MINISTRY OF WORKS

CIDB MALAYSIA

CREAM CONSTRUCTION RESEARCH INSTITUTE OF MALAYSIA

GUIDELINES FOR CONSTRUCTION ON PEAT AND ORGANIC SOILS IN MALAYSIA

SECOND EDITION

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SECOND EDITION

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Foreword

Peat occurs over 25,000 square km in Malaysia corresponding to about 8% of the country's land area. Malaysia despite being a relatively small country has, on a country basis, the 9th largest peat area in the world. About 69 % of Malaysia's peat area is in Sarawak.

Construction on peat is always more challenging than on soft clay in terms of access, earthworks and settlement. Over the last 25 years the industry has made appreciable advances in methods of construction over peat. This document "GUIDELINES FOR CONSTRUCTION ON PEAT AND ORGANIC SOILS IN MALAYSIA" commissioned by Construction Research Institute of Malaysia (CREAM) a research institute fully funded by CIDB Malaysia and supported by the Ministry of Works Malaysia was prepared by a committee of practising engineers, geologists and academicians. The guidelines constitute an embodiment of design and construction experience developed from practice in Malaysia over the last 30 years.

This document is an updated version of "GUIDELINES FOR CONSTRUCTION ON PEAT AND ORGANIC SOILS IN MALAYSIA" developed in 2015. This new version supersedes the 2015 first publication. The main changes of this updated version incorporate new information obtained from research and revision carried out by local universities, government agencies and private consultants.

This second edition contains high resolution and refined maps for all peat land in Malaysia. These updated maps were contributed by Jabatan Mineral dan Geosains Malaysia (JMG).

Local universities such as Universiti Tun Hussien Onn Malaysia, Universiti Malaysia Pahang, Universiti Malaysia Sarawak and Monash University Malaysia contributed on the engineering properties of peat. More local data were incorporated in this new document. Correlations on design properties were updated as reference for engineers and designers.

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December 2019

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Contents

List of Symbols

Symbol	
ha	Hectare
km	Kilometre
m	Metre
S_u	Undrained shear strength (total stress)
S_{uv}	Vane shear strength
Φ'	Effective fiction angle
σ_{vo}'	Initial in-situ effective vertical stress
C_c	Coefficient of primary consolidation
C_α	Coefficient of secondary consolidation
C	Correction factor for the calculation of organic content
c_v	Coefficient of Consolidation
e_o	Initial void ratio
e	Void ratio'
$\Delta\sigma_v$	Increment in vertical stress
t	Time
t_p	Time corresponding to end of primary consolidation
k	Coefficient of permeability
M	Critical state strength parameter
H	Thickness of soft clay
γd, ρd	Dry density
γb, ρ	Bulk density
f_s	Sleeve friction
G_s	Specific gravity
q_t	Tip resistance
R_f	Cone penetration test friction ratio
τ_h	Horizontal shear stress
τ_v	Vertical shear stress
ϕ'	Effective friction angle
μ	Pore Pressure

List of Abbreviations

Abbreviation	
CPT	Cone Penetration Test
LL	Liquid limit
LOI	Loss on Ignition
N	SPT N Value
OC	Organic content
SPT	Standard Penetration Test
JMG	Jabatan Mineral dan Geosains Malaysia
msl	Mean sea level
PSF	Peat swamp forest
CRS	Constant Rate of Strain
CD	Drained triaxial test
CU	Consolidated undrained triaxial test

Chapter 1

Engineering Classification of Peat and Organic Soils

1.1. DEFINITIONS

1.1.1 Peat

The term peat is described as “organic soil” and as a histosol; a naturally occurring highly organic substance, which consist of undecomposed, partially decomposed, and highly decomposed plant remains (Zulkifley et al., 2013). Peat distinguished from other organic soil materials by organic matter of more than 75% and ash content is less than 25% by dry weight (Jarrett, 1995 – Geoguide 6: Site Investigation for Organic Soils and Peat; ASTM D4427). From field identification, peat is completely organic, black or dark brown in color, contains many recognizable plant remains and has low density.

