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The Characteristics and Engineering Properties of Soft Soil at Cyberjaya

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Abstract

This paper provides information on the distribution and characteristics of peat and organic soil which is distributed around the Multimedia Super Corridor area. Peat and organic soils are the ultimate soft soils in engineering terms. The behavior of peat and organic soils is usually determined using the concepts and methods developed for inorganic soil. However, important anomalies exist, and these are given emphasis in the present overview of the mechanical behavior of these soils. Peat and organic soils are difficult to sample and test using normal soil techniques, and in fact there is not even an adequate engineering system in place for classifying these soils. The characteristics and engineering properties of these soils are presented with respect to its earthwork and geotechnical performance. A preliminary classification system of these soils are also proposed.

Cirian dan Sifat Kejuruteraan Tanah Lembut di Cyberjaya

Abstrak

Kertas ini membincangkan taburan dan kriteria bagi gambut dan tanah berorganik yang meliputi sekitar kawasan Koridor Raya Multimedia. Tanah ini diklasifikasikan kepada tanah asas mengikut istilah kejuruteraan. Sifat tanah gambut dan organik ini dikenalpasti menerusi konsep dan kaedah penilaian bagi tanah tak berorganik. Walau bagaimanapun ianya dapat dibezakan dari segi sifat mekanikal berdasarkan anomali yang wujud. Sehingga sekarang masih belum terdapat sebarang sistem pengelasan bagi tanah ini dan ianya sukar untuk disampel dan diuji mengikut kaedah biasa. Kriteria dan sifat kejuruteraan tanah gambut dikawasan ini diberikan berdasarkan keupayaan geoteknik dan kerjatanah. Satu sistem pengkelasan bagi tanah ini juga diperkenalkan.

INTRODUCTION

As development proceeds at a rapid pace throughout the region, projects are increasingly being located on poor ground. Malaysia has considerable tracts of low lying land, which comprise strata that impose difficult design and construction conditions, due to the presence of soft clay or peat soils.

Slope and embankment failures on poor ground during construction has become a problem, and with the accelerated rate of development, this problem will certainly worsen unless proper planning and management of the site is adopted at an early stage of any proposed construction. In order to facilitate proper planning, a study was initiated to investigate possible engineering and geological factors that have contributed to earthwork problems. The study was focused on the Cyberjaya Development project.

To improve understanding of the problems that are likely to be encountered, the characteristics and engineering properties of the soft soil in this area was determined. The distribution of this soil in the study area was also investigated. In this paper, emphasis will be made on addressing the selection of parameters for the design of slopes or deep excavation.

SITE GEOLOGY

The data in this paper is obtained from pre-construction and construction soil investigations conducted during the Cyberjaya Development project. The geology and soil distribution of the study area is shown in Figure 1.

Peat and Soft Soil

The low-lying swampy areas are extensively covered with peat of an average thickness of 2.0 m, although thickness of up to 10.0 m has been recorded. The peat can normally be differentiated as dark brown spongy amorphous peat and spongy fibrous peat. The peat is also associated with decayed wood and root. It is formed under both topogeneous and ombrogenous conditions.

Immediately below the peat is a layer of very soft to soft compressible clay, which has generally been described as marine clay. This soft clays is light grey in color and is very soft to very stiff silty clay to sandy silty clay. The soft soil deposits are categorised as the Pengkalan Member of the Beruas Formation (Bosch, 1988). The total depth of peat and very soft clay over much of the area is less than 5.0 m to 7.0 m (Figure 2). Depths of up to 15.0 m to 25.0 m have, however, been identified along the line of the perimeter road and in the park area (Plate 1).

