CHAPTER 5

CHARACTERISTICS OF WEATHERING PROFILES OVER QUARTZ-MICA SCHIST

CHAPTER 5

CHARACTERISTICS OF WEATHERING PROFILES OVER QUARTZ-MICA SCHISTS

5.1 Introduction

A complete weathering profile over quartz-mica schist as concluded in Chapter 4 is made up of Rock, Saprock, Saprolite, Pedoplasmation Zone and Soil. This weathering profile is at first divided into horizontal morphological zones (ZI, ZII & ZIII) based on laterally similar morphological features (e.g. colour and texture) and physical properties (e.g. grain size, density, hardness, plasticity). Each zone is then divided into smaller zones or horizons based on the different stages of weathering of the bedrock material. These horizonation have taken into consideration the pedological classification criteria, descriptive and soil index properties and the degree of preservation of original bedrock textures and structures (Fig 5.1). Having identified the various morphological zones and horizons, each zone was then studied in detail to determine the geotechnical characteristics of its constituent material. Specific tests were run on adjacent samples from the same cut slope to determine any vertical or horizontal variation. Tests were also carried out on samples from similar profiles over adjacent cut slopes in the area to determine the existence of any lateral variation.

WEATHERING PROFILE	MORPHOLOGICAL ZONES	MORPHOLOGICAL HORIZONING CRITERIAS	MORPH. HORIZONS	DESCRIPTION
SOIL	ZONE I	-colour & texture	IA	-yellowish red -friable -clayey
			IB	-red -firm -gravelly
PEDOPLASMATION ZONE			IC	-reddish yellow -stiff -mottled clayey
SAPROLITE	ZONE II	-degree of preservation of original bedrock texture (degree of weathering)	IIA	-pinkish -crumbly -completely weathered bedrock (γ)
SAPROCK			IIB	-whitish -hard -bands of 50% completely weathered bedrock (γ) and 50% less weathered bedrock (β)
			IIC	-pinkish white -hard -bands of 20% less weathered bedrock (β) and 80% least weathered bedrock (α)
ROCK	ZONE III			

Figure 5.1 : Morphological zoning and horizonation criteria for the weathering profile exposed at cut slopes on Quartz-Mica schists in the Seremban-Siliau area.

As mentioned in Chapter 4, only morphological zones ZI and ZII have been found exposed on cut slopes in the study area. ZI is made up of the Soil and Pedoplasmation Zone zones of the weathering profile while ZII is made up of the Saprock and Saprolite zones. With the absence of exposed ZIII or fresh bedrock, discussions on the characteristics of weathering profile will begin on that of the least weathered Saprock followed by the more weathered Saprolite, Pedoplasmation Zone and Soil. Each zone will be expounded in subchapters 5.2 – 5.5 on its individual constituent material properties such as the inherent and engineering properties. The inherent properties are related to the properties of the constituent particles i.e. grain size distribution, mineralogy, Atterberg limits, plasticity index and activity index. These properties are determined using the Sieve and Hydrometer Method, AAS (Atomic Absorbtion Spectrophotometry) analysis, Conepenetrometer Method and XRD (X-ray Diffraction) analysis respectively. The engineering properties (e.g. shear strength) will describe the physical behaviour of soils under various conditions and the shear strength parameters i.e. C (cohesion) and ϕ (angle of internal friction), are determined using the undrained Shear Box Test (for undisturbed samples) and Ring Shear Test (for disturbed samples) methods (Plates 5.1-5.4). All these methods of analysis are given in Appendixes VI to XI.

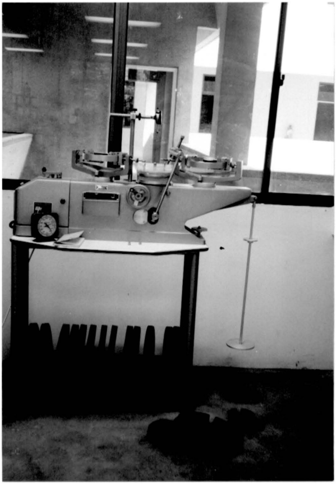

Plate 5.1 Bromhead ring shear apparatus

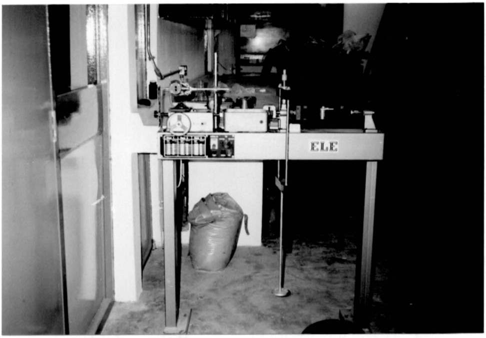

Plate 5.2 Motorised direct residual shear box machine

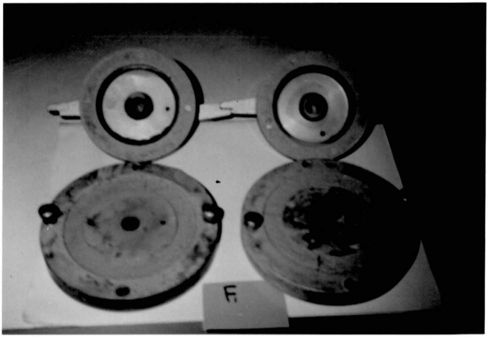

Plate 5.3 Remoulded soil samples sheared (undrained) in annular rings using the motorised Bromhead ring shear apparatus (refer Plate 5.1).

Plate 5.4 Oven-dried undisturbed square soil samples sheared (undrained) using the motorised Wykeham direct residual shear box apparatus (refer Plate 5.4).

5.2 Saprock

5.2.1 General

Saprock of the weathering profile, which makes up the lower part of morphological zone ZII, is found above the morphological zone ZIII of fresh bedrock. It comprises the least weathered IIC and the intermediate or less weathered lower IIB morphological horizons. Horizon IIB is made up of alternating bands of completely weathered and less weathered material whereas horizon IIC is made up of thin bands of completely weathered material and thick bands of less weathered material. Both these horizons have distinct relict textures, banding, and foliation, fracture planes and quartz veins. Saprock is generally white in colour, though in some places it may appear pinkish. It is hard and is made up of 50-80 % fresh bedrock. It has an average width of about 3.5m.

5.2.2 Geotechnical properties

Acquiring undisturbed sample of Saprock was not possible at some locations due to its hardness and the presence of quartz veins. Therefore, inherent properties such as grain size distribution, plasticity index, activity index, specific gravity and engineering properties such as shear strength parameters were determined

on tests run on both disturbed and undisturbed samples. The final results of all these tests mentioned are as shown in Figure 5.2.

5.2.2.1 Inherent Properties

The following would be discussions on constituent particle related properties. Each property will be discussed in the order of grain size distribution, mineralogy, specific gravity, plasticity index and activity index respectively.

The results of grain size analysis are given in Figure 5.3. On the average, lower Saprock, horizon IIC, has a dominant silt sized fraction of 86% followed by a 10% sand sized fraction and a 4% clay sized fraction. No gravel-sized particle is found. Samples from horizon IIC of adjacent cuts have an average of 76% silt, 17% sand, 7% clay and 0% gravel. With a high fraction of silt and low clay fraction, the determination of neither the plasticity nor activity indexes was possible for horizon IIC. Horizon IIC of lower Saprock is therefore, classified as low plasticity silt (ML) with an average specific gravity value of about 2.7. The upper Saprock, which comprises of the lower part of horizon IIB has a somewhat similar grain size distribution with a 87% silt sized fraction followed by 7% sand sized fraction, 6% clay sized fraction and 0% gravel. The high silt content here has also hindered the determination of the Atterberg limits and the activity index. However, samples from adjacent cuts with a lower silt

on tests run on both disturbed and undisturbed samples. The final results of all these tests mentioned are as shown in Figure 5.2.

5.2.2.1 Inherent Properties

The following would be discussions on constituent particle related properties. Each property will be discussed in the order of grain size distribution, mineralogy, specific gravity, plasticity index and activity index respectively.

The results of grain size analysis are given in Figure 5.3. On the average, lower Saprock, horizon IIC, has a dominant silt sized fraction of 86% followed by a 10% sand sized fraction and a 4% clay sized fraction. No gravel-sized particle is found. Samples from horizon IIC of adjacent cuts have an average of 76% silt, 17% sand, 7% clay and 0% gravel. With a high fraction of silt and low clay fraction, the determination of neither the plasticity nor activity indexes was possible for horizon IIC. Horizon IIC of lower Saprock is therefore, classified as low plasticity silt (ML) with an average specific gravity value of about 2.7. The upper Saprock, which comprises of the lower part of horizon IIB has a somewhat similar grain size distribution with a 87% silt sized fraction followed by 7% sand sized fraction, 6% clay sized fraction and 0% gravel. The high silt content here has also hindered the determination of the Atterberg limits and the activity index. However, samples from adjacent cuts with a lower silt

on tests run on both disturbed and undisturbed samples. The final results of all these tests mentioned are as shown in Figure 5.2.