1.1.2 Organic Soils

Organic soil is a soil that contains a significant amount of organic material derived from plant remains. In general, soils with an organic content of greater than 20% and less than 75% are termed organic soil. In the field, a slightly organic silts or clays will appear as inorganic fine grained soils, probably black or dark brown in color, have an organic odor and possibly some visible organic remains.

1.2. PEAT AND ORGANIC SOILS CLASSIFICATION

1.2.1 Peat Classification

Peat commonly occurs as extremely soft, wet, unconsolidated superficial deposits normally as an integral of wetland systems. They may also occur as strata beneath other superficial deposits. It is formed when organic (usually plant) matter accumulates more quickly than it humidifies (decays). This usually occurs when organic matter is preserved below high water table like in swamps or wetlands. Peat is brownish-black in dye which consists of decayed organic and mineral substance. Basically, peat is predominantly made up entirely of plant remains such as leaves and stems. It is produced by the incomplete decomposition and disintegration of sedges, trees, mosses and other plants growing in wet place and marshes in the condition of lack of oxygen (Kazemian et al., 2011a).

Therefore, the color of peat is usually dark brown or black with a distinctive odour (Craig, 1992). Since the main component is organic matter, peat is very spongy, highly compressible and combustible in characteristic. This characteristic also makes peat posessing its own distinctive geotechnical properties compared to other inorganic soils like clay and sandy soils which are made up only by soil particles (Deboucha, 2008).

Decomposition is the breakdown process of the plant remains by the soil micro flora, bacteria and fungi in the aerobic decay. In this procedure, as mentioned earlier, there is disappearance of the peat structure and change in the primary chemical composition of peat. At the end, carbon dioxide and water are the products of the decomposition process. The degree of decomposition varies throughout peat since some plants or some parts of the plants are more resistant than others. Also, the degree of decomposition of peat depends on a combination of conditions, such as the chemistry of the water supply, the temperature of the region, aeration and the biochemical stability of the peat-forming plant (Lishtvan, 1985).

The basis for classification of peat (refer Table 1-1) is developed based on three classes: (i) fibre content, (ii) ash content, and (iii) acidity of peat in accordance to American Society for Testing and Materials standard (ASTM D4427, 2007). Also, Table 1-2 presented by Andrejko *et al*., (1983); Landva *et al*., (1983) on classification system of peat based on ash and organic content.

Table 1-1 Classification of peat based on ASTM standards

Fiber Content (ASTM D1997)	·	Fibric: Peat with greater than 67% fibers
	·	Hemic: Peat with between 33% and 67% fibers
	·	Sapric: Peat with less than 33% fibers
Ash Content (ASTM D2974)	·	Low Ash: Peat with less than 5% ash
	·	Medium Ash: Peat with between 5% and 15% ash
	·	High Ash: Peat with more than 15% ash
Acidity (ASTM D2976)	·	Highly Acidic: Peat with a PH less than 4.5
	·	Moderately Acidic: Peat with a PH between 4.5 and 5.5
	·	Slightly Acidic: Peat with a PH greater than 5.5 and less than 7

Note: These fiber content categories related to widely used field assessment of the degree of humification (H) developed by von Post (1922). Fibric corresponds approximately to H1 – H3; Hemic to H4 – H6 and Sapric to H7 – H10.

The classification of peat is usually assessed using Von Post (1922) scale, which is based on botanical composition, degree of humification and the colour of peat water and examined in-field. This method requires the user to verify the scale of humification of ten degree (*H1* to *H10*) based on the apperance of peat water and peat that escaped between fingers upon squeezing in the hand. Field identification using von Post scale is described in Table 1-3. In addition, Jarrett (1995) developed the extended Malaysian Soil Classification System in which various peats are differentiated by degree of humification whereby fibric or fibrous peat (Ptf): humification range H1-H3, hemic or moderately decomposed peats (Pth): H4-H6 and sapric or amorphous peats (Pta): H7-H10) (refer to Table 1-3). The Field-Emission Scanning Electron Microscope (FESEM) of the peat collected; (i) fibric (ii) hemic and (iii) sapric is shown in Figure 1-1.