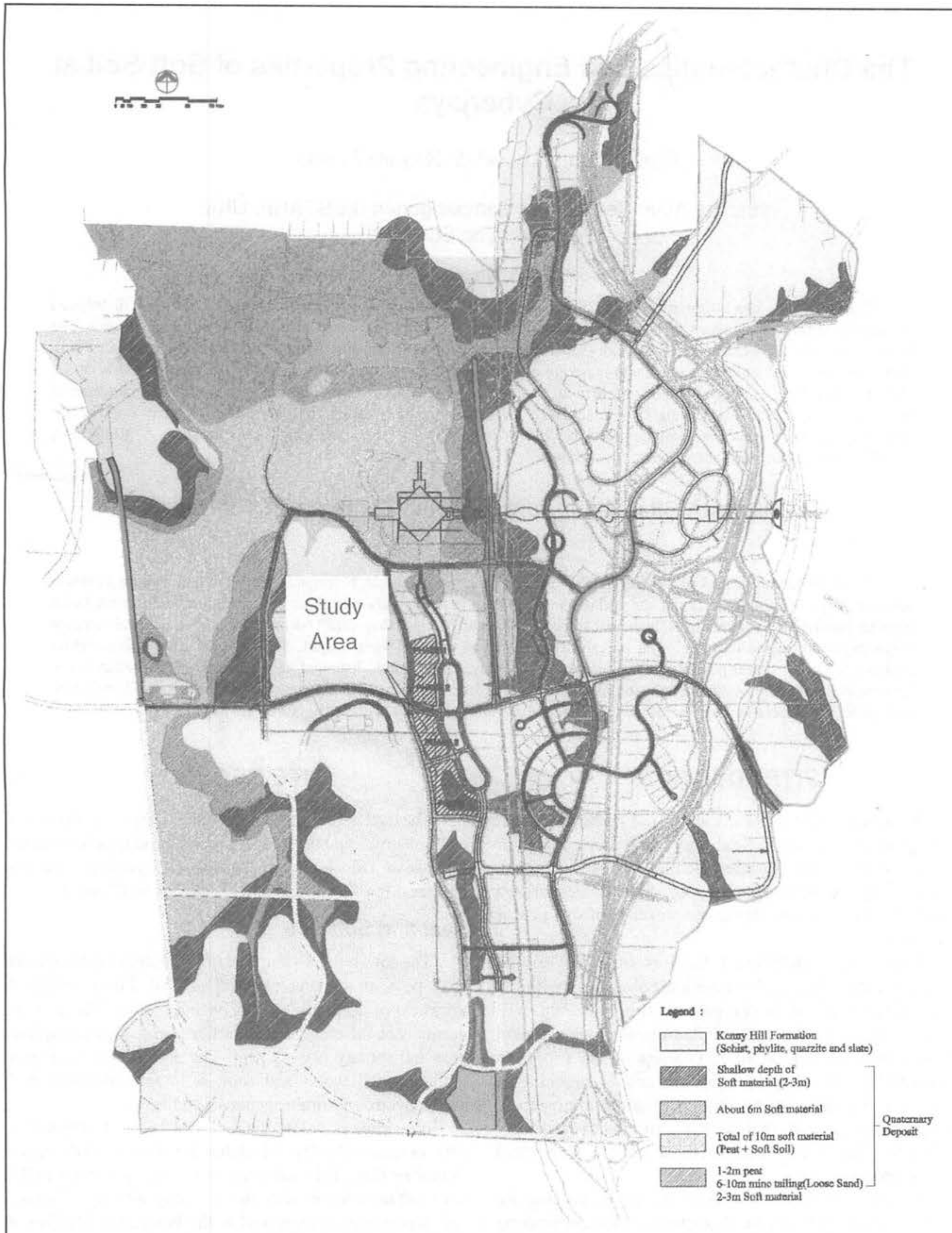

Figure 1: Map showing the geology and soil distribution in the study area.

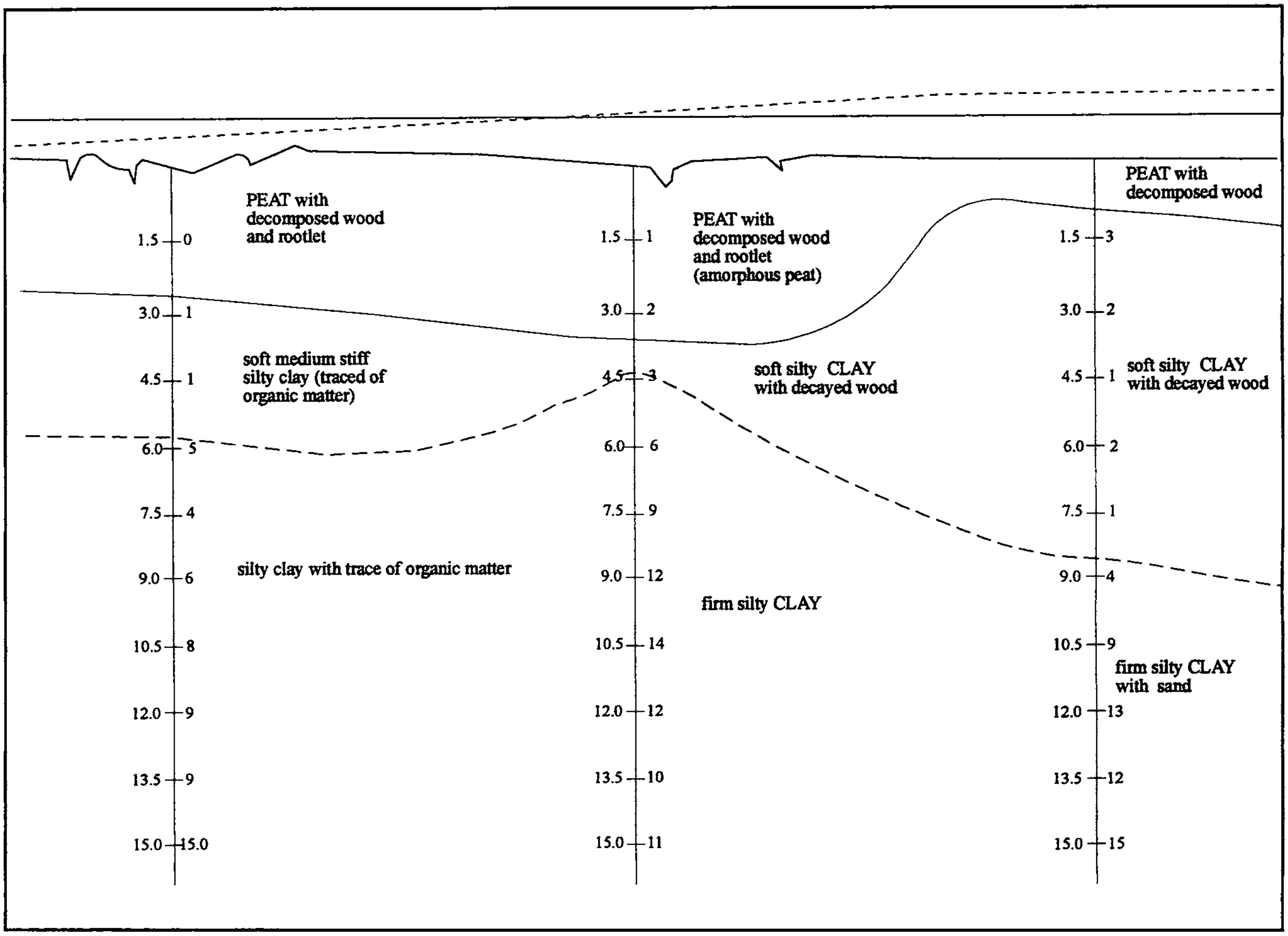

Figure 2: Soft soil profile.

