

**WEATHERING AND STABILITY OF CUT SLOPES IN
QUARTZ-MICA SCHISTS OF THE SEREMBAN-SILIAU AREA,
NEGERI SEMBILAN, MALAYSIA.**

BY

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**WHAT ISN'T
TRIED,
WON'T WORK**

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ABSTRACT

Weathering profiles over quartz-diorite schists in the Sjöman-Sjöen area, north of Gäddede along only the Forängen-Månham-Sjöen and Sjöen-Råman-Lerumhag roads are characterized by a vertical zonation of weathered materials with laterally diverse features and properties. A complete weathering profile over quartz-diorite schists in the study area consists of Soil, Pedoplasma Zone, Sapropite, Saprock and Rock. The complete profile can at first be divided into three main morphological zones, namely the upper ZII, the intermediate ZII and the lower ZIII zones. The Soil consists of Soil and Pedoplasma Zone, ZII consists of Sapropite and Saprock and ZIII consists of Rock. ZII is partially, laterally and geographically altered, ZB is geographically altered and ZIII is unaltered and fresh. The weathering front is between ZIII (Rock) and lower ZII (Saprock) while the pedogenesis front is between the upper ZII (Sapropite) and lower ZII (Pedoplasma Zone). These morphological zones are then divided further into smaller subzones or horizons. ZII is further divided into horizons IA, IB and IC based on the thickness and grain size distribution. Horizons IA and IB consist of Soil and horizon IC consists of Pedoplasma Zone. ZIII is also divided further into subzones or horizons IIA, IIB and IIC based on the degree of weathering. Sapropite makes up the horizon IIA and upper horizon IIB. Saprock makes up the lower horizon IIB and horizon IIC. With the advance of weathering, vertical and lateral changes are observed in the inherent properties (e.g. are crystalline, fibrous, ductile, actively indurated and engineering properties) and the angle of internal friction (ϕ) of the materials. Lateral variations are apparent between the various horizons. The weathering profile shows a vertical zonation in the granular distribution of the materials. The upper zones tend to clayey materials in the upper zones. The weathering levels too vary corresponding to these changes. Vertical variation is also seen in the type of clay minerals present in these zones. Illite is the main clay mineral found in the lower zones (least weathered) which alters into interstratified illite-muscovite (mainly in the intermediate zones, more weathered) and subsequently alters into kaolinite in the upper zones (more weathered). The C and ϕ values show general increase with weathering. Lateral variations are apparent amongst similar zones of profiles exposed on adjacent cut slopes. These variations though slight, can be seen in the grain size distributions that vary within their respective soil classifications. Other inherent and engineering properties vary in correspondence with these stratified lateral variations. Stability analyses on existing cut slopes and existing failure in quartz-diorite schist show that most of the existing slopes are very stable slope with very high admissible factors of safety, except for an existing failure that is expected to fail again soon and another with an expected high probability of failing again. On the red clayey, free cut slopes are found to be less dangerous in case of a fall because the spillage of debris from the adjacent road would be minimal and of minor hindrance to the road users. All other existing cut slopes and failures are of no danger to the road users or adjacent premises since the completed potential failure would not involve the adjacent roads or premises and an spillage onto the adjacent road is expected. The existing instabilities are due to unstable slope geometry, high seasonal rainfall, exposed slope surface and the presence of poorly preserved water structures.

