INSTRUMENTED PHYSICAL MODEL STUDIES OF THE PEAT SOIL-ENGINEERING STRUCTURE INTERACTION

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PERPUSTAKAAN TUNKU TUN AMINAH

“For my beloved family”

Mohd Razali Jaafar
Zaharah Abdullah
Zahariah
Norhaini
Kamsany
Kamsalmi
Kamsyahrull Afendy
Amyrull Alyff, Nazarul Afwan, Ainn Nour & Danial Hakimy
Faris Aiman, Alisa, Qistina, Fahrin Aqiel & Qaisara
Kaf Ammar, Khasiff & Daniel Haikal
Syafiqah

“For my beloved friends”

Kak Salina, Kak Bee Lin, Rasi, Sue, Cdomp, Syieda, Noor and all.

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ABSTRACT

The engineering structures are mostly constructed directly in contact with the ground and the response between the soil and the structure is termed as soil-engineering structure interaction. To understand the interaction, physical modelling is considered as a prime method of study. This physical model study has been conducted on peat soils obtained from the Malaysian Agricultural Research and Development Institute-Integrated Peat Research Station (MARDI-IPRS) in Pontian, Johor. Peat is considered as unsuitable soil for supporting foundations in its natural state due to the high moisture content (>100%), high compressibility (0.9-1.5) and low shear strength (5-20 kPa) values. Peat also contains high organic matter (>75%), large deformation, high compressibility and high magnitude and rates of creep. The objectives of this study are to identify the engineering characteristic of the peat, analyse the deformation behaviour in peat soil based on physical modelling, analyse using physical model the stress distribution beneath the structure in peat soil and to compare the peat behaviour with sand. The reason of comparing these two different types of soil was to obtain the significant difference in terms of the settlement, stress and failure pattern. This study also helps to acquire basic understanding of the behaviour of settlement and stress of peat soil when load is applied to it. The rectangular model and the square model were used in pre-model study (PMS) to identify suitable indicators and observed the deformation of the peat/sand after the loading process. Meanwhile, a plane strain model cm was used in plain strain study (PSS) with instrumentations (Displacement Transducers and Soil Pressure Gauge) to investigate and observed the settlement and stress on the peat/sand. Various static loads were applied at the surface and the interaction between peat soil and sand with the structure was recorded based on all the deformations and stresses at various positions and levels. The water level was maintained at a constant level that is at the surface of the soil to prevent any induce stress due to the seepage of water and to omit settlement due to the lowering of the water table. The observations showed that the settlement in peat was higher compared to the settlement in sand because of the properties of peat that highly compressible compared to sand. The deformation of sand corresponds to general bearing capacity failure and deformation in peat shows punching shear failure. However, the stress in the sand was higher than the stress in peat because of the presence of water that affects the value of stress in peat.