The deposition of soft soil in the site are in single layers of 2.0 m to 25.0 m in thickness.

Residual Soil, Colluvium and Bedrock

The high ground in the study area rises between 30 m to 150 m. This high ground is mainly covered by residual soils, derived from the weathering of foliated metasedimentary rock, which occur as a series of parallel hills aligned in a south-easterly to north westerly direction with a dip of between 65° and 95°. The metasedimentary rocks are inferred to be of the Kenny Hill Formation comprising essentially sandstone, shale, phyllite and quartzite (Plate 2). The denudation of residual soils has led to the formation of the present valley systems. This contact zone between the soft sediments and the residual soils is quite complex and an overlying deposit of colluvium generally masks its location.

The colluvium is generally encountered as soft to stiff silty clay overlying medium dense to dense very clayey gravel or sand. The residual soil is typically firm to stiff, becoming very stiff and hard sand silty clay with increasing depth. Residual soil eventually grades into moderately to completely weathered rock, a hard dense clayey sand or sandy silt but generally only at depths greater than 20 m.

Ground Water

In the plains and valleys, the groundwater level is generally near to the ground surface, at depths of at between 0.1 m and 0.5 m. The level is slightly lower at the upper end of some valleys but even then it is not more than 1 m in depth.

SOFT SOIL DESCRIPTION, TEST METHOD AND CLASSIFICATION

Description

Soft clay is defined as soils with large fractions of fine particles such as silty and clayey soils, which have high moisture content, peat foundations and loose sand deposits, located near or under the water table (Kamon and Bergado, 1991).

Any discussion on construction involving peats or soft soils requires a definition of the terms used to describe these materials. Depending on the geographic origin and training of the engineer or geoscientist involved, a "peat/soft soil" may be defined as soil with an organic content greater than anywhere from 20% to 70% of the total weight. At worst "peat/soft soil" may be used interchangeably with

Plate 1: Peat at the proposed Cyberjaya Park, Cyberjaya Flagship Zone.

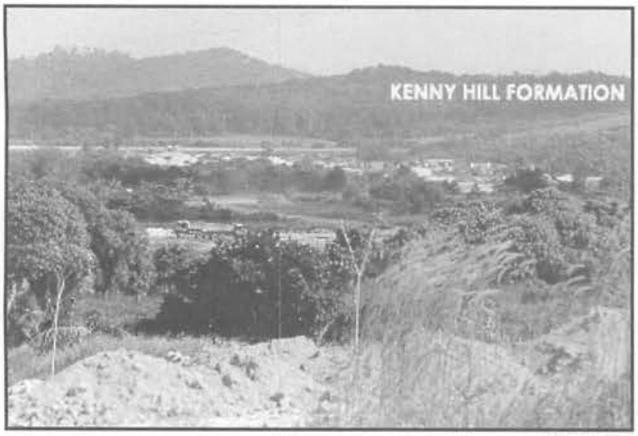

Plate 2: View of the Kenny Hill Formation at the Cyberjaya Park.

the term "organic soil" to describe any soil that appears to have some organic content. In the Unified Soil Classification System (USCS) peats are described as soils consisting "predominantly" of plant remains, often with a distinctive smell. Organic clay, silt or sand contains "substantial amounts" of vegetable matter.

Test Method

The following parameters were determined to characterize the soft soil:

- Water content : The water content is measured using procedures specified in ASTM D2974 or BS 1377.
- Organic Content : As a percentage of dry weight. The organic content is measured in the laboratory using a Loss on Ignition Test, ASTM D2974 or BS 1377 Part 3(4), or a Chemical Oxidation Test, BS 1377 Part 3(3).
- Degree of Humification (Decomposition) of the organic material. The degree of humification represents the degree to which the organic remains have decayed. The range lies between fresh plant remains and a completely decayed visibly amorphous material with no recognizable plant structure. Where a soft soil/peat lies within this spectrum radically affects its engineering behaviour. In the field it may be assessed by the Von Post Squeeze Test. A sample of the peat is squeezed in the hand. The color and form of fluid that is extruded between the fingers is observed together with the pressed residue remaining in the hand after squeezing. The degree of humification on a 10-point scale, H1 to H10, is obtained by comparing the observations to those described in Table 1.
- Atterberg Limits: The fibres in peat make determination of the Atterberg limits difficult, and results depend strongly on the methods used to prepare the samples.

USCS Classification

This classification is used by most engineers. It is outlined in Tables 2 and 3. The definition of having greater than 75% organic content, is most commonly used by engineers in North America, ASTM D4427, Classification of Peat Samples by Laboratory Testing, is described as follows:

(a) Slightly Organic Silts or Clays will most probably appear as inorganic fine grained soils, probably black or dark brown in colour, have an organic odor and possibly some visible organic remains. Their plasticity limits should be evaluated as for other fine grained inorganic soils. These soil would then be classified as silts or clays of low, medium or high plasticity, for example ML, CH. It is suggested that a small ''o'' be appended to indicate that they are slighty organic differentiate them from purely inorganic soils, MLo and CHo.

