The geological feature is the research location where marine and continental unconsolidated deposits such as peat, humic clay and silt as shown in Figure 1.

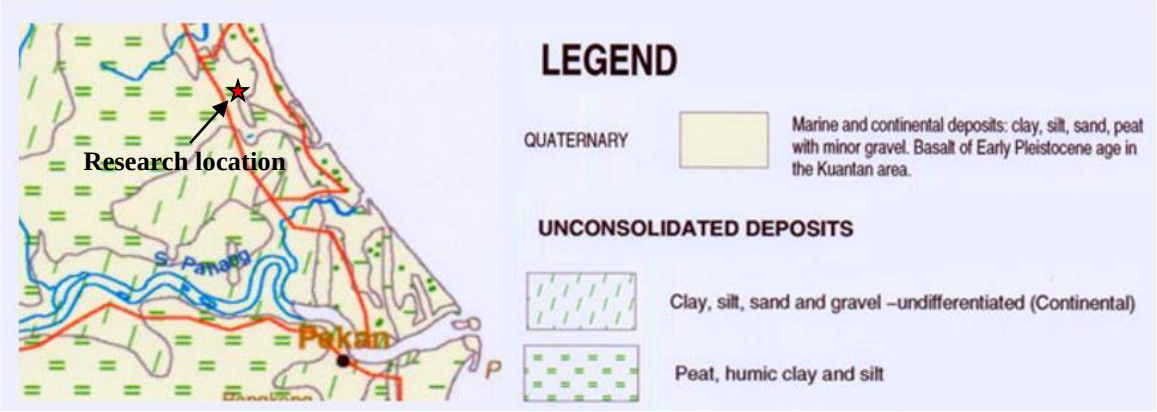



**Figure 1.** Geological map at Penor, Pahang (Jabatan Mineral dan Geosains Malaysia, 1985) [13].

## 5. Methodology

### *5.1. Determining peat soil density using peat sampler.*

The density of peat was determined on site by using the peat sampler for every 0.5 meters depth. Peat sample has a semi-cylindrical shape after taken from specified depth. To ensure sample disturbance in minimum, the peat sample was measured it's diameter and length on site, then put into a sealed plastic bag to ensure minimum moisture reduction and measured its weight in laboratory. The soil sample was cut approximately 150 mm length and taken from the top part of soil sample for every 0.5 meters. The diameter and length of sample were measured to calculate its volume, then calculate the peat in-situ density after measuring its weight. Peat density determination for each study were repeated for three times to obtain average peat density.

### *5.2. Multi-channel Analysis of Surface Wave*

This method just required a 7 kg of sledgehammer was used as a seismic source that impacted vertically to the aluminium plate. As a recorder, ABEM Terraloc MK-8 seismograph was used and connected with 24 units of 4.5 Hz vertical geophone is used as a sensor. Figure 2 shows the MASW field acquisition arrangement.

For record length, it requires time from 2 second until 4 second recording depend on the times requires to observe surface wave at the seismograph. Thus sampling interval need to be adjusted from 250 μs - 500 μs and number of samples is 4096 - 8192. Any filtering of noise turns off to prevent changes in the quality of any noise from the ground. Numbers of background noise record must not stack together. Array line cable is put across the research site in linear with a length of 23 meters long with 1 meter spacing between geophones and offset distance from 1st geophone is 5 meters. For the geophone should be placed in a clear area and approximately level with the ground. This is to ensure the accuracy of seismic data. For each study location, there are five lines and offset distance between lines is 0.5 meters.

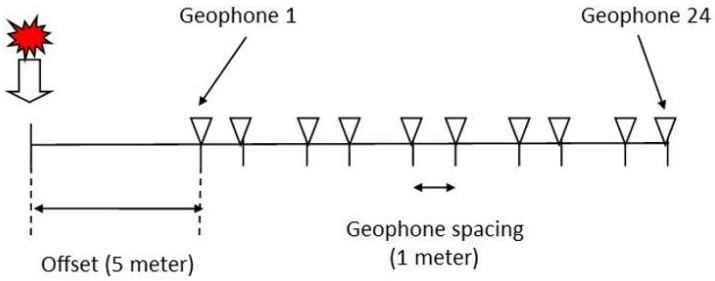



**Figure 2.** MASW field acquisition arrangement.

## 6. Result and Discussion

### *6.1. Shear wave velocity, soil profile*

Surface wave seismic data were exported from seismograph then process it using SeisImager software. As shown in Figure 3 the shear wave velocity on peat from the surface to 1.0 m depth are ranging between 32.94 – 95.89 m/s. Peat mixed soft clay layer at 1.5 m depth where the shear wave velocity has decreased that are ranged from 41.57 – 69.73 m/s. When reached depth of 2.5 m of clay, the velocity continued to increase from 66.51 – 87.96 m/s.