5.2.2.1 Inherent Properties

The following would be discussions on constituent particle related properties. Each property will be discussed in the order of grain size distribution, mineralogy, specific gravity, plasticity index and activity index respectively.

The results of grain size analysis are given in Figure 5.3. On the average, lower Saprock, horizon IIC, has a dominant silt sized fraction of 86% followed by a 10% sand sized fraction and a 4% clay sized fraction. No gravel-sized particle is found. Samples from horizon IIC of adjacent cuts have an average of 76% silt, 17% sand, 7% clay and 0% gravel. With a high fraction of silt and low clay fraction, the determination of neither the plasticity nor activity indexes was possible for horizon IIC. Horizon IIC of lower Saprock is therefore, classified as low plasticity silt (ML) with an average specific gravity value of about 2.7. The upper Saprock, which comprises of the lower part of horizon IIB has a somewhat similar grain size distribution with a 87% silt sized fraction followed by 7% sand sized fraction, 6% clay sized fraction and 0% gravel. The high silt content here has also hindered the determination of the Atterberg limits and the activity index. However, samples from adjacent cuts with a lower silt

on tests run on both disturbed and undisturbed samples. The final results of all these tests mentioned are as shown in Figure 5.2.

5.2.2.1 Inherent Properties

The following would be discussions on constituent particle related properties. Each property will be discussed in the order of grain size distribution, mineralogy, specific gravity, plasticity index and activity index respectively.

The results of grain size analysis are given in Figure 5.3. On the average, lower Saprock, horizon IIC, has a dominant silt sized fraction of 86% followed by a 10% sand sized fraction and a 4% clay sized fraction. No gravel-sized particle is found. Samples from horizon IIC of adjacent cuts have an average of 76% silt, 17% sand, 7% clay and 0% gravel. With a high fraction of silt and low clay fraction, the determination of neither the plasticity nor activity indexes was possible for horizon IIC. Horizon IIC of lower Saprock is therefore, classified as low plasticity silt (ML) with an average specific gravity value of about 2.7. The upper Saprock, which comprises of the lower part of horizon IIB has a somewhat similar grain size distribution with a 87% silt sized fraction followed by 7% sand sized fraction, 6% clay sized fraction and 0% gravel. The high silt content here has also hindered the determination of the Atterberg limits and the activity index. However, samples from adjacent cuts with a lower silt

WEATHERING PROFILE	MORPH. HORIZON	GRAIN SIZE DISTRIBUTION % clay		silt		sand		gravel		SOIL CLASSIFICATIO		LIQUID LIMIT(%)		PLASTIC LIMIT(%)		PLASTICITY INDEX (Ip%)		ACTIVITY INDEX (Ia)		'C'		'Ø'		MOISTURE CONTENT(%		SPECIFIC GRAVITY	
		sc	ac	sc	ac	sc	ac	sc	ac	sc	ac	sc	ac	sc	ac	sc	ac	sc	ac	sc	ac	sc	ac	sc	ac	sc	ac
SOIL	IA	37	56	36	12	27	32	0	0	CH	CH	64	67	25	25	39	42	1.1	0.75	158.88	172.7	28	27	10	12	2.60	2.6
	IB	19	36	17	12	46	34	18	18	SC	SC	49	65	22	22	27	43	2.5	1.19	82.9	96.68	32	28	16	15	2.72	2.72
PEDOPLASMATION ZONE	IC	19	30	62	25	18	42	1	3	CL	CH	33	61	20	20	13	41	0.7	1.37	124.31	138.1	33	25	13	18	2.70	2.78
SAPROLITE	IIA	6	18	75	72	19	10	0	0	ML	MI	-	38	-	20	-	18	-	1.00	103.62 -	69.08 13.82	34 -	19 43	10 -	24 10	2.76	2.66
	UPPER IIB	6	12	87	59	7	29	0	0	ML	CL	-	41	-	20	-	21	-	1.75	62.17	55.26	35	13	10	40	2.70	2.64
SAPROCK	LOWER IIB																										
	IIC	4	7	86	76	10	17	0	0	ML	ML	-	-	-	-	-	-	-	-	55.26 -	62.17 -	36 -	19 -	27 -	34 -	2.70	2.61

Figure 5.2 : Inherent and engineering properties of the weathering profile exposed over cut slopes on Ouartz-Mica Schists in the Seremban-Siliau Area

* Note
- sc - samples from the same cut
- ac - samples from the same horizon of similar profile over adjacent cut
- 23, 26, 38 - remoulded samples
- 23, 26, 38 - undisturbed samples
- 'C' - cohesion (kPa)
- 'Ø' - angle of internal friction (deg)

(values shown above are average values)

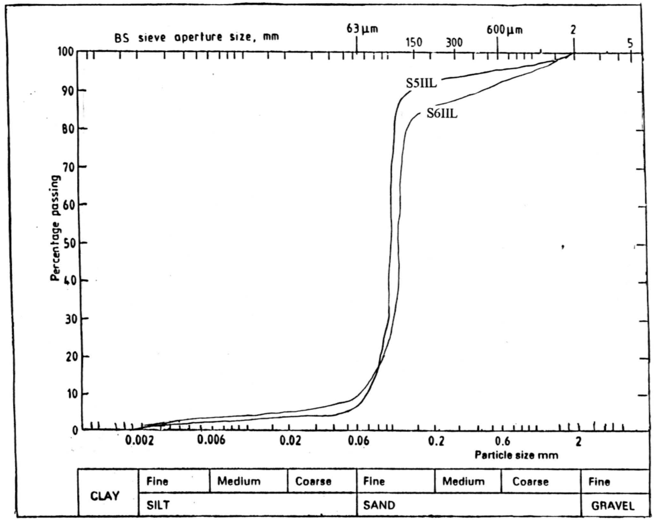

Figure 5.3 Grain size distribution of samples from the morphological Saprock zone

content of 59% and a higher sand and clay content of 29% and clay of 12% respectively have allowed the determination of these aforementioned properties. These samples have a *Ip* (plasticity index) of 21% with a *LL* (liquid limit) of 41% and a *PL* (plastic limit) of 20%. With an *Ia* (activity index) of 1.75 and a specific gravity of 2.70, upper Saprock or lower horizon IIB, is classified as low plasticity clay (CL). The *Ia* of 1.75 suggests the presence of active clay such as montmorillonite in upper Saprock.

X-ray diffractograms analysis results (Fig. 5.4) shows untreated diffractograms of narrow and asymmetrical reflections at 8°-9°, 17°-18° and 26°-27°. The presence of the 8°-9° reflection on the glycolated and the heated diffractograms of the sample indicates the presence of illite, the only clay mineral found in the lower part of the weathering profile (IIC) (Raj, 1993). Illite is the product of disaggregation and disintegration of micaceous minerals which occur during the weathering of quartz-mica schist bedrock.

5.2.2.2 Engineering Properties

The most vital engineering properties discussed here will be the shear strength parameters, C (cohesion) and ϕ (angle of internal friction) (Fig. 5.5). The remoulded C value obtained at the lower Saprock or horizon IIC is about 55.26 kPa at a moisture content of 27% with a ϕ value of 36°. Undisturbed samples from adjacent cuts show a higher C value of 62.17 kPa and a lower ϕ value of 19° at a moisture content of

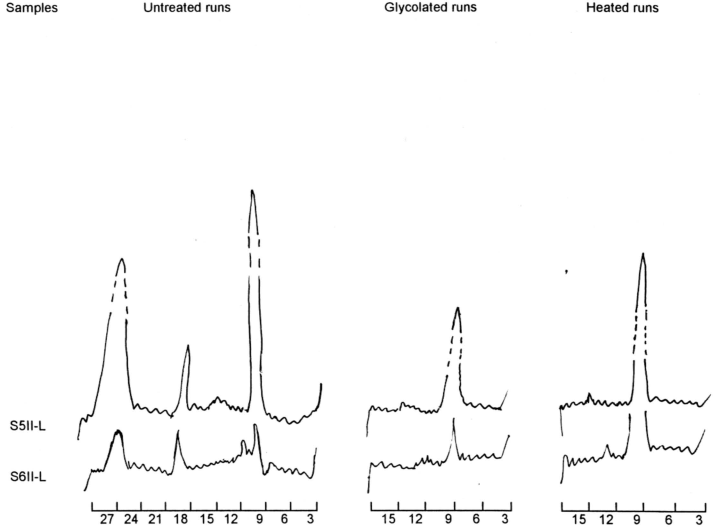

Figure 5.4 X-ray diffraction results on tests run on samples from the morphological Saprock zone