(b) Peat on the other hand may well appear to be completely organic, contain recognizable plant remains, have a low density and also black or dark brown. Following a Von Post test it could be categorised as listed in Tables 3 and 4.

Thus, for example, a peat could be described as a Fibrous Peat and given a symbol, Ptf.

(c) Organic Soils is more difficult to sub-divide lying, as it does, between the other two categories. There is insufficient information at present to determine whether this group can be meaningfully sub categorised. Currently, for these materials, an attempt should be made to provide both the Atterberg Limits and the Degree of Humification to allow establishment of a database from which future analyses can be made. In fact, it may be that neither of these tests work for the Organic Soil category. The degree of humification is only meaningful for soils that are predominantly organic. The presence of inorganic material tends to confuse the interpretation of the degree of humification. Similarly the Atterberg limits are only truly meaningful for soil that are primarily inorganic and the presence of organic material may well interfere with those tests.

VARIATION OF SOFT SOIL PROPERTIES

The soil data in this paper is from pre-construction and construction soil investigations conducted for the Cyberjaya Development project. Unlike other construction materials,

Table 1: Von Post degree of humification.

Degree of Humification	Description
H1	Completely undecomposed peat which releases almost clear water. Plant remains easily identifiable. No amorphous material present.
H2	Almost completely undecomposed peat, which releases clear or yellowish water. Plant remains still easily between the fingers. 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 releases very muddy dark water. No peat is passed between the fingers but the plant remain are slightly pasty and have lost some of identifiable features.
H5	Moderately decomposed peat which releases very "muddy" water with also a very small amount of amorphous granular peat escaping between the fingers. The structure of plant remains is quite indistinct, although it is still possible certain features. The residue is strongly pasty.
H6	Moderately strongly decomposed peat with a very indistinct plan structure. When squeezed, about one-third of the peat escapes between the finger. The residue is strongly pasty but shows the plant structure more distinctly than before squeezing.
H7	Strongly decomposed peat. Contains a lot of amorphous material with very faintly recognizable plant structure. When squeezed, about one-half of the peat escapes between the fingers. The water, if any is released, is very dark and almost pasty.
H8	Very strongly decomposed peat with a large quantity of amorphous material and very dry indistinct plant structure. When squeezed, about two-third 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 residual such as roots and fibers that resist decomposition.
H9	Practically fully decomposed peat in which there is hardly any recognizable plant structure. When squeezed, almost all of the peat escapes between the fingers as a fairly uniform paste.
H10	Completely decomposed peat with no discernible plant structure. When squeezed, all the wet peat escapes between the fingers.

Table 2: Organic content of soil.

Basic Soil Type	Descriptor	Organic Content (%)
Clay or Silt or Sand	Slightly Organic	3 - 20
Organic Soil	Organic Soil	20 - 75
Peat	Peat	> 75

soft soil is non-homogeneous and its properties are highly variable and complex.

The distribution of the soft soil ranges from fibrous to amorphous and consists of peat, clay and silt (Table 5 and Figure 3). Some engineering properties of the soft soil identified from boreholes is shown in Table 6. The natural water contents are greater than liquid limits at most depths. The natural moisture content of the Cyberjaya soft soil is extremely variable and range between 10% to 700%. Figure 4 shows the trend decreasing with depth. The high water content is due to the nature of soft soil characteristics and its location below the water table.

Wet seiving was used to obtain the grading curves shown in Figure 5. Grain size distribution range from sand to clay size. The profiles show decreasing clay content and increasing silt content with depth, i.e. upper parts of distribution profile have higher clay content than lower part. The clay content generally decreases with depth, from 2% and 25%. On the other hand, the clay content increases with depth to a depth of 16 m from 25 % and 75%.

The variations of the Atterberg limit increases with depth (Figure 6). The typical range of plastic limit (PL) is between 10% and 80% while for the liquid limit (LL) it is between 10% and 90%. The plastic index (PI) is from 3% and 50%. The liquid limit increases with depths, reflecting the decrease in sand content with depth.

Figures 7 shows the variation between the following compressibility parameters: compression index (Cc), the recompression index (Cr), and the coefficient of consolidation (Cv) against depth. Generally, the compressibility parameters increase with depth. This increase is consistent with the effect of the increase in moisture content with depth and the decrease in the sand content with depth.

The variation of recompression ratio (Cr) with depth indicates that there are no obvious trends between the recompression ratio (Cr) and depth. Consequently, the variability in this measure is more a function of the soil test than soil properties.

The preconsolidation pressure (Pc) is important in determining the settlement of soft soil under external loading. Figure 8 shows the trend between preconsolidation pressure (Pc) and depth. The trend shows a general increase in Pc with increasing depth. Ho and Dobie (1990) describe how uniform incremental loading can be used to determine Pc

Table 3: Qualifying terms and symbols for peats and organic soil.