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Weathering profiles over quartz-diorite schists in the Sjöman-Sjöen area, north of Gäddede along only the Forängen-Månham-Sjöen and Sjöen-Råman-Lerumhag roads are characterized by a vertical zonation of weathered materials with laterally diverse features and properties. A complete weathering profile over quartz-diorite schists in the study area consists of Soil, Pedoplasma Zone, Sapropite, Saprock and Rock. The complete profile can at first be divided into three main morphological zones, namely the upper ZII, the intermediate ZII and the lower ZIII zones. The Soil consists of Soil and Pedoplasma Zone, ZII consists of Sapropite and Saprock and ZIII consists of Rock. ZII is partially, laterally and geographically altered, ZB is geographically altered and ZIII is unaltered and fresh. The weathering front is between ZIII (Rock) and lower ZII (Saprock) while the pedogenesis front is between the upper ZII (Sapropite) and lower ZII (Pedoplasma Zone). These morphological zones are then divided further into smaller subzones or horizons. ZII is further divided into horizons IA, IB and IC based on the thickness and grain size distribution. Horizons IA and IB consist of Soil and horizon IC consists of Pedoplasma Zone. ZIII is also divided further into subzones or horizons IIA, IIB and IIC based on the degree of weathering. Sapropite makes up the horizon IIA and upper horizon IIB. Saprock makes up the lower horizon IIB and horizon IIC. With the advance of weathering, vertical and lateral changes are observed in the inherent properties (e.g. are crystalline, fibrous, ductile, actively indurated and engineering properties) and the angle of internal friction (ϕ) of the materials. Lateral variations are apparent between the various horizons. The weathering profile shows a vertical zonation in the granular distribution of the materials. The upper zones tend to clayey materials in the upper zones. The weathering levels too vary corresponding to these changes. Vertical variation is also seen in the type of clay minerals present in these zones. Illite is the main clay mineral found in the lower zones (least weathered) which alters into interstratified illite-muscovite (mainly in the intermediate zones, more weathered) and subsequently alters into kaolinite in the upper zones (more weathered). The C and ϕ values show general increase with weathering. Lateral variations are apparent amongst similar zones of profiles exposed on adjacent cut slopes. These variations though slight, can be seen in the grain size distributions that vary within their respective soil classifications. Other inherent and engineering properties vary in correspondence with these stratified lateral variations. Stability analyses on existing cut slopes and existing failure in quartz-diorite schist show that most of the existing slopes are very stable slope with very high admissible factors of safety, except for an existing failure that is expected to fail again soon and another with an expected high probability of failing again. On the red clayey, free cut slopes are found to be less dangerous in case of a fall because the spillage of debris from the adjacent road would be minimal and of minor hindrance to the road users. All other existing cut slopes and failures are of no danger to the road users or adjacent premises since the completed potential failure would not involve the adjacent roads or premises and an spillage onto the adjacent road is expected. The existing instabilities are due to unstable slope geometry, high seasonal rainfall, exposed slope surface and the presence of poorly preserved water structures.

ABSTRACT

Weathering profiles over quartz-mica schists in the Seremban-Siliau area which are found along only the Seremban-Mambau-Siliau and Siliau-Rantau-Seremban roads are characterized by a vertical zonation of weathered materials with laterally similar features and properties. A complete weathering profile over quart-mica schist in the study area consists of Soil, Pedoplasmtion Zone, Saprolite, Saprock and Rock. This complete profile can at first be divided into three main morphological zones, namely the upper ZI, the intermediate ZII and the lower ZIII zones.). ZI consists of Soil and Pedoplasmtion Zone, ZII consists of Saprolite and Saprock and ZIII consists of Rock. ZI is pedologically and geochemically altered, ZII is geochemically altered and ZIII is unaltered and fresh. The weathering front is between ZIII (Rock) and lower ZII (Saprock) while the pedoplasmtion front is between the upper ZII (Saprolite) and lower ZI (Pedoplasmtion Zone). These mophological zones are then divided further into smaller subzones or horizons. ZI is further divided into horizons IA, IB and IC based on the hardness and grain size distribution. Horizons IA and IB consist of Soil and horizon IC consists of Pedoplasmtion Zone. ZII is also divided further into subzones or horizons IIA, IIB and IIC based on the degree of weathering. Saprolite makes up the horizon IIA and upper horizon IIB. Saprock makes up the lower horizon IIB and horizon IIC. With the advance of weathering, vertical and lateral changes are noted in the inherent properties (grain size distribution, Atterberg limits, activity index) and engineering properties (shear strength parameters, cohesion (C) and angle of internal friction (ϕ)) of the weathered slope forming materials. Vertical variations are apparent between the various zones of the same cut slope and are especially distinct in the grain size distribution which varies from silty materials at the lower zones to clayey materials at the upper zones. The Atterberg limits too vary corresponding to these changes. Vertical variation is also seen in the type of clay minerals present in these zones. Illite is the main clay mineral found in the lower zones (least weathered) which alters into interstratified illite-montmorillonite in the intermediate zones (less weathered) and subsequently alters into kaolinite in the upper zones (more weathered). The C and ϕ values show general increase with weathering. Lateral variations are apparent amongst similar zones of profiles exposed on adjacent cut slopes. These variations though slight, can be seen in the grain size distributions that vary within their respective soil classifications. Other inherent and engineering properties vary in correspondence with these aforementioned lateral variations. Stability analyses on existing cut slopes and existing failures in quartz-mica schist show that most of the existing slopes are very stable slope with very high minimum factors of safety; except for an existing failure that is expected to fail again soon and another with an expected high possibility of failing again. On the risk ranking, two cut slopes are found to be less dangerous in case it fails because the spillage of debris onto the adjacent road would be minimal and of minor hindrance to the road users. All other existing cut slopes and failures are of no danger to the road users or adjacent premises since the computed potential failure would not involve the adjacent roads or premise and no spillage onto the adjacent road is expected. The existing instabilities are due to unsuitable slope geometry, high seasonal rainfall, exposed slope surface and the presence of poorly preserved relict structures.