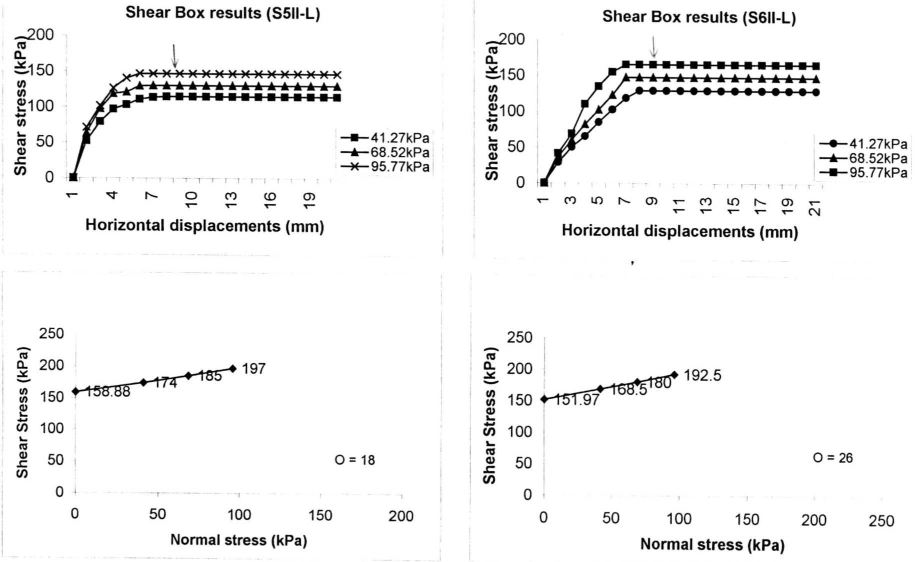

Figure 5. 5 Shear strength parameters determined using the Shear Box apparatus on samples (S5IIL & S6IIL) taken from Saprock exposed on cut slopes in the Seremban-Siliau area

34%. At upper Saprock (lower horizon IIB), the remoulded C and ϕ values obtained are 62.17kPa and 35° respectively with a moisture content of 10%. However, undisturbed samples from adjacent cuts give a lower C values of 55.26kPa and a lower ϕ value of 13° with a moisture content of 40%. Varying shear strength parameters of samples within the Saprock of the same cut and adjacent cuts suggest the possible existence of vertical variation. The existence of lateral variation, however, is not determinable since no comparison is possible between remoulded samples of one cut and undisturbed samples of an adjacent cut.

5.3 Saprolite

5.3.1 General

Saprolite is the upper portion of morphological zone, ZII. It is made up of morphological horizons IIA and upper IIB. Alternating bands of completely weathered material make up horizon IIA while the upper part of horizon IIB consists of alternating bands of completely weathered and less weathered material. Therefore giving Saprolite a make up of more completely weathered material though it still has quartz veins, distinct relict textures, banding and foliation. Saprolite has a width which varies from 1.5m to 5.0m.

5.3.2 Geotechnical Properties

Since undisturbed samples could only be obtained from certain profiles, the geotechnical properties have been determined using both undisturbed and remoulded samples where necessary. The properties determined are the inherent properties: grain size distribution, Atterberg limits, activity index, specific gravity; and the engineering properties: shear strength parameters.

5.3.2.1 Inherent properties

The grain size analysis (Figure 5.6) shows upper Saprolite, horizon IIA, to be of silty soil nature with 75% silt, 19% sand, 6% clay and 0% gravel. Its plasticity index was not determinable, due to the high silt and sand content. However, samples of similar profile from adjacent cut slopes show a slightly higher clay (18%) and a lower sand (10%) content with a somewhat similar silt content (72%). Thus allowing the determination of its *Ip* (plasticity index) value of 18% with a *LL* (liquid limit) of 38% and a *PL* (plastic limit) of 20%, which classifies upper Saprolite as ML to MI (low to intermediate plasticity). These varied values also suggest the possibility of lateral variation (Figure 5.2). Grain size analysis of samples from lower Saprolite, upper horizon IIB, show a low plasticity silt (ML) grain size distribution of 87% silt, 7% sand, 6% clay and 0% gravel for samples from the same cut. Samples from adjacent cuts are classified as low plasticity clay (CL) of 59% silt, 29% sand, 12% clay and 0%

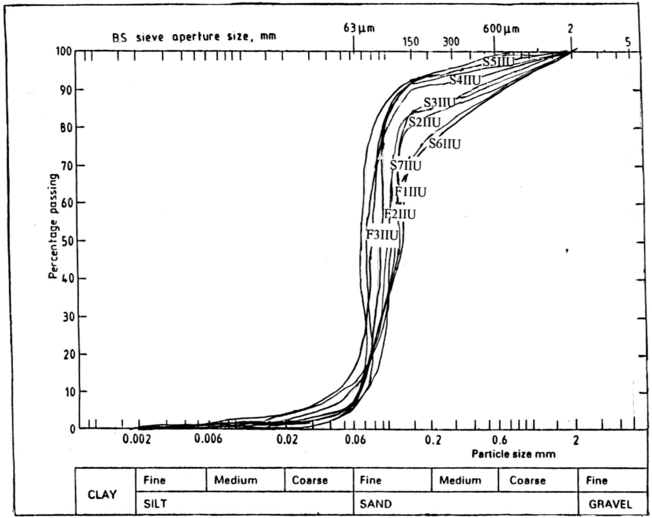

Figure 5.6 Grain size distribution of samples from the morphological Saprolite zone

gravel. These variations in the grain size distribution of samples from the similar zones of adjacent cuts strongly suggest the existence of lateral variation.

The *Ia* (activity index) value of 1.00 for upper Saprolite indicate the presence of common clay, illite, while the *Ia* value of 1.75 for lower Saprolite indicate the presence of active clay such as montmorillonite. The presence of these clay minerals are further substantiated by the X-ray diffraction test results as shown in Figure 5.7. The narrow and asymmetrical reflections at 8°-9°, 17°-18° and 26°-27° on untreated diffractograms and the unchanging 8°-9° on the glycolated and heated diffractograms indicate the presence of illite. The presence of broad and asymmetrical reflections of between 7°-8.5° and around 17.8° on untreated diffractograms suggest the presence of mixed or inter-stratified layers. The broad reflection of 7°-8.5° which shifts to lower angles upon glycolation and to 8.5° on heating, represents the inter-stratified illite-montmorillonite. The 12°-13° and 24°-25° reflections on untreated diffractograms and the appearance of the 12°-13° reflection on glycolated diffractograms which then disappears upon heating is a strong indication that kaolinite is also present in the sample being tested. Therefore, based on the X-ray diffraction test results and the calculated *Ia* values, it is evident that the clay minerals found in Saprolite are kaolinite, illite-montmorillonite and illite.

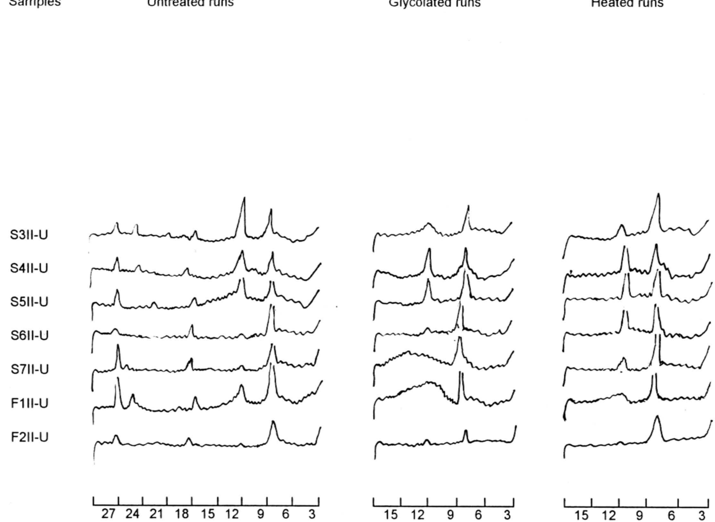

Figure 5.7 X-ray diffraction results on tests run on samples from the morphological Saprolite zone

5.3.2.2 Engineering properties

The shear box and ring shear tests results are as shown in Figures 5.8a - 5.8d. Undisturbed samples from upper Saprolite (horizon IIA) have an average C (cohesive) value of 103.6 kPa with an average ϕ (angle of internal friction) value of 34° at a 10% moisture content. Samples from similar zone of adjacent cuts have lower C and ϕ values of about 69.08 kPa and 19° respectively at a moisture content of 24%. These varying C and ϕ values of samples from similar zones of adjacent cuts are evident of lateral variation. In the case of remoulded samples from adjacent cuts, a much lower C value of 13.82 kPa is obtained compared to a much higher value ϕ of 43° at a moisture content of 10%.