The dispersions of surface wave are commonly affected by the variation formation of soil layer on the ground and shown variations in shear wave velocity. For peat, it contains a lot of organic matter and effected surface wave propagation on peat which makes the picking of the dispersion curve in phase velocity in the frequency domain are difficult to choose fundamental mode of the dispersion curve. The surface wave propagation also affected by void ratio of peats and void ratio are depends on

the organic content and fibre content of peat. The shear wave velocity affected by void ratio through the fibre content [2]. In saturated soils, mass density will be directly related to the void ratio. This existence of peat void ratio caused the surface wave propagation have been absorbed before detected by the geophones. According to Beamish [14] seismic wave attenuation across the soil profile is controlled by moisture content in concurrence with the density and porosity of the materials especially for peat and organic soils.

*6.2. Shear modulus estimation.*

Shear modulus of peat has been estimated using the formula and obtained the in-situ density of Penor peat. In geophysical theory, shear modulus related to shear velocity as shown in Eq. 1. From the Eq. 1, it's show shear velocity is directly proportional with maximum shear modulus. Thus maximum shear modulus will increase if shear velocity also increases.

$$G_{max} = \quad \rho V_s^2 \tag{1}$$

Where Gmax is small-strain shear modulus and ρ is density of soil

As shown in Figure 3, the shear modulus of peat were ranged between 0.93 – 8.01 MPa. Meanwhile Peat mixed soft clay layer at 1.5 m depth where modulus has decreased that are ranged from 2.01 – 8.38 Mpa. At a depth of 2.5 m of clay, the shear modulus maintains to increase from 7.16 – 12.52 MPa.

In geotechnical engineering properties such as the shear modulus for determination of peat stiffness, are mainly affected by the fibre content, moisture contents and degree of degradation. The percentage of fibre content can change the shear strength of peat where high fibre content will give high shear strength. The contents affected the density of peats where increasing of both contents will increase the peat density and vice versa. Meanwhile degree of decomposition is decrease of organic matter that causes the disappearance of the peat structure and changing the primary chemical composition of the peat [15]. As the degree of decomposition are high, the density of peat will decrease since the decomposition affects the weight of peat, organic matter which become lighter than low degree peat of decomposition. Peats with high moisture content makes it heavier compared with less moisture content and then can increase the density of peats. Peat soil contains more fibre or organic content and thus it has a high water absorption capacity since the soil fibre are very loose and hollow [7,15]. Even though most of organic matter in peats have been decomposed, there are few organic components such as small roots and partially decomposed organics are included during sampling the peat for measuring its weight and the components increase the weight and directly increase the density of peat.