Organic Components	Von Post Degree of Humification	Qualifying Terms	Symbol
Peat			Pt
	H1 - H3	Fibric or Fibrous (over 66% fibre)	F
	H4 - H6	Hemic or Moderately Decomposed (33-66%)	H
	H7 - H10	Sapric or Amorphous (less than 33%)	A
Organic Soil			O

Table 4: Malaysian Soil Classification Systems for engineering purposes and their field identification for organic soils and peat (after JKR and Jarrett, 1995)

Soil Group		Sub-group laboratory identification						Field Identification
		Description	Group Symbol	Sub Group Symbol	WL (%)	Degree of Humification	Sub Group Name	
Organic Soil	Slightly Organic Soils	Slightly Organic SILT	Mo	Mo			Slightly Organic SILT (Co)	Usually very dark to black and contain a small amount of organic. Often has distinctive small
			Fo	Clo	< 35		Slightly Organic CLAY of low plasticity	
				Cio	35 - 50		Slightly Organic CLAY of intermediate plasticity	
	Organiic Content 3%-20%	Slightly Organic CLAY	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 Soil Organic Content 20%-75%	ORGANIC SOIL	O				Subdivision of Organic Soils is difficult, as neither the plasticity tests not the humification tests are reliable for them. Such a "best attemp"is the probable outcome of subdivision leading to description such as "Fibrous ORGANIC SOIL"or Amorphous ORGANIC SOIL of Intermediate Plasticity	
	Peats Organic Content more than 75%	PEAT	Pt	Ptf		H1 - H3	Fabric or Fibrous Peat	Dark brown to black in colour. Has low density so seems light. Contains of mass is organic so if fibrous the mass will be recognizable plant. More likely to smell strongly if humified
				Pth		H4 - H6	Hemic or Moderately Decomposed Peat	
				Ptn		H7 - H10	Sapric or Amorphous Peat	

Table 5: Profile of typical soft soil in Cyberjaya.

Depth (m)	Description	Basic Soil Type	Descriptor	Von Post Classification	Qualifying Terms	Symbols
1.00 - 1.80	Dark brown very soft CLAY with organic material with some of decayed wood and roots	Peat	Peat	H1 - H3	Fibrous	Pt
3.50 - 3.95	Dark grey soft sandy silty CLAY	Organic Soil	-	H3	Fibrous	f
4.50 - 4.95	Light greyish brown with slightly of greenish grey soft silty CLAY with traces of sand	Clay	Slightly Organic	H3 - H4	Moderately Decomposed	H
5.00 - 5.80	Pale yellow to brownish light grey clayey SILT with traces of sand	Silt	Slightly Organic	H5	Moderately Decomposed	H
6.00 - 6.80	Light grey with slightly of greenish grey silty CLAY with traces of SAND	Clay	Slightly Organic	H5 - H6	Moderately Decomposed	H
7.00 - 7.80	Pale yellow to light brown slightly sandy clayey SILT	Silt	Slightly Organic	H7	Amorphous	a
8.00 - 8.45	Yellowish brown with traces of purple stiff clayey SILT with traces of sand	Silt	Slightly Organic	H7	Amorphous	a
9.50 - 10.30	Yellowish brown medium stiff sandy silty CLAY	Clay	Slightly Organic	H7	Amorphous	a

Table 6: Some engineering properties of typical borehole samples of soft soil.

Depth (m)	Bulk Density	Moisture Content	Plastic Limit	Liquid Limit	Plastic Index	Clay	Silt	Sand	Gravel	LOI	σ_3	$\sigma_3 - \sigma_1$	C_u	Pc	e_0	Cc	Cr	Cv	Organic Content
1	*	610		NP				*		48.1		*				*			
2		425	32	74	42	39	26	35	0										
3		205	33	67	34	50	36	14	0										
4	1.77	143	31	63	32	48	42	10	0		100	114	55	450	0.90	0.35	0.18	27.31	
5	1.82	96	31	54	23	59	40	1	0		120	63	44	450	0.90	0.26	0.14	26.87	
6	1.81	45	37	99	62	74	20	6	0		65	124	66						
7	1.92	35	30	77	43	57	29	14	0		75	105	98						
8	2.02	21	17	28	21	27	14	59	0					230	0.60	0.20	0.13	23.90	0.51
9	2.02	18	18	41	23	25	11	64	0		200	324	141						

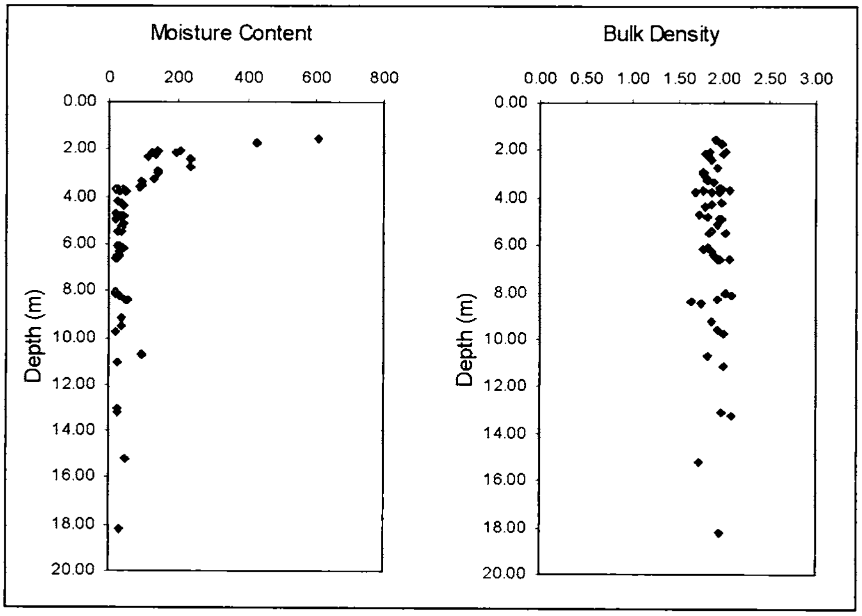

Figure 3: Plots of moisture content and bulk density with depth (m).