Samples from lower Saprolite, upper horizon IIB, exhibit a lower undisturbed cohesive strength of 55.26kPa with a ϕ value of 13° at a 40% moisture content. Remoulded samples of lower Saprolite have a much higher cohesive strength at 62.17kPa as well as a much higher ϕ at 35° with a moisture content of 10%. The existence of lateral variation in lower Saprolite could not be determined since the samples used were of different conditions, i.e. undisturbed and remoulded.

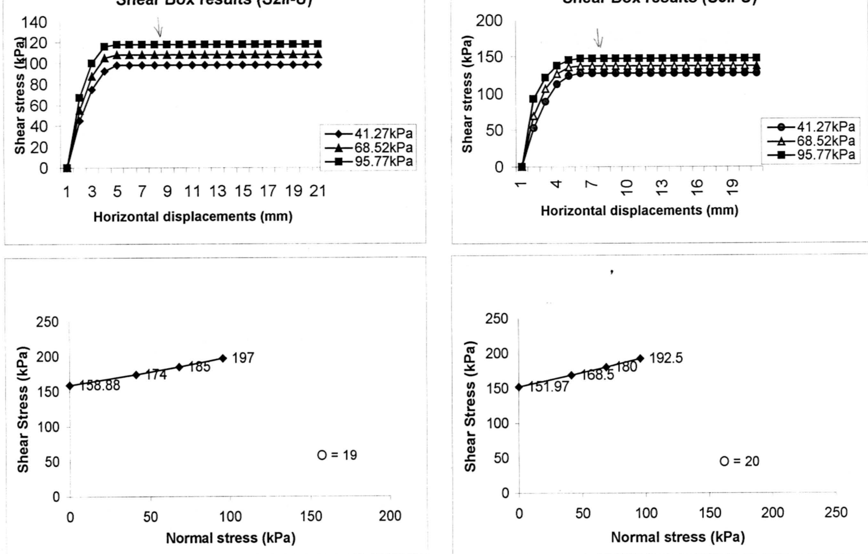

Figure 5.8a Shear strength parameters determined using the Shear Box apparatus on samples (S2IIU & S3IIU) taken from Saprolite exposed on cut slopes in the Seremban-Siliau area

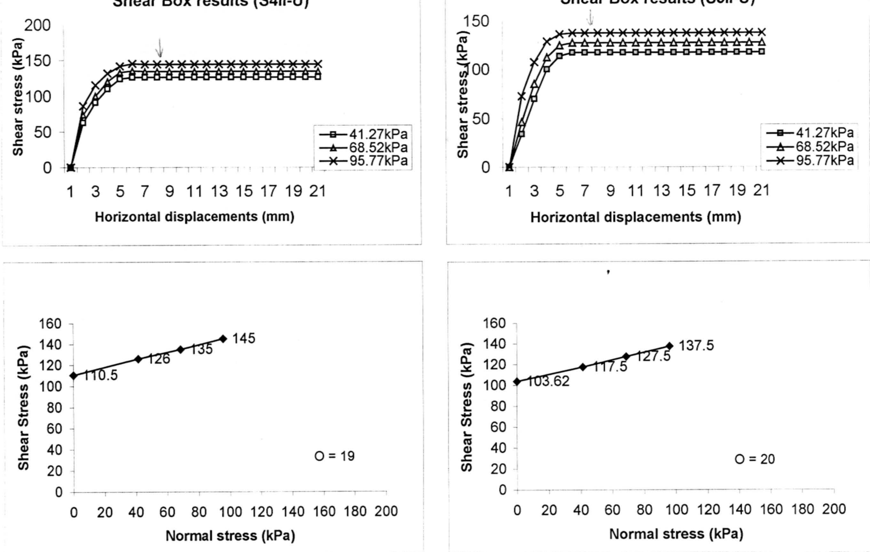

Figure 5.8b Shear strength parameters determined using the Shear Box apparatus on samples (S4IIU & S5IIU) taken from Saprolite exposed on cut slopes in the Seremban-Siliau area

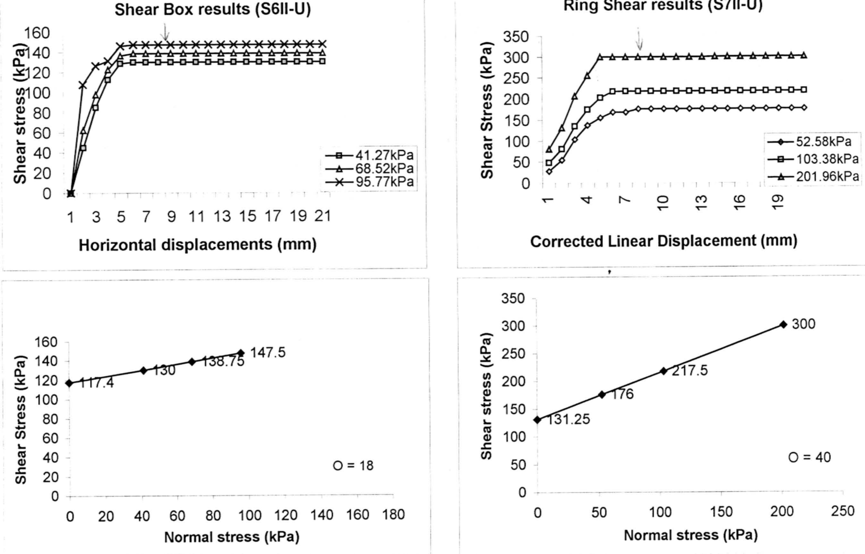

Figure 5.8c Shear strength parameters determined using the Shear Box and Ring Shear apparatus on samples (S6IIU & S7IIU) taken from Saprolite exposed on cut slopes in the Seremban-Siliau area

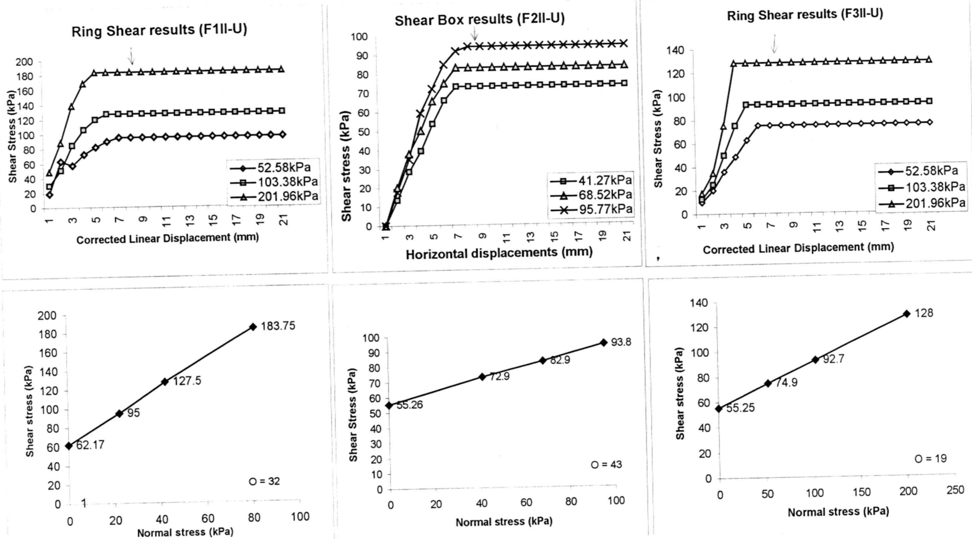

Figure 5.8d Shear strength parameters determined using the Shear Box and Ring Shear apparatus on samples (F1IIU, F2IIU & F3IIU) taken from Saprolite exposed on cut slopes in the Seremban-Siliau area

5.4 Pedoplasmation Zone

5.4.1 General

Pedoplasmation Zone is the intermediate zone or the "soil formation zone" where the geochemically altered bedrock material of Saprolite now undergoes pedochemical alteration before it changes into soil. It makes up the lower part of morphological zone ZI which comprises of morphological horizon IC which is the most advanced stage of weathering of the bedrock material. It is reddish yellow in colour and has a texture that varies from mottled clay to stiff stilty clay with the increase of the degree of pedological alteration. It has a width of about 0.25 - 0.5 metres.