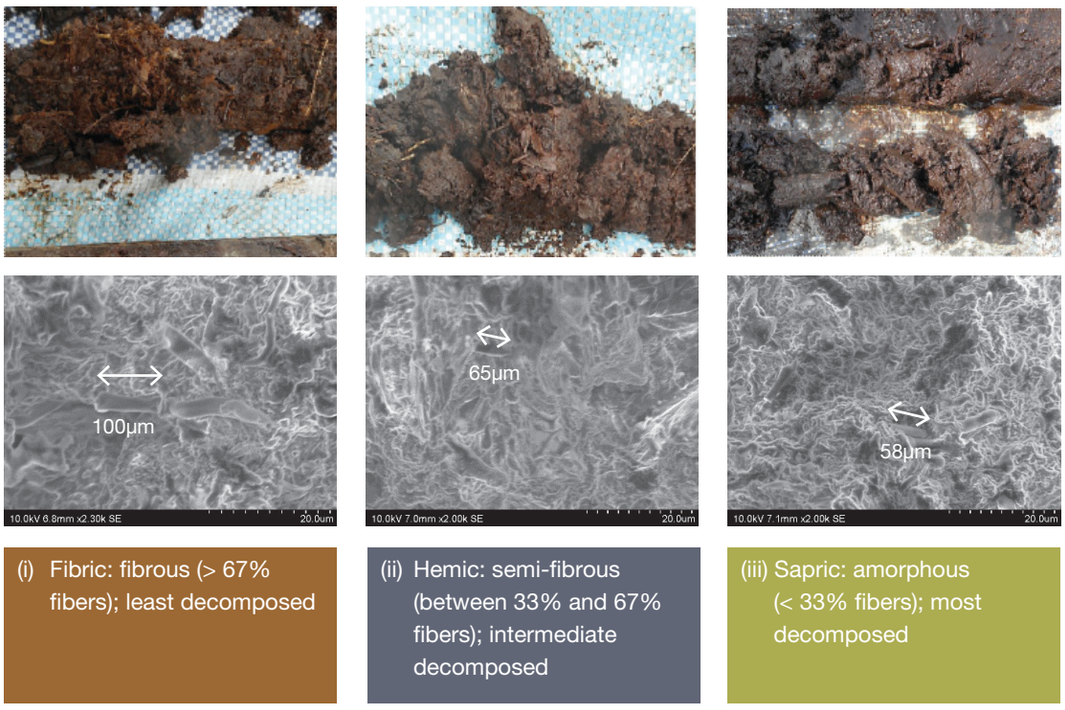


Figure 1-1 Field-Emission Scanning Electron Microscope (FESEM) of the peat

Note: The peat samples is provided by Sarawak Tropical Peat Research Institute (TROPI) and FeSEM images by Monash University Malaysia.