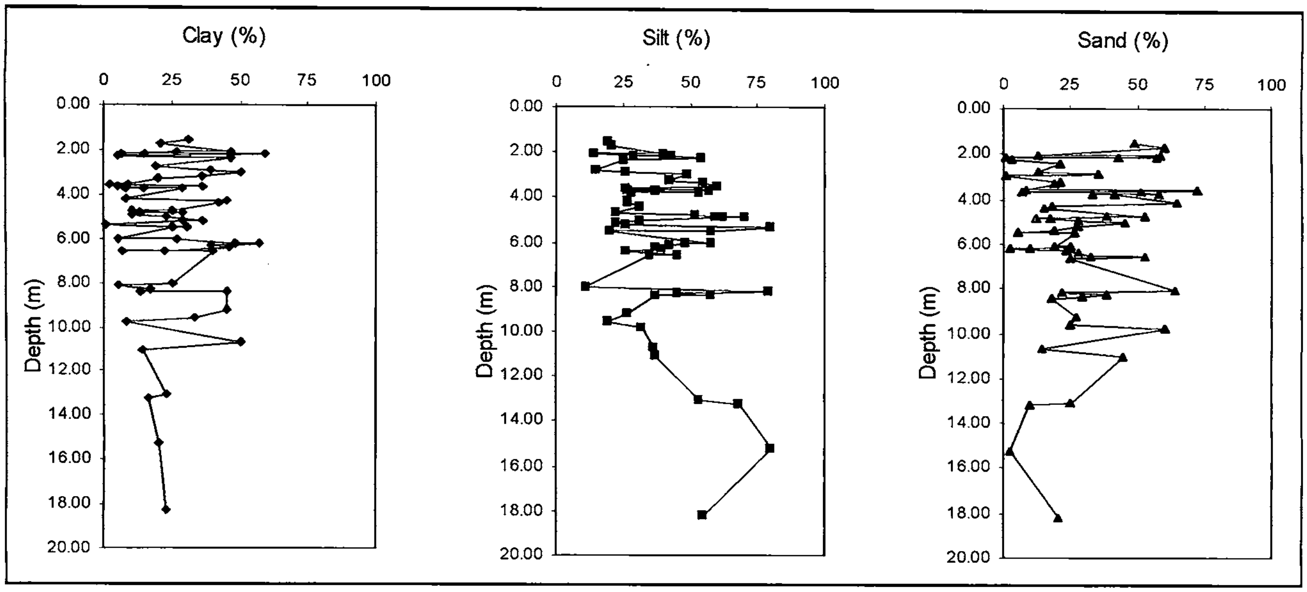

Figure 4: Plots of clay, silt and sand contents with depth.

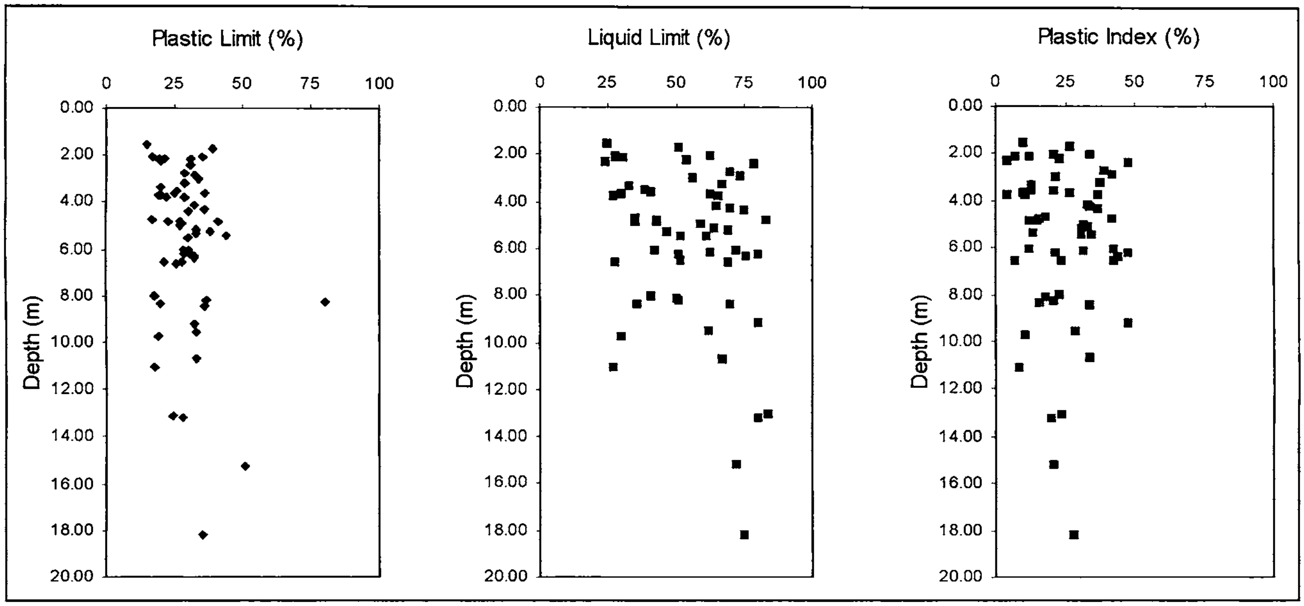

Figure 5: Variation of the Atterberg limits with depth.

more accurately than recognized international standards. In this trend, Pc for soft soil deposits may be determined together with the extent to which it will consolidate. This is extremely useful when any ground treatment is to be undertaken.