5.4.2 Geotechnical properties

Though Pedoplasmation Zone is generally firm and stiff, it was possible to obtain undisturbed sample from certain parts of this zone for laboratory testing. Therefore, geotechnical properties of Pedoplasmation Zone material were determined from tests run on undisturbed samples.

5.4.2.1 Inherent properties

Results of the grain size analysis (Fig. 5.9) show a more clayey Pedoplasmation Zone with a soil of 62% silt, 19% clay, 18% sand and 1% gravel on some profiles and a 42% sand, 30% clay, 25% silt and 3% gravel on similar profile over adjacent cut slopes in the area. The average specific gravity for samples from Pedoplasmation Zone of the same cut and adjacent cuts are 2.70 and 2.78 respectively. An average *Ip* (plasticity index) value of 13% with a *LL* (liquid limit) of 33% and a *PL* (plastic limit) of 20% were obtained from tests on samples on the same cut slope and a *Ip* of 41% with a *LL* of 61% and a *PL* of 20% from samples of similar profile on adjacent cut slopes (Fig. 5.2). The varying results of grain size analysis and plasticity index of samples from the same cut slope profile is due to the varying degree of pedological alteration within horizon IC. The variability is also seen in the activity index values. The calculated *IA* (activity index) values for samples of the same cut slope suggest the presence of non-active clay mineral such as kaolinite. The samples from adjacent cuts show a calculated value of 1.37 which is more characteristic of active clay mineral such as montmorillonite. The differences in these values of samples from similar profiles on adjacent cut slopes strongly suggests the existence of lateral variation.

X-ray diffraction test results on samples from Pedoplasmation Zone are as shown in Figure 5.10. The untreated diffractograms show narrow and symmetrical

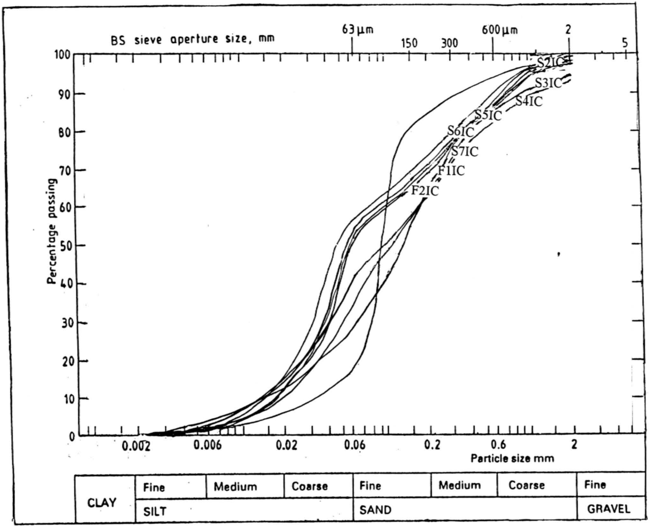

Figure 5.9 Grain size distribution of samples from the morphological Pedoplasmation zone

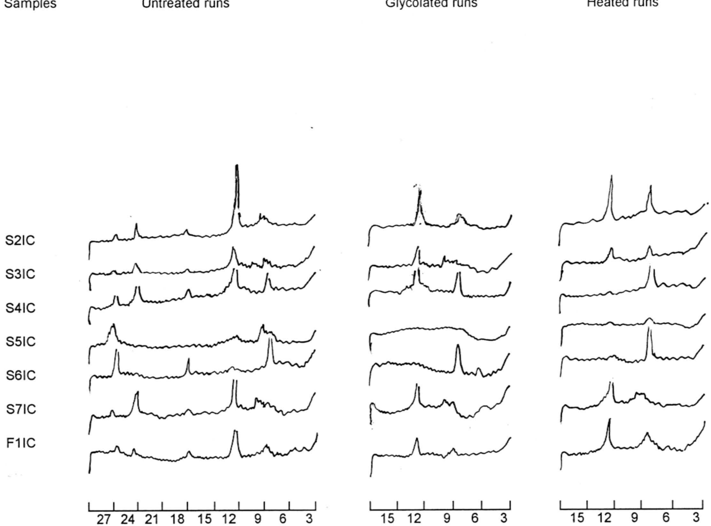

Figure 5.10 X-ray diffraction results on tests run on samples from the morphological Pedoplasmation zone

reflections at 12°-13° and 24°-25°. The appearance of 12°-13° on glycolated runs and its disappearance on the heated runs is evident of the presence of kaolinite. Narrow and asymmetrical reflections at 8°-9°, 17°-18° and 26°-27° on untreated runs which on glycolation and heating, all but reflection 8°-9° remains indicate the presence of illite. Broad and asymmetrical reflections at 7°-8.5° and 17.8° which on glycolation shift to low angles and upon heating only reflection 8.5° remains is representative of inter-stratified illite-montmorillonite. Therefore, based on the *IA* values which suggest the presence of kaolinite and montmorillonite, and the x-ray diffraction results, which indicate the presence of kaolinite, illite and inter-stratified illite-montmorillonite, it can be concluded that the clay minerals present in Pedoplasmation Zone are kaolinite, inter-stratified illite-montmorillonite and illite. The concentration of the inter-stratified illite-montmorillonite is much higher than illite.

5.4.2.2 Engineering properties

The shear strength values are as shown in Figures 5.11a - 5.11d. The shear strength values obtained from Pedoplasmation Zone (morphological horizon IC) were based on undisturbed samples. The average undisturbed cohesion and internal friction values are C = 124.31 kPa and ϕ = 33° at a moisture content of 13% for samples of the same cut and a C value of 138.12 kPa and a ϕ value of 25° with a moisture content of 25% for samples from similar zones of adjacent cuts. Samples of the same cut have a specific gravity value of 2.7 while samples from adjacent cuts have a slightly higher

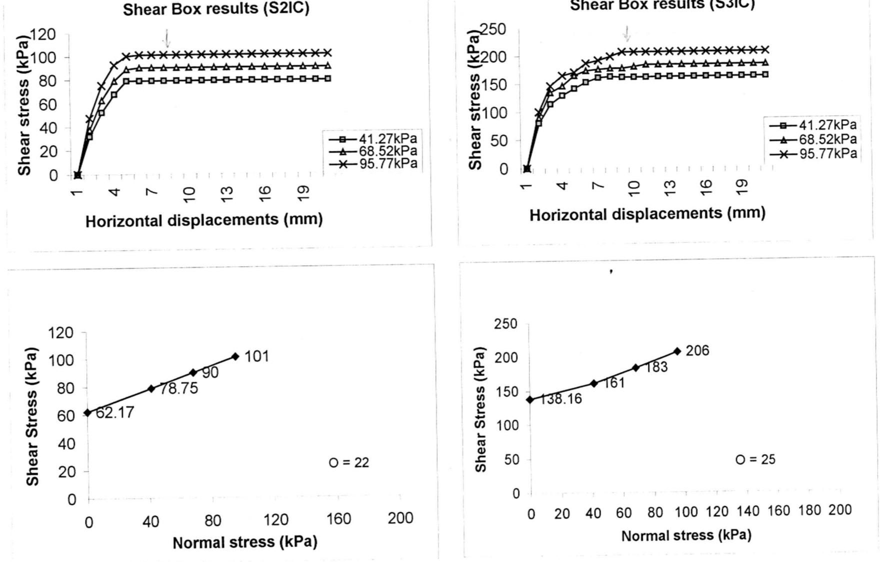

Figure 5.11a Shear strength parameters determined using the Shear Box apparatus on samples (S2IC & S3IC) taken from Pedoplasmation Zone exposed on cut slopes in the Seremban-Siliau area

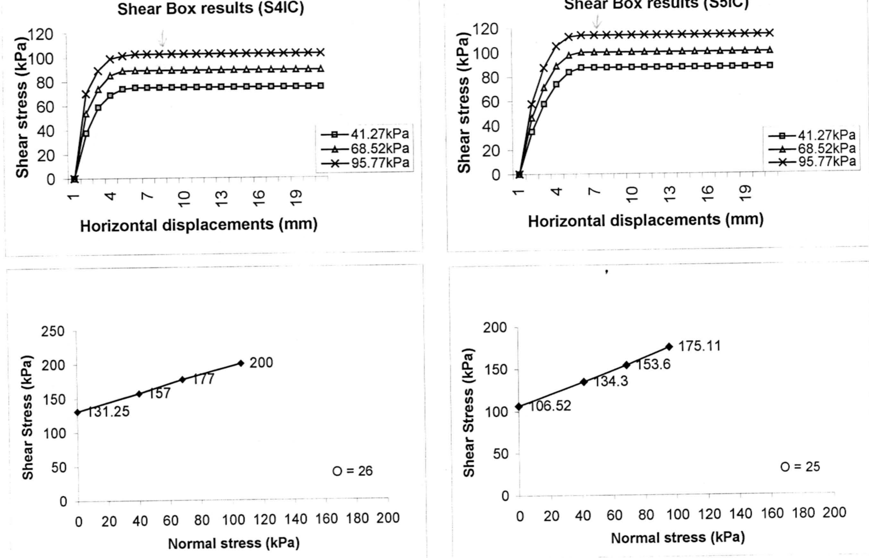

Figure 5.11b Shear strength parameters determined using the Shear Box apparatus on samples (S4IC & S5IC) taken from Pedoplasmation Zone exposed on cut slopes in the Seremban-Siliau