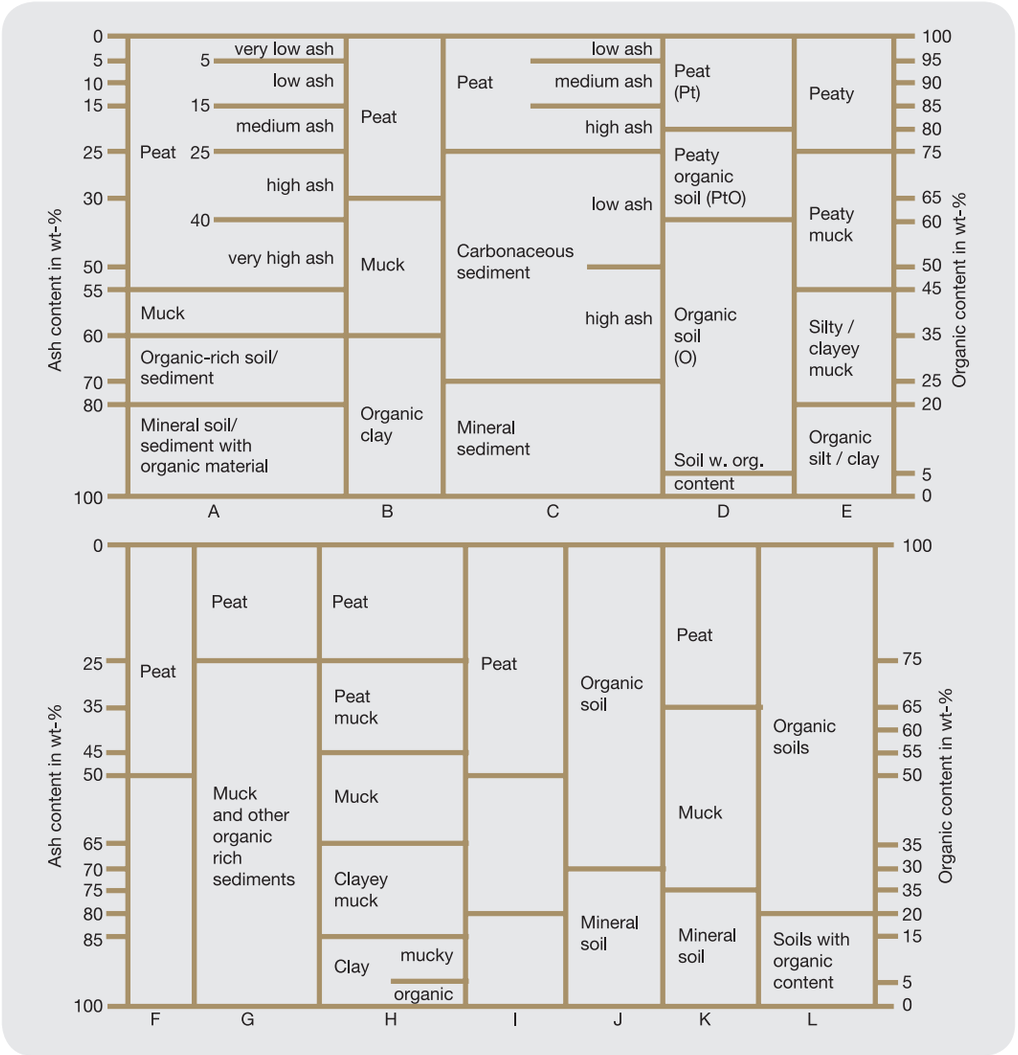
Photos of peat is extract from PLANMalaysia@Selangor (2018)

1.2.2 Organic Soils Classification

It is difficult to identify organic soil in the field as it has combination of mineral soil and organic matters which content is wide range. Table 1-2 provides the classification system for organic soils based on ash and organic content determination presented by Andrejko *et al*., (1983) and Landva *et al*., (1983).

From Jarrett (1995), definitive categorization can only be made after the organic content is measured in the laboratory. The extended Malaysian Soil Classification System by Jarrett (1995) classifies the organic soils into two categories based on organic content which are (1) SLIGHTLY ORGANIC SOILS with organic content of 3%-20% and (2) ORGANIC SOILS with organic content of 20%-75%. The classification is further refined based on liquid limit as tabulated in Table 1-4. Tables 1-2 until 1-4 show the various classification system of peat and organic soils.

Table 1-2 Various classification system of peat and organic soils based on ash and organic content (Andrejko *et al.*, 1983; Landva *et al.*, 1983)



Notes to Table 1-2:

(A) Proposed classification of this study, (B) the Moris classification (Moris, 1989), (C) the classification of the Organic Sediments Research Center of the University of South Carolina (Andrejko et al., 1983), (D) the system of the American Society for Testing and Materials (Landva et al., 1983), (E) the Jarrett system (Jarrett, 1983), (F) the Russian classification (Mankinen and Gelfer, 1982), (G) the previous classification of the American Society for Testing and Materials (ASTM, 1982), (H) the Louisiana Geological Survey system (Kearns et al., 1982), (I) the classification of the International Peat Society (Kivinen, 1968), (J) the Canadian System of Soil Classification (CSSC, 1987), (K) the Davis classification (Davis, 1946) and (L) the Arman system (Arman, 1923).