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ABSTRAK

Struktur kejuruteraan kebanyakannya di bina secara langsung menyentuh permukaan tanah dan tindak balas di antara tanah dan struktur di panggil sebagai interaksi struktur kejuruteraan – tanah. Untuk memahami interaksi, model fizikal dianggap sebagai kaedah utama kajian. Model fizikal ini telah dijalankan ke atas tanah gambut yang di perolehi dari *Malaysian Agricultural Research and Development Institute-Integrated Peat Research Station* (MARDI-IPRS) di Pontian, Johor. Gambut di anggap sebagai tanah yang tidak sesuai untuk menyokong asas dalam keadaan smulajadi kerana nilai kandungan lembapan yang tinggi (>100%), kebolehmampatan yang tinggi (0.9–1.5) dan kekuatan ricih yang rendah (5– 20 kPa). Gambut juga mengandungi kadungan organik yang tinggi (>75%), ubah bentuk yang besar, kebolehmampatan yang tinggi, magnitud dan kadar rayapan yang tinggi. Objektif kajian adalah untuk mengenalpasti ciri-ciri kejuruteraan tanah gambut, analisis, analisis kelakuan ubah bentuk di dalam tanah gambut berdasarkan model fizikal, analisis dengan menggunakan model fizikal untuk agihan tegasan di bawah struktur di kawasan tanah gambut dan untuk bandingkan kelakuan gambut dan pasir. Kedua-dua jenis tanah ini dibandingkan adalah untuk mendapatkan perbezaan ketara dari segi enapan, tekanan dan corak kegagalan. Kajian ini juga membantu untuk pemahaman asas tingkah laku enapan dan tekanan tanah gambut apabila beban dikenakan kepadanya. Model segi empat tepat dan model segi empat sama telah digunakan dalam kajian pra-model (PMS) untuk mengenal pasti penunjuk yang sesuai dan memerhatikan ubah bentuk gambut/pasir selepas proses pembebanan. Sementara itu, model terikan kosong telah digunakan dalam kajian terikan kosong (PSS) dengan instrumentasi *(Displacement Transducers* dan *Soil Pressure Gauge)* untuk menyiasat dan memerhatikan enapan dan tekanan pada gambut/sand. Sifat – sifat indeks dan sifat – sifat kekuatan tanah gambut juga telah ditentukan. Model PSS telah dibina untuk menguji gambut dan pasir. Pelbagai beban statik telah digunakan di permukaan dan interaksi antara tanah gambut dan pasir dengan structur di catatkan berdasarkan ubah bentuk dan tekanan pada pelbagai kedudukan dan tahap. Paras air dikekalkan pada tahap yang tetap iaitu berada pada permukaan tanah untuk mengelakkan sebarang tekanan aruhan disebabkan oleh resapan air dan untuk abaikan enapan yang disebabkan oleh penurunan aras air. Pemerhatian menunjukkan bahawa enapan tanah gambut lebih tinggi berbanding enapan pasir disebabkan oleh cirri-ciri tanah gambut yang tinggi kemampatan berbanding pasir. Ubah bentuk pasir adalah sepadan dengan kegagalan keupayaan am dan ubah bentuk pada gambut menunjukkan kegagalan ricih menebuk. Walaubagaimanapun, tekanan dalam pasir adalah lebih tinggi berbanding tekanan pada tanah gambut kerana kehadiran air mengurangkan nilai tekanan di dalam tanah gambut.

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LIST OF SYMBOLS AND ABBREVIATIONS

$\Delta\sigma$	Increase of stress
σ'_0	Effective overburden pressure
$\Delta\sigma'$	Effective pressure
ν_s	Poisson's ratio of soil
B	Width of loading plate
C'_α	Secondary compression index
C_c	Compression index
DS	Dry sand
DT	Displacement transducer
E	Young Modulus
E_u	Undrained modulus
E_s	Modulus of elasticity of the soil under the foundation
e_0	Initial void ratio
Gs	Specific Gravity
H	Thickness of the soil
I_s	Shape factor
I_f	Depth factor
L	Length of loading plate
LL	Liquid Limit
PL	Plastic Limit
PPT	Pore pressure transducer
PT	Peat
q	Uniformly distributed load per unit area
SPG	Soil pressure gauge
Sc	Primary settlement
Si	Immediate settlement
Ss	Secondary compression
St	Total settlement
t_1, t_2	Time
WS	Wet sand

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CHAPTER 1

INTRODUCTION

1.1 Preamble

Peat is a very weak material in its normal (unloaded) state on which to construct a road/building (Forestry Civil Engineering, 2010). The peat soil is a soft soil with high compressibility and it is widely identified in Malaysia. The peat soil was identified as one of the major group in Malaysia. Huat (2004) clarified that the total area of tropical peat swamps forests or tropical peat land in the world amounts to about 30 million hectares and some 3.0 million hectares or 8% of the total area of Malaysia was covered by peat as shown in Figure 1.1. Generally, peat soils occur both in the highlands and lowlands. However, the highland organic soils are not extensive. The lowland peat occurs almost entirely in low-lying, poorly drained depressions or basins in the coastal areas. In Peninsular Malaysia, they are found in the coastal areas of the east and west coast, especially in the coastal area of West Johor, Kuantan and Pekan districts, the Rompin- Endau area, northwest Selangor and the Trans-Perak areas in the Perak Tengah and Hilir Perak districts (Huat, 2004). There are two types of peat deposit, the shallow deposit usually less than 3m thick while the thickness of deep peat deposit in Malaysia exceeds 5 m (Hashim and Islam, 2008a).