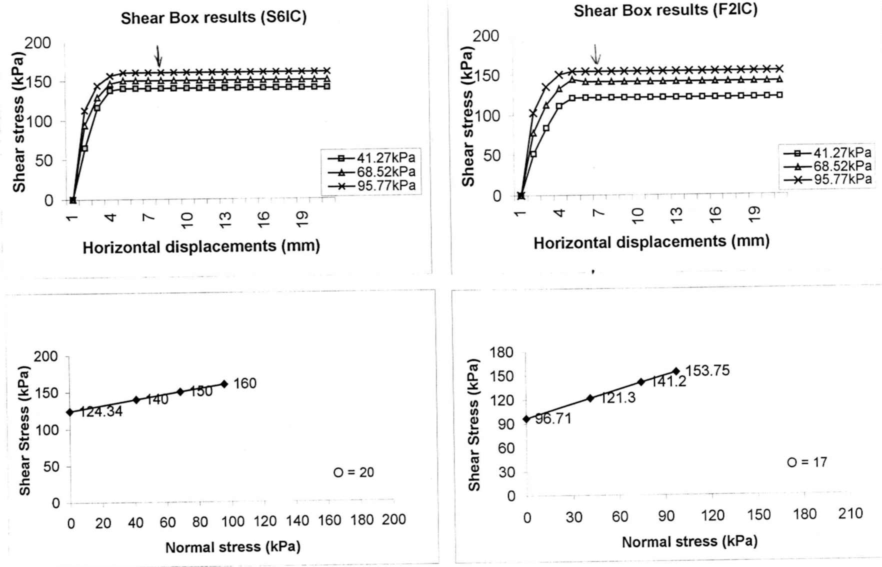

Figure 5.11c Shear strength parameters determined using the Shear Box apparatus on samples (S6IC & F2IC) taken from Pedoplasmation Zone exposed on cut slopes in the Seremban-Siliau area

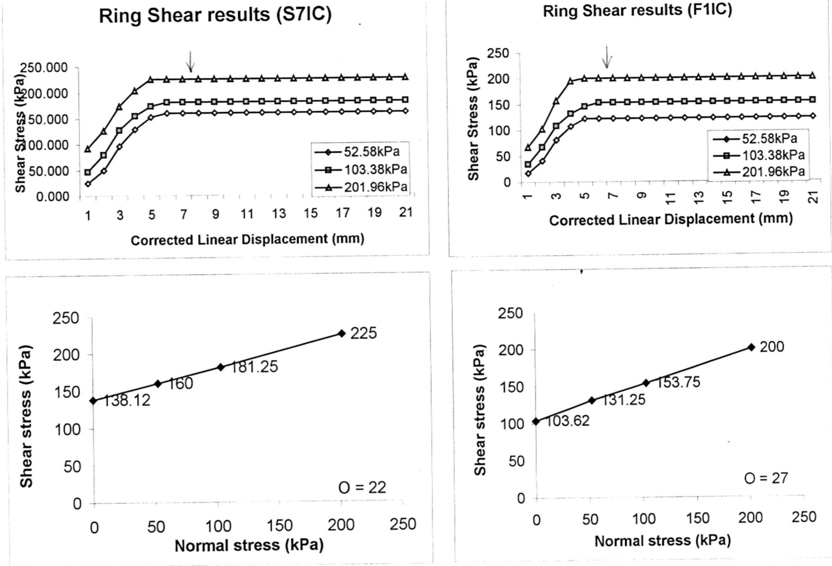

Figure 5.11d Shear strength parameters determined using the Ring Shear apparatus on samples (S7IC & F1IC) taken from Pedoplasmation Zone exposed on cut slopes in the Seremban-Siliau area

specific gravity value of 2.78. Based on the aforementioned values, it is evident of lateral variation in Pedoplasmation Zone.

5.5 Soil

5.5.1 General

Soil makes up the final part of the weathering profile. It makes up the upper part of the morphological zone ZI which consists morphological horizons IA and IB. It is yellowish red in colour and friable of clayey to gravelly texture. It has a width of about 0.07-1.5 meters. It has a much higher organic content due the roots of vegetation growing over it.

5.5.2 Geotechnical properties

On most profiles the soil zone was found to be either too thin or with high organic content. Therefore, both disturbed and undisturbed samples were used to obtain the inherent and engineering properties of Soil of the weathering profile over quartz-mica schist..

5.5.2.1 Inherent properties

The grain size analysis results (Figs. 5.12) show Soil to be of sandy clay to high plasticity clay (SC and HC). Upper Soil which is made up of horizon IA is of high plasticity clay with a grain size distribution of 37% clay, 36% silt, 27% sand and 0% gravel for samples of the same cut and a distribution of 56% clay, 32% sand, 12% silt and 0% gravel for samples from similar horizons of adjacent cuts. Lower Soil which is made up of horizon IB is classified as sandy clay with a 46% sand, 19% clay, 17% silt, and 10% gravel distribution for samples of the same cut and a somewhat varied distribution of 36% clay, 34% sand, 18% gravel and 12% silt for samples from similar horizons of adjacent cuts. Upper Soil samples from the same cut have an average *Ip* (plasticity index) of 39% with a *LL* (liquid limit) of 64% and a *PL* (plastic limit) of 25% while samples from adjacent cuts exhibit a *Ip* of 42% with a *LL* of 67% and a *PL* of 25%. Lower Soil samples from the same cut have an average *Ip* of 27% with a *LL* of 49% and a *PL* of 22% while samples from adjacent cuts show a *Ip* of 43% with a *LL* of 65% and a *PL* of 22%.

Samples from the same cut and adjacent cuts of Upper Soil exhibit a similar specific gravity of 2.6 but differ in their *Ia* (activity index) values. Samples of the same cut have a *Ia* of 1.1 which is characteristic of common clay, illite. Meanwhile, samples of adjacent cuts have a *Ia* of 0.75 which is characteristic of either non-active clay, kaolinite, or common clay, illite. Lower Soil samples which have an average specific gravity of 2.72 exhibit a *Ia* of 2.5 for samples of the same cut which indicates

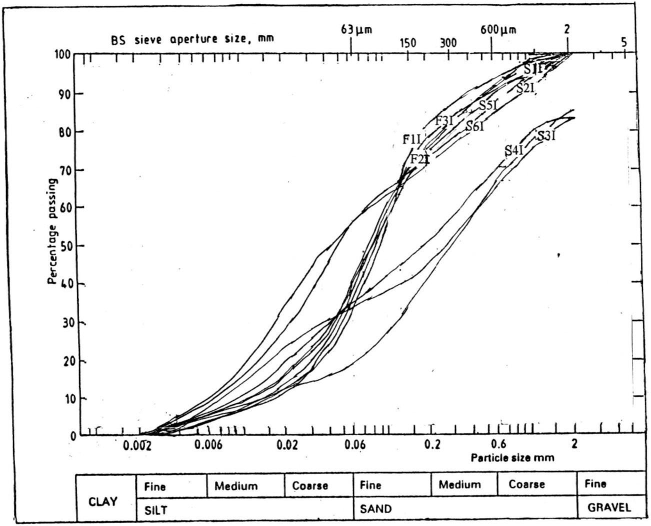

Figure 5.12 Grain size distribution of samples from the morphological Soil zone

the presence of active clay, montmorillonite. Samples from adjacent cuts, however, have a *Ia* of 1.19 which is characteristic of common clay illite.

X-ray diffraction test results (Fig. 5.13) of Soil show among others narrow and symmetrical reflections at 12°-13° and 24°-25°, broad and asymmetrical reflections at 7°-8° and 17°-18° and narrow and asymmetrical reflections at 8°-9°, 17°-18° and 26°-27°. The 12°-13° reflection which remains on glycolated runs but disappears on heated runs indicate the presence of kaolinite. The 7°-8° and 17°-18° reflections which shift to low angles on glycolation and to 8.5° upon heating, is indicative of the presence of inter-stratified illite-montmorillonite. The 8°-9°, 17°-18° and 26°-27° reflections which (except for reflection 8°-9°) disappear on glycolated and heated runs are indicative of the presence of illite.