Table 1-3 Comparison of classification scheme based on the degree of humification for peat deposits according to the von Post system (1922), the US Soil Taxonomy system (Soil Survey Staff. 1990), the Esterle system (Esterle, 1990) and Wüst et al system (2003)

Von Post (1922)	US Soil Tax. (1990)	Esterle (1990)		Wüst et al, (2003)
H1 Completely undecomposed peat which releases almost clear water. Plant remains easily identifiable. No amorphous material present.	***FIBRIC*** *Mostly Sphagnum* *High fiber content*	**Fibric** Reddish-brown peat with >66% fibres: long slender roots and rootlets with diameter 1-10 mm embedded in fibrous or granular matrix from clear water can be extracted	**Peat, organic soil material containing less than 25% wt-%ash** / **Peat, muck, organic soil material containing less than 65% wt-%ash**	**Fibric**
H2 Almost completely undecomposed peat which releases clear or yellowish water. Plant remains still easily identifiable. No amorphous material present.				
H3 Very slightly decomposed peat which releases muddy brown water but for which no peat passes between the fingers. Plant remains still identifiable and no amorphous material present.				
H4 Slightly decomposed peat which, when squeezed, releases very muddy dark water. No peat is passed between the fingers but the plant remains are slightly pasty and have lost some of their identifiable features.	***HEMIC*** *Mostly reed-sedge* *Moderate fiber content*	**Coarse Hemic** Hemic peat with long, slender roots and rootlets **Hemic** Reddish-brown peat with 33-66% fibres; short or equant fragments of roots and rootlets, bark and leaf fragments generally, less than 1cm embedded in granular matrix from which clear to murky water can be extracted Fine hemic Fine grained hemic peat with sapric matrix, partially extrudes through fingers		**Hemic**
H5 Moderately decomposed peat which, when squeezed, releases very “muddy” water with a very small amount of amorphous granular peat escaping between the fingers. The structure of the plant remains is quite indistinct although it is still possible to recognconize certain features. The residue is very pasty.				
H6 Moderately decomposed peat which a very indistinct plant structure. When squeezed, about one-third of the peat escapes between the fingers. The structure more distinctly than before squeezing.				
H7 Highly decomposed peat. Contains a lot of amorphous material with very faintly recognizable plant structure. When sequeezed, about one – half of the peat escapes between the fingers. The water, if any is released, is very dark and almost pasty.	***SAPRIC*** *Low fiber content* *Often high ash*			
H8 Very highly decomposed peat with large quantity of amorphous material with very indistinct plant structure. When squeezed, about two thirds of the peat escapes between the fingers. A small quantity of pasty water may be released. The plant material remaining in the hand consists of residues such as roots and fibers that resist decomposition.		**Sapric** Dark brown to black, with <35% fibres; fine granular material with the consistency of paste from which water can not extruded and deforms as paste upon squeezing		**Sapric**
H9 Practically fully decomposed peat in which there is hardly any recognizable plant structure. When squeezed it is fairly uniform paste.				
H10 Completely decomposed peat with no discernible plant structure. When squeezed, all the wet peat escapes between the fingers.				

The extended Malaysian Soil Classification System for Engineering Purposes and Field Identification (Jarrett 1995) includes organic content and degree of humification in classification of peat, is tabulated in Table 1-4 and followed by Figure 1-2.