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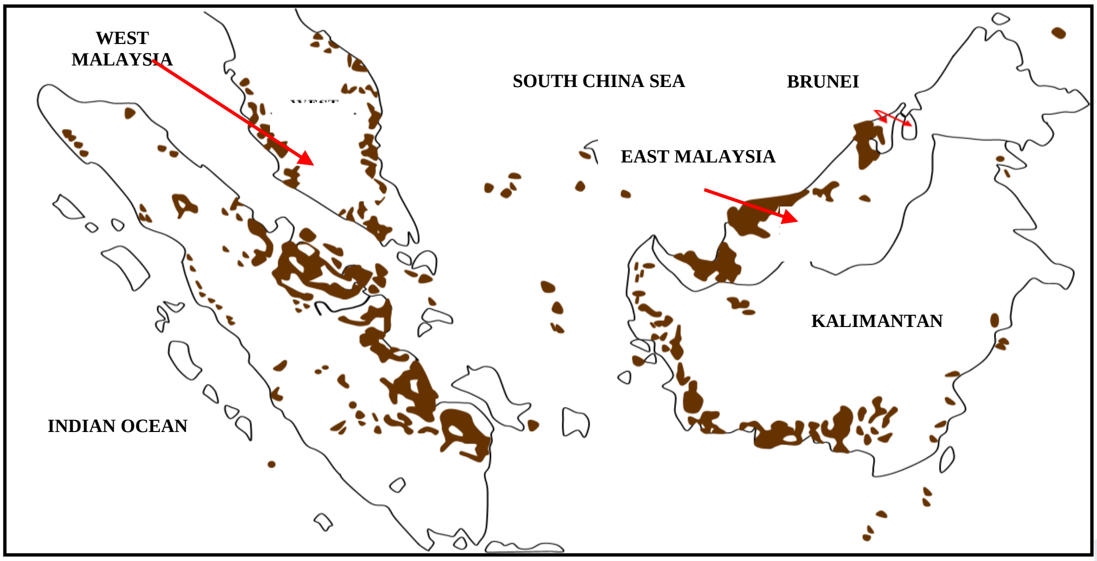

Figure 1. 1: The distribution of Peat in Malaysia (Andriesse, 1974)

Peat in Malaysia can be categorized as a tropical peat with unique characteristics. Thus, this makes it significantly different from other peat. In its natural state, this soil is normally dark reddish brown to black in colour and consists of partly decomposed leaves, branches, twigs and tree trunks with a low mineral content (Zainorabidin and Wijeyesekera, 2007). Table 1.1 shows the characteristics of peat in Malaysia.

Table 1. 1: Characteristics of Peat Swamps in Malaysia (Muttalib, 1991). (Cited by Zainorabidin and Wijeyesekera, 2007)

Region	Location	Topography	Total Area	Characteristics
Peninsular	West Johore, Kuantan, Pekan, Selangor, Perak.	Peat land is flat.	Approximately 80, 000 km^2 with 89% of its having deep peat (> 1m).	Normally found in the coastal areas of the east and west coasts.
Sarawak	Kuching, Samarahan, Sri Aman, Sibu, Sarikei, Bintulu, Miri and Lambang.	The basin peat swamps are dome-shaped.	16500 km^2 with 89% of its having deep peat (> 1m)	Peat occurs mainly between the lower stretches of the main river courses (basin peats) and in poorly drained interior valleys (valley peats).
Sabah	Kota Belud, Sugut, Labuk, Kinabatangan.	Peat land is flat.	86 km^2. There were no estimates on the depths.	Peat soils are found on the coastal areas.