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SUMMARY

Two main lithological units have been found in the study area. They are the Older Schist Series (Gneiss-schistosity) and the Younger Schist Series (Lower Devonian). The Older Schist Series consists of two main lithological subunits, a dominant light grey to grey quartz-mica schists inter-bedded with quartz-schist and a lesser dark to very dark grey gneiss and quartz-graphite-mica schist. The dominant subunit is considered equivalent to the Glading Formation (the Schist) of the Kuala Lumpur area while the minor subunit is considered equivalent to the Hardschists Formation (Gneiss). The Older Schist Series is also similar to the Posh Schist. The Younger Schist Series consist of massive to moderately mafic sandstone with minor interbeddings of light grey shale and is variably metamorphosed to meta-quartzite and meta-graphite. The Younger Schist Series is found to be similar to the Kuala Lumpur Formation (Lower Devonian) of the Kuala Lumpur area. Quartz-mica schists studied in the study area was part of the dominant subunit of the Older Schist Series (Gneiss-schistosity) and is folded towards the north, northwest, west and eastward of the study area. A total of seven exposed out slopes (S1-S7) and three existing mines (P1-P3) are identified in the quartz-mica schist. These features are all found only along the Seremban-Mambau Road and Shioh-Kahru-Seremban Road.

Based on the textural and mineralogical characteristics, the schists in the study area is considered to be of medium to high grade metamorphism. It is identified as quartz-mica schist, quartz-schist, gneiss-schist and rock. The schistosity is generally parallel to the foliation. The lithological units namely ZI, ZII and ZIII. ZI consists of Schist and Pseudotachylite Zone, ZII of Schist and Foliated Zone, and ZIII of Rock. ZI is predominantly and geochemically altered while ZII is only geochemically altered. ZIII is unaltered and fresh. These morphological units can be further divided into smaller subzones of lithology. ZI is divided into horizon IA, IB and IC based on their weathering and colour characteristics. Horizon IA, IB and IC are yellowish, red and red and reddish yellow in colour respectively. Horizons IA and IB make up bed and horizon IC make up pseudotachylite zone. ZII is divided into horizon IIA, IIB and IIC based on the degree of weathering of schistosity from the original bedrock. Horizon IIC is the least weathered (x), horizon IIB is the least weathered (y) and horizon IIA is the most weathered (z) of the ZII horizon. Horizon IIA and upper horizon IIB make up schistosity while lower horizon IIB and horizon IIC make up bedrock. The weathering from top to bottom zones ZII (Schist) and lower ZII (Schist) while the pseudotachylite zone is between upper upper ZII (Schist) and lower ZI (Pseudotachylite Zone). Only zones ZI and ZII are found exposed in the study area.

In engineering perspective, variations are observed in the mineralogy and composition properties of the slope forming materials. The relevant properties considered are the grain size distribution, Atterberg limits and liquid index (LI). The engineering properties are the shear strength parameters, c (cohesion) and ϕ (angle of internal friction). The variations observed are both vertical and lateral.

SUMMARY

Two main lithological units have been found in the study area. They are the Older Schist Series (Silurian-Ordovician) and the