In addition to the organic and fibre content, and degree of humification, other index parameters such as water content, liquid limits, specific gravity, unit weights are also useful parameters for peat and organic soils. Hobbs (1986) and Edil (2003) suggested the following characteristics should be included in a full description of peat.

a) Color, which indicates the state of the peat.
b) Degree of humification, which as described above, represents the degree to which the organic content has decayed (fibric, hemic, sapric).
c) Water content determined by oven drying method at 105 ˚C.
d) Organic content as percentage of dry weight, determined from loss of ignition at 450-550 ˚C as percentage of oven dried mass at 105 ˚C.
e) Liquid limit and plastic limit (optional).
f) Fibre content determined from dry weight of fibre retained on #100 sieve (>0.15 mm) as percentage of oven dried mass (optional).

Table 1-4. Extended Malaysian Soil Classification System for engineering purpose and field identification (Jarrett, 1995)

Soil Group	Subgroup and laboratory identification						Field Identification
	Description	Group symbol	Subgroup symbol	Liquid Limit (%)	Degree of humification	Subgroup name	
ORGANIC SOILS AND PEATS							
SLIGHTLY ORGANIC SOILS Organic Content 3%-20%	Slightly organic SILT	Mo	Mo			Slightly organic SILT (subdivide like Co)	Usually very dark to black in colour, small amount of organic matter maybe visible. Often has distinctive organic smell
	Slightly organic CLAY	Fo	CLo	<35		Slightly organic CLAY of low plasticity	
			Clo	35-50		Slightly organic CLAY of intermediate plasticity	
		Co	Cho	50-70		Slightly organic CLAY of high plasticity	
			Cvo	70-90		Slightly organic CLAY of very high plasticity	
			CEo	>90		Slightly organic CLAY of extremely high plasticity	
ORGANIC SOILS Organic Content 20%-75%	ORGANIC SOILS	O				Subdivision of organic soil is difficult, as neither the plasticity tests nor the humification tests are reliable for them. As such, the best attempt is the probable outcome of subdivision leading to descriptions such as “fibrous ORGANIC SOILS” or “ amorphous ORGANIC SOILS of intermediate plasticity.	
PEATS Organic content More than 75%	PEAT	Pt	Ptf		H1-H3	Fibric or Fibrous Peat	Dark brown to black in color. Material has low density so seems light. Majority of mass is organic so if fibrous the whole mess will be recognizable plant remains. More likely to smell strongly if highly humified.
			Pth		H4-H6	Hemic or Moderately Decomposed Peats	
			Pta		H7-H10	Sapric or Amorphous Peats	