Therefore, based on the calculated *Ia* and the x-ray diffractograms obtained on samples from Soil, it can be concluded that the clay minerals present in Soil are kaolinite, illite-montmorillonite and illite.

5.5.2.2 Engineering properties

The shear strength values determined for samples from Soil are as shown in Figures 5.14a – 5.14e. The upper Soil has an undisturbed C (cohesion) value of 158.88

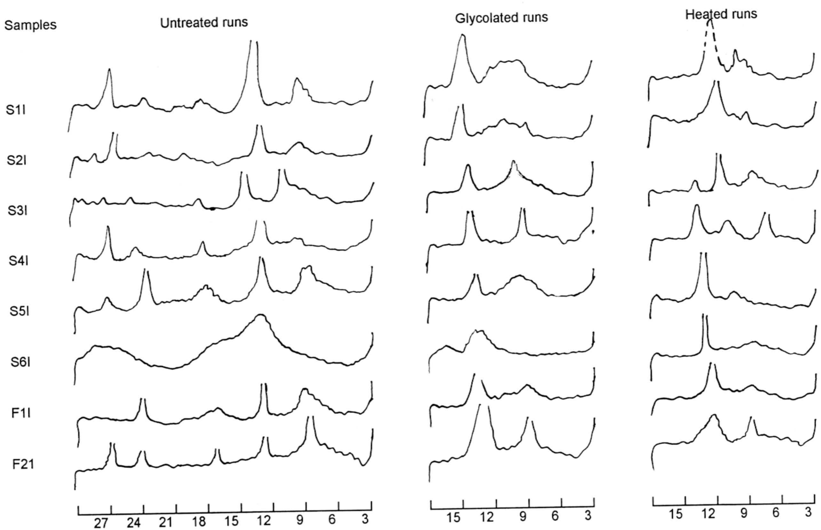

Figure 5.13 X-ray diffraction tests run on samples from the morphological Soil zone

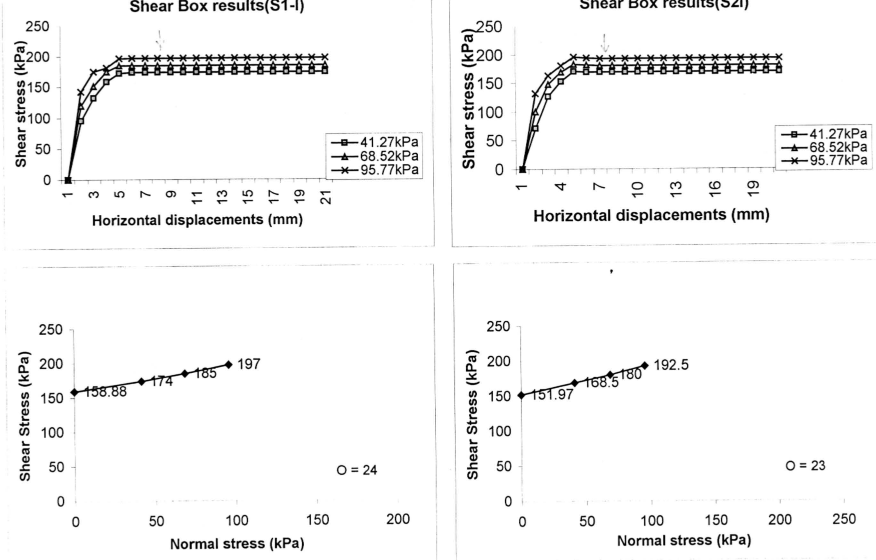

Figure 5.14a Shear strength parameters determined using the Shear Box apparatus on samples (S1I & S2I) taken from Soil exposed on cut slopes in the Seremban-Siliau area

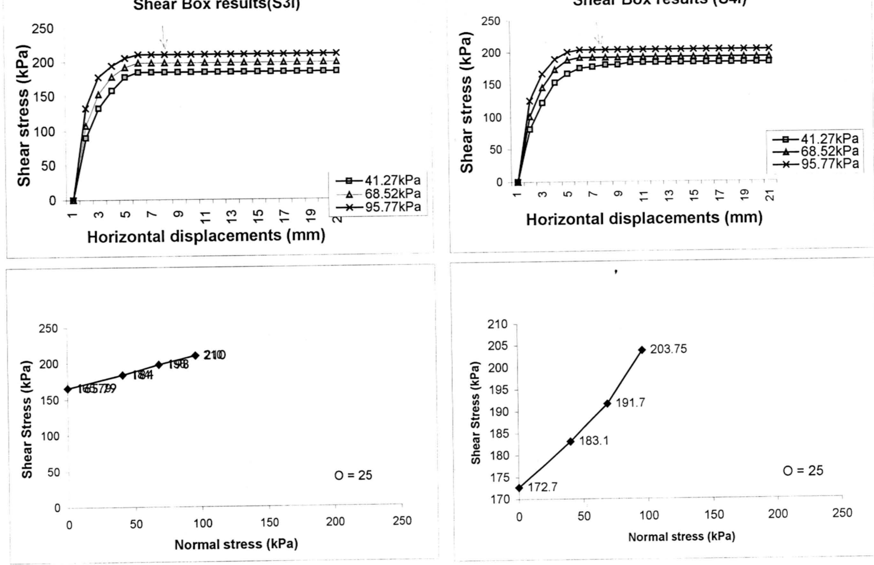

Figure 5.14b Shear strength parameters determined using the Shear Box apparatus on samples (S3I & S4I) taken from Soil exposed on cut slopes in the Seremban-Siliau area

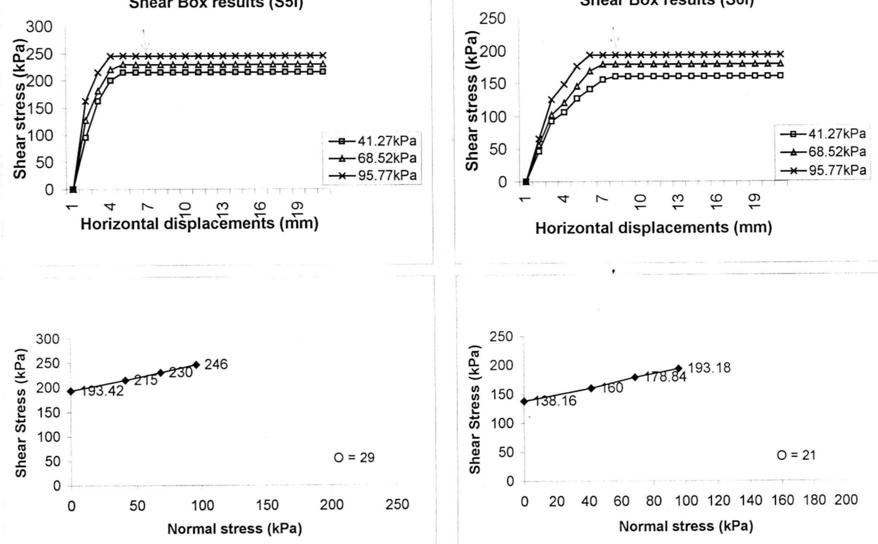

Figure 5.14c Shear strength parameters determined using the Shear Box apparatus on samples (S5I & S6I) taken from Soil exposed on cut slopes in the Seremban-Siliau area

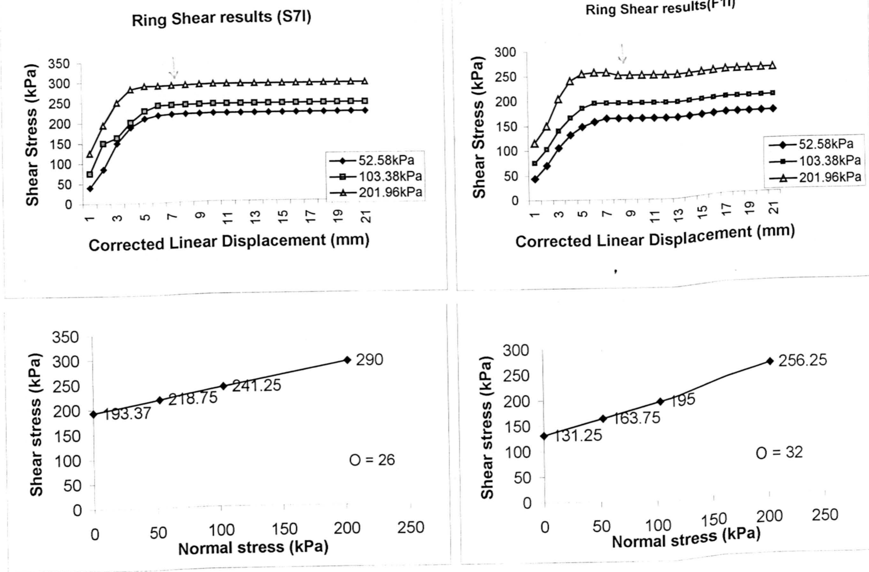

Figure 5.14d Shear strength parameters determined using the Ring Shear apparatus on samples (S7I & F1I) taken from Soil exposed on cut slopes in the Seremban-Siliau area