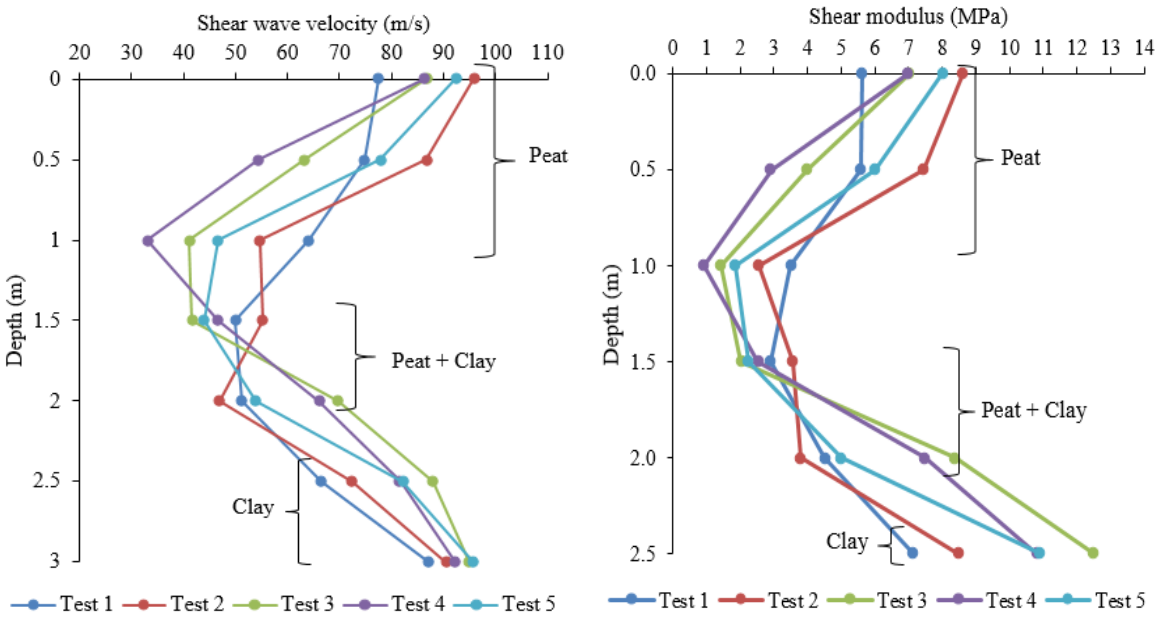



**Figure 3.** Shear wave velocity and shear modulus of Penor peat

## 7. Conclusion

The dynamic behaviour of Penor peat was determined using the MASW method. Shear wave velocity is ranged between 32.94 – 95.89 m/s and shear modulus are ranging between 0.93 – 8.01 MPa. The differences of both dynamic properties are due to the changes of peat density and affected by the fibre content, organic content, degree of degradation and moisture content.

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## Reference

[1] Luna R & Jadi H 2000 Determination of Dynamic Soil Properties Using Geophysical Methods. Proceedings of the First International Conference on the Application of Geophysical and NDT Methodologies to Transportation Facilities and Infrastructure. St. Louis. Pp. 1 – 15.

[2] Schneider J A, Hoyos L, Jr. Mayne P W, Macari E J & Rix G J 1999 Field and Laboratory Measurements of Dynamic Shear Modulus of Piedmont Residual Soils. Behavioral Characteristics of Residual Soils. *Geotechnical Special Publication*. 92 pp. 12-25.

[3] Bødker L 1998 Behaviour of Soil Subjected to Dynamic Loads. *In Dynamics of Structures 1993 1997*. Denmark: Aalborg University. pp. 65 – 76.

[4] Shafiee A, Brandenberg S and Stewart J 2013 Laboratory Investigation of the Pre- and Post-Cyclic Volume Change Properties of Sherman Island Peat. *Geo-Congress*. 5 pp. 139 – 148.

[5] Hashim R & Islam S 2008 Engineering Properties of Peat Soils in Peninsular Malaysia. *Journal of Applied Science*. 8(22) pp. 4215 – 4219.

[6] Zainorabidin A, Wijeyesekera D C & Jayaratne R 2010 Fabric of Peat Soils Using Image Analysis. *Proceedings of Advances in Computing and Technology, (AC&T) the School of Computing and Technology 5th Annual Conference*. University of East London. pp 38 – 44.

[7] Kolay P K, Sii H Y & Taib S N L 2011 Tropical Peat Soil Stabilization using Class F Pond Ash from Coal Fired Power Plant. *International Journal of Civil and Environmental Engineering*. 3(2) pp. 79 – 83.
[8] Nordin S H 2013 The Shrinkage Measurement Peat Soil at Penor Site. Universiti Tun Hussein Onn Malaysia: Bachelor Degree Thesis.
[9] American Society for Testing and Materials, 2001 Standard Test Method for Laboratory Determination of the Fiber Content of Peat Samples by Dry Mass. United States. D 1997-91.
[10] Eker A M 2012 Local Site Characterization And Seismic Zonation Study By Utilizing Active And Passive Surface Wave Methods: A Case Study For The Northern Side Of Ankara, Turkey, *Engineering Geology* 151. Elsevier Journal. pp. 64 – 81.
[11] Neelima D S 2010 Multi-Channel Analysis Of Surface Wave (MASW) Testing For Dynamic Site Characterization Of Delhi Region, *Fifth International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics*. Paper No. 1.01b
[12] Jianghai X, Richard D M, Choon B P, James A H and James B H 2000 Comparing Shear-wave Velocity Profiles from MASW with Borehole Measurements in Unconsolidated Sediments, Fraser River Delta, B.C., Canada, *Journal of Environmental and Engineering Geophysics*. 5(3) pp. 1 – 13.
[13] Jabatan Mineral dan Geosains Malaysia. 1985 Geological Map of Peninsular Malaysia. Kuala Lumpur: Ministry Of Natural Resources and Environment.
[14] Beamish D 2014 Peat Mapping Associations of Airborne Radiometric Survey Data. Remote Sensing Journal. 6 pp. 521 – 539.
[15] Huat B B K, Kazemian S, Prasad A & Barghchi M 2011 A Study of The Compressibility Behaviour of Peat Stabilized by DMM: Lab Model And FE Analysis. *Scientific Research and Essays*. 6(1) pp. 196 – 204.