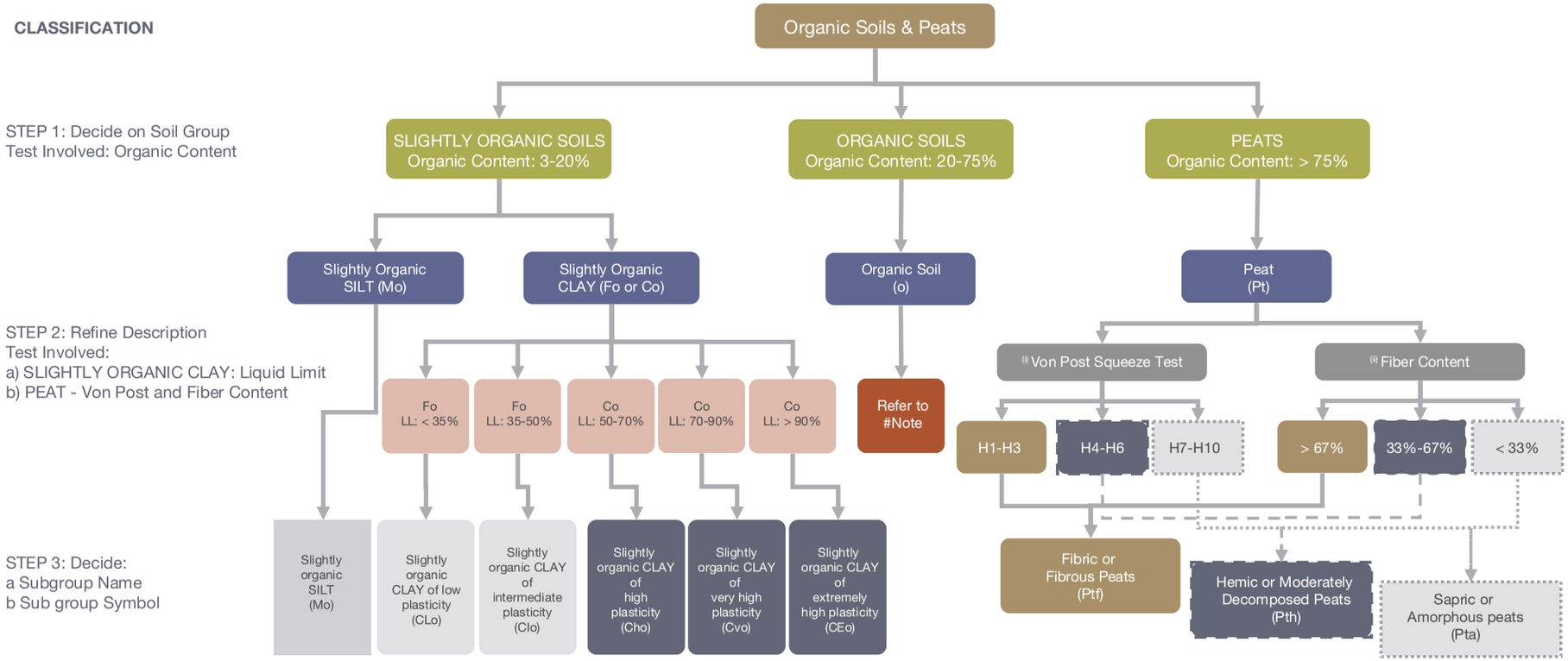
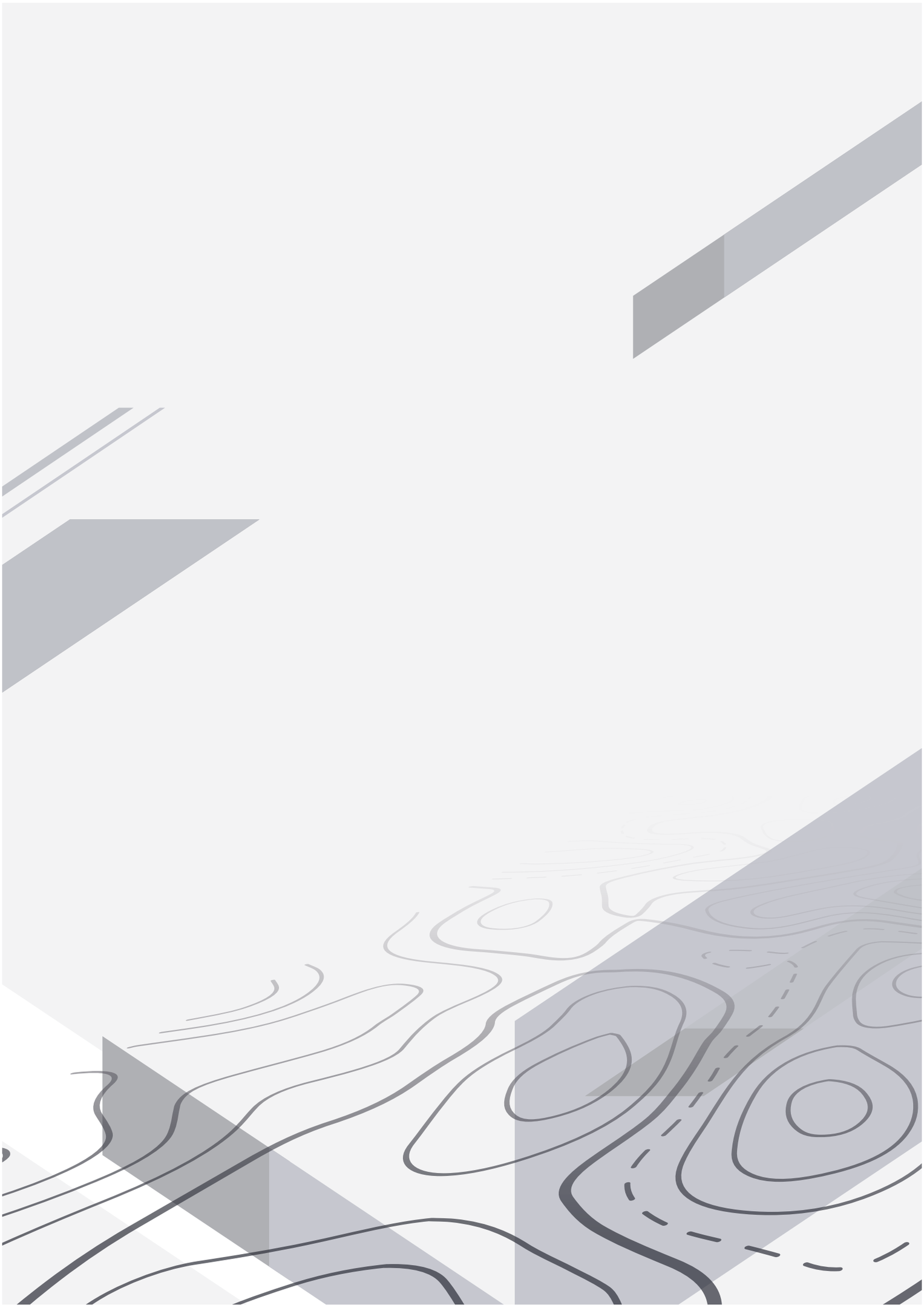