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Road construction over peat presents great challenges to road builder not only in the construction process but also in the management of the engineering properties of peat which have high water content (>200%), high compressibility (0.9 to 1.5), high organic content (>75%) low shear strength (5-20kPa) and low bearing capacity (<8kN/m^2), large deformation and high magnitude and rates of creep (Zainorabidin and Wijeyesekera, 2007; Haan and Kurse, 2006). This unique characteristic of peat has led to the problems of the construction become challenging in Malaysia (Zainorabidin and Bakar, 2003; Hashim and Islam, 2008a).

The peat which was formerly considered unsuitable foundation for the construction had to be used because of the land use or demand. The challenges faced by engineers in road/building construction over peat include limited accessibility, drainage problem and stability problems. Hence, construction process on peat soil has become more complex. In order to construct a safe, stable and serviceable road, a road engineer has to overcome this engineering problem by using suitable solutions to construct roads on peat soil. It is also important for engineers to know the nature of the distribution of stress along a given cross section of the soil profile that is, what fraction of the normal stress at a given depth in a soil mass to analyse the problems such as compressibility of soils, bearing capacity of foundations, stability of embankment, and lateral pressure on earth-retaining structures (Das, 2011).

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1.2 Description of Problems

Peat is considered as a worst soiling foundation compared to other types of soil with low strength, high permeability and high water content. Zainorabidin and Wijeyesekera (2007) discussed the geotechnical challenges that need to be faced by geotechnical engineers in Malaysia during the designing and managing the construction on peat soil. Among the challenges include the difficulty to get the samples of hemic and fibrous peat using conventional undisturbed samplers and the different method of sampling for the different depth of peat soil.

Staley (2007) stated that the impact of settlement can be significant, particularly where the differential settlement occurs due to a peat deposit having variable thickness, groundwater flow direction, slopes, differential loading or previous compressions. Because of settlement occurs gradually, it is important to give more attention on impacts of additional loading and water level against the settlement. In this study the effect of additional loading was observed and the water level was maintained.

Ferguson (as cited in Wartman 2006) stated that physical models have served important functions in engineering research, practice and education for hundreds of years. In additional, the full scale experiments are very expensive, difficult to run, and are hard to repeat (Meguid, 2008). Hence, because of this reason, this study focussed on physical models in the laboratory.

One of the case studies in Malaysia was in Sibu, Sarawak. The peat formations in some parts of Sibu are well over 10 meters in depth (Vincent, 2009). Figure 1.2 shows the settlement in a housing area in Sibu town, which cause a serious problem. This problem caused high risk to occupant in terms of safety. Duraisamy and Huat (2008) highlighted that ground subsidence on peat generally resulted in negative gradients to drainage. This scenario resulting of unhealthy water stagnation in many parts of the town and it is also prone to flooding (Kolay et al, 2011).

Figure 1.2: Settlement in the Housing Area, Sibu, Sarawak (Author, 2009)

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Figure 1.3 shows the settlement near Salim-Airport Road By-pass, Sibu, Sarawak. The figure 1.3 (a) shows the gap between the pipeline with the ground surface and Figure 1.3 (b) show the settlement under a lamp post. According to Duraisamy and Huat (2008), the problem of this settlement is mainly caused by either uncontrolled land filling or ground water lowering due to over drainage or due to both of the activities.

(a) **(b)**

Figure 1.3: Settlement for (a) pipeline and (b) lamp post near Salim-Airport Road By-Pass, Sibu, Sarawak (Author, 2009)

Figure 1.4 was taken during a site investigation in Parit Nipah, Johor, which is in the housing area. This house has been built on peat soil. The author observed that the settlement occurred and this can clearly see in the columns that support the house. It is dangerous to the occupants. The owner needs to place an object like a rock or wooden block between column and foundation because of some columns appear hanging as shown in Figure 1.4 (a).

The interaction between structure and foundation is important especially to distribute the loading of the structure uniformly into the foundation. Sekhar (2002) stated that the force quantities and the settlement at the finally adjusted condition can only be obtained through interactive analysis of the soil-structure analysis. Figure 1.4 (b) shows higher settlement value in the peat. Loading from a small wooden house have been distributed to the ground and resulted in the settlement. The settlement in this area was in the range of 150 mm. Peat is not suitable to support higher loads because of the high compressibility.

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