The plasticity chart plot (Figure 9) shows that the soft soil material are variable. Generally, the soft soil material can be classified as very low plastic to highly plastic. The influence of increasing clay content on the plasticity index is also depicted in Figure 9. In accordance with Skempton (1953), the activity index (AI) is an indicator of clay mineralogy. A high activity index (AI > 1.25) usually denotes montmorillonite, while a low activity index (AI < 0.75) denotes kaolinite.

The results from the study area, shows that the soft soil have a high activity index (AI > 1.25), even though the clay mineralogy of the soft soils comprise mainly kaolinite and high illite. Figure 10 shows the relationship between the plasticity index, percentage of clay fraction and the activity of the clay. The figure indicates that the clay samples from this soft soil have activities ranging from 0.2 to more than 2.0. The liquidity index falls in the low expansion to medium expansion categories.

Figure 11 shows that soft soils have range from inorganic clays of high plasticity limits into inorganic silts of high compressibility and organic clays. The Cyberjaya soft soils is similar to the organic silt and clay of Venezuela Clay and New London Clay.

SUMMARY AND CONCLUSION

This paper provides an overview of the distribution and characteristics of soft soil in Cyberjaya, with emphasis

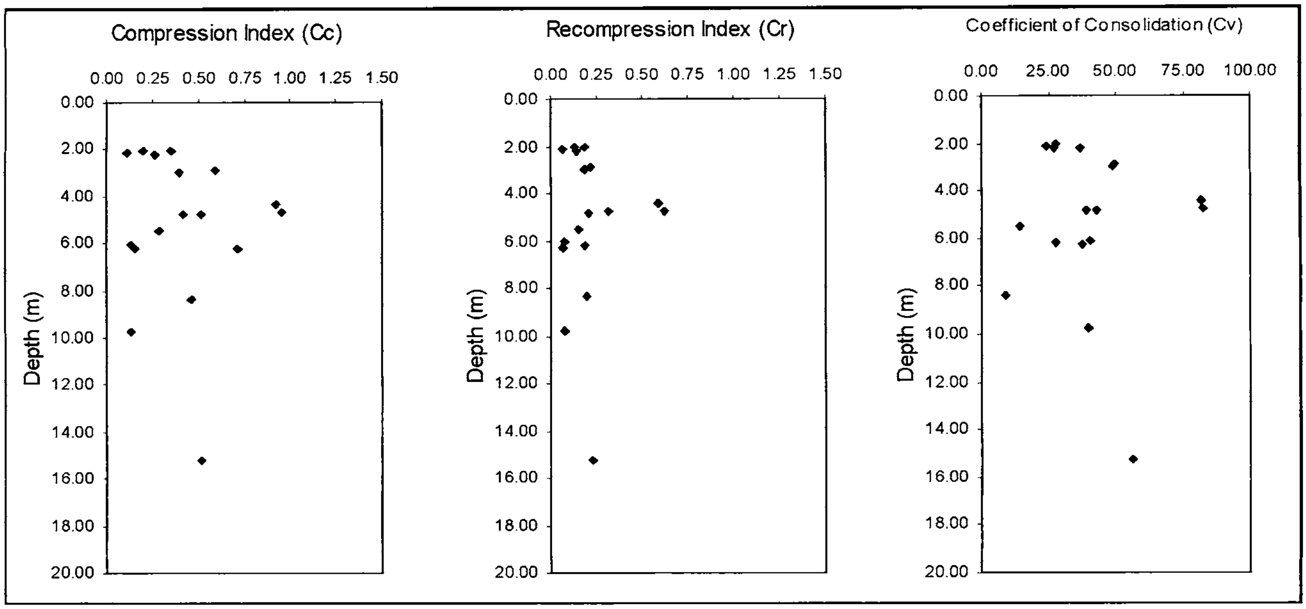

Figure 6: Variation compressibility parameters with depth.

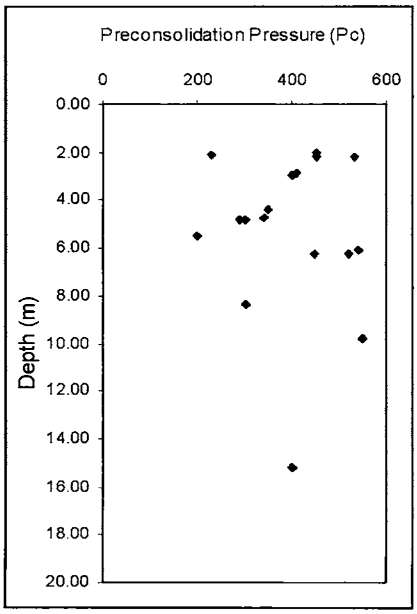

Figure 7: Plot of preconsolidation pressure (Pc) with depth.

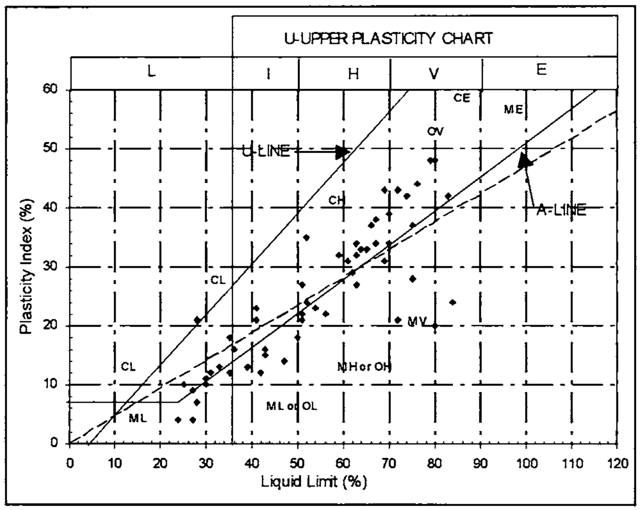

Figure 8: Modified plasticity chart for use with Unified Soil Classification system. Soil represented by points within shaded area are considered borderline and are given dual symbols (after USBR, 1974). Note: L:low; I:intermediate; H:high; V:very high; E:extremely high; M:silt; and C:clay.

on its anomalies relative to the behaviour of inorganic clays. Some of the anomalies and outstanding characteristics as well as the research needs are listed below:

- Deposits of peat and organic soils are extremely variable, large differences occur over centimeters or decimeters. The variability extends throughout all scales up to the kilometer scale in many cases.
- Any site investigation involving organic soils must involve measurement of the organic content of all forms of organic soil and the degree of humification of soft soil. A rational engineering classification system must be adopted for soils with an organic content.
- Methods of analysis have been developed that will allow greater confidence in design involving these soft soils.
- Water content can be used to identify and compare the range of different soft soils by using the Atterberg Limit characteristics.
- The distribution of Cyberjaya soft soil ranges from fibrous to amorphous and consists of peat, clay and silt.
- Generally, Cyberjaya soft soil material can be classified as very low plastic to highly plastic.
- Cyberjaya soft soils is similar to organic silt and clay of Venezuela Clay and New London Clay.

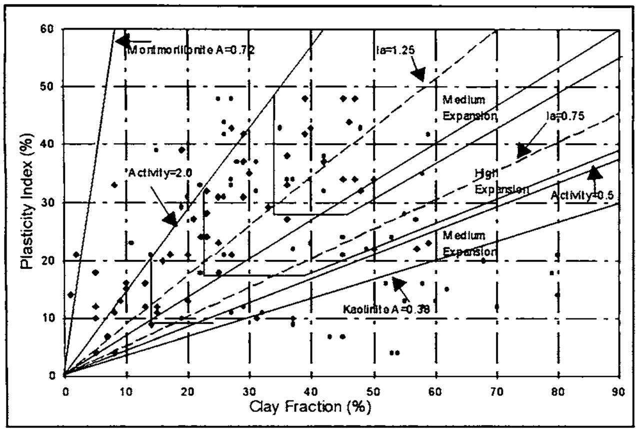

Figure 9: Chart indicating activity of clay.

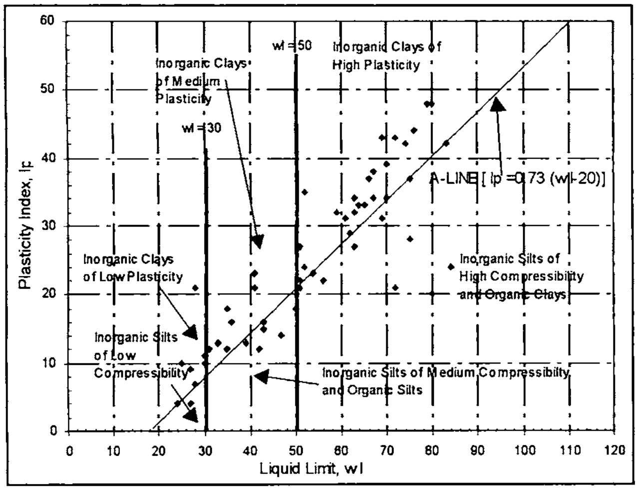

Figure 10: Correlation between the Atterberg limits using the plasticity chart (after Casagrande, 1932 in Terzaghi & Peck, 1995).

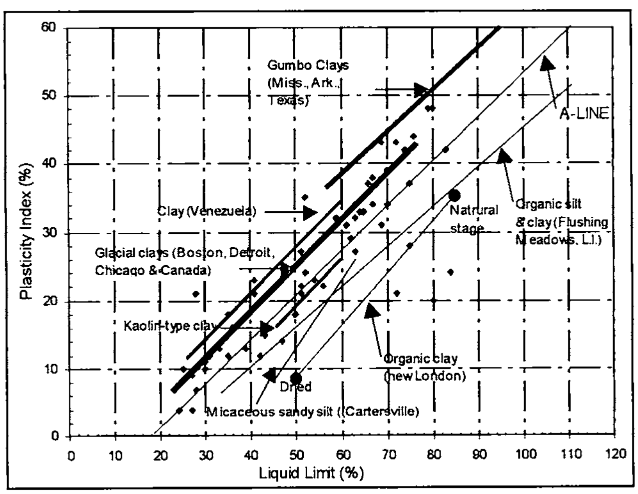

Figure 11: Relationship between Liquid Limit and Plasticity Index for typical soils (after Casagrande, 1932 in Terzaghi & Peck, 1995).

There is a need for detailed mapping of the Cyberjaya area to determined the extent of the terrain that is covered by peat, as defined from the engineering and geology perspectives. Isopach contours to delineated the thickness of the peat should also be established. In addition, other varieties of soft soils should be delineated.

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