Figure 1-2 Flowchart – Organic Soils and Peat Classification

#**Note**: Subdivision of organic soil is difficult, as neither the plasticity tests nor the humification tests are reliable for them. As such, the best attempt is the probable outcome of subdivision leading to descriptions such as "fibrous ORGANIC SOILS" or " amorphous ORGANIC SOILS of intermediate plasticity.
STEP 1 to **STEP 3** is in accordance to Extended Malaysian Soil Classification System for engineering purpose and field identification (Jarrett, 1995) (refer Table 1-4).
(i)Von Post Squeeze Tests is based on the degree of humification for peat deposits of the von Post system (1922) (refer Table 1-3).
(ii)Fiber Content is referring to ASTM D1997 (refer Table 1-1).



Chapter 2

Formation and Distribution of Peat and Organic Soil

2.1 INTRODUCTION

Peat is found in many countries throughout the world and peatlands constitute about 3% of the land surface of the Earth. More than 95% of the total peatlands of the world are concentrated in the temperate climates of the Northern Hemisphere, which Canada and Russia having the greatest concentration of peatlands with a combined area of over 300 million ha.

Peat also can be found in the tropical climates, wherever the conditions are favourable for its formation. The tropical peatlands are scattered in a few areas in Africa and parts of Central America, but two thirds of its world's total area of 30 million ha is reported to be found in Southeast Asia. Table 2 - 1 shows the distribution of peatlands around the world.

Table 2 - 1. Distribution of peat deposit around the world (Mesri and Ajlouni, 2007)

Country	Area (km^2)	Country	Area (km^2)
Canada	1,500,000	Germany	16,000
U.S.S.R (the former)	1,500,000	Brazil	15,000
United States	600,000	Ireland	14,000
Indonesia	170,000	Uganda	14,000
Finland	100,000	Poland	13,000
Sweden	70,000	Falklands	12,000
China	42,000	Chile	11,000
Norway	30,000	Zambia	11,000
Malaysia	25,000	26 other countries	220 to 10,000

The largest area of tropical peatland is located on the islands of Borneo and Sumatra. It can also be found significantly in other parts of Indonesia, Malaysia, Vietnam, Thailand and Philippines.