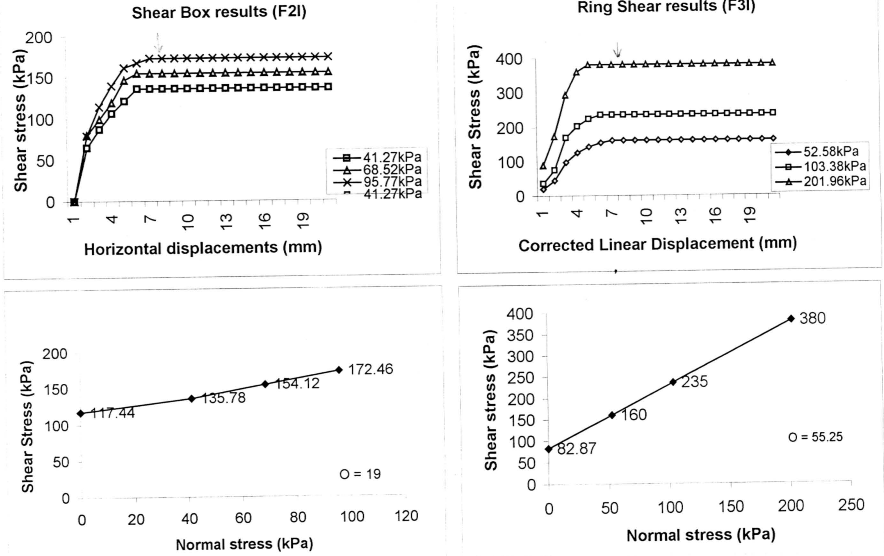

Figure 5.14e Shear strength parameters determined using the Shear Box and Ring Shear apparatus on samples (F2I & F3I) taken from Soil exposed on cut slopes in the Seremban-Siliau area

(cohesion) value of 158.88 kPa and a ϕ (angle of internal friction) of 28% at a moisture content of 10%. Undisturbed C and ϕ values obtained from samples of similar zone at adjacent cuts are 172.7 kPa and 27° respectively with a moisture content of 12%. Samples from lower Soil (horizon IIB) has remoulded C and ϕ values of 82.9 kPa and 32° respectively at a moisture content of 16%. Samples from similar zones of adjacent cuts have a C value of 96.68 kPa and a ϕ value of 28° at a moisture content of 15%.

The varied C and ϕ values of both the undisturbed and remoulded samples between adjacent cuts are proof of lateral variation which exists in Soil. Soil, which has a generally high clay content (>35%), is a more cohesive soil that has a higher shear strength value. Though Soil has a more clayey texture, its high sand content (≅33%) and silt content (12%) contribute to the friction within Soil, thus giving Soil a much higher angle of internal friction, ϕ.

5.6 Summary

With the advance of weathering, vertical and lateral variations have been noted in the inherent properties (grain size distribution, Atterberg limits and activity index) and the engineering properties (shear strength parameters, C and ϕ) of the bedrock material. Vertical variations in these values are found in the various horizontal morphological horizons which make up the weathering profile exposed on a cut slope whereas lateral variations are found on the same horizons of similar weathering profile exposed on adjacent cut slopes in the area.

As weathering increases, vertical variation is very apparent in the grain size distribution where a general drop in the grain size of the original bedrock minerals is noted. There is a distinct gradation in the grain size and soil type from the least weathered Saprock to the most weathered Soil zones of the weathering profile which changes from the least weathered silty texture to the more weathered clayey texture. This change causes a general decrease in the porosity and increase the density of the weathered material due to the relative increase in the clay content which is in part due to illuviation of clay from overlying pedological soil horizons. In cases where the clay content is more than 10%, the weathered material becomes relatively impervious to water compared to sandy or silty material. There is also a general vertical increase in the plasticity index due to the increase in the clay content as weathering increases, especially in the Soil and Pedoplasmation Zone of the weathering profile. Lateral variations, though slight, are obvious in the grain size distribution amongst samples of the same horizons of similar profiles exposed on adjacent cut slopes. The plasticity indexes of these samples also show variations corresponding to variation in the grain size distribution.

With the advance of weathering, there are obvious change in the activity index, *Ia*, within the weathering profile. These changes correspond with the x-ray diffractograms of each weathering zone of the profile.The lower part of the weathering profile (Saprock) indicates the presence of mainly illite. X-ray diffractograms of the intermediate part of the profile (Saprolite & Pedoplasmation Zone) show the presence of mainly clay minerals such as inter-stratified illite-montmorillonite, illite and kaolinite where there is more illite than kaolinite present. The x-ray diffractograms of the upper part of the profile (Soil) indicate the presence on kaolinite, inter-stratified illite-montmorillonite and illite, in that order of decreasing intensity. As weathering increases, illite which is the main clay mineral found in the lower part of the weathering profile alters into mixed or inter-stratified illite-montmorillonite of the intermediate or the middle part of the weathering profile. The inter-stratified illite-montmorillonite then alters into kaolinite in the upper zone as weathering advances. Therefore more illite and less inter-stratified illite-montmorillonite are found in the least weathered zone of the weathering profile while less illite, more inter-stratified illite-montmorillonite and less kaolinite are found in the intermediate zone. In the upper zone, even lesser illite, lesser inter-stratified illite-montmorillonite and more kaolinite are found.

The most important engineering properties stressed here, the shear strength parameters, C (cohesion) and ϕ (angle of internal friction), show both vertical and lateral variations too (Table 5.1). The vertical variations are very obvious in the relatively higher C and ϕ values of the Soil and Pedoplasmation Zone of ZI compared to the Saprock and Saprolite of ZII; thus giving ZI a much higher shear strength value which is very much the influence of higher clay content in ZI compared to the siltier ZII. Lateral variation is observed on all morphological zones throughout the profile which is obviously due to the varied grain size distribution. There is a general lateral

PE ER	HEIGH (m)	WIDTH (m)	LENGTH (m)	SLOPE ANGLE	MORPHOLOGICAL ZONES EXPOSED* Soil	 Ped. Zn'	 Saprolite	 Saprock	C (kPa)	Ø (Phi)
1	1.5	1.8	70	40	1.5				158.88	24
2	6	5.6	64	46	1.5	0.5	4		151.97 62.17 82.9	23 22 19
3	6	4.4	107	54	1.5	0.5	4		165.79 138.16 110.53	25 25 33
4	3	1.4	75	65	0.75	0.25	2		172.7 131.25 110.53	25 26 19
5	7	1.4	69	55	1.25	0.25	1.5	4	193.42 106.52 103.62 96.71	29 25 20 18
6	6	1.1	69	47	1	0.5	1.5	3	138.16 124.34 117.44 110.53	21 20 18 20
7	5	3.6	55	54	1	0.25	3.75		193.42 138.12 131.25	26 22 40
F1	3	0.5	6.68	80	0.75	0.25	2		131.25 103.62 62.17	32 27 32
F2	8	4.4	5	50	1.5	0.5	2.5		117.44 96.71 55.26	19 17 18
F3	5	18.7	5	15	0.07	-	4.93		82.9 55.26	30 19

le 5.1 Characteristics of cut slopes and existing failures in the study area.
(see Fig 3.1 for locations)

egend - - * thickness of each zones in meter
' Ped. Zn - Pedoplasmation zone
C - cohesion
Ø - angle of internal friction
S - existing slopes
F - failured slopes

change in clay, silt and sand sized fractions in all morphological zones. However, these variations are within their respective soil classification.

Remoulding too has variable effects on the C and ϕ values. Though ZI has much higher C and ϕ values compared to that of ZII, the remoulded values for ZI and ZII are larger ϕ and smaller C values compared to their undisturbed values. The siltier ZII (Saprock and Saprolite) has a much smaller remoulded C and a larger remoulded ϕ compared to the clayey ZI (Soil and Pedoplasmation Zone) with a low to moderate remoulded C and larger remoulded ϕ. This is a much expected effect since remoulding destroys any existing foliated texture, which subsequently cause an increase in the internal friction amongst the grains which form the cut slope material.

Therefore, as the degree of weathering increases, the product of weathering is less silty and more clayey with an increase in plasticity, cohesion and angle of internal friction. Likewise, more kaolinite and inter-stratified illite-montmorillonite are formed as more illite alters with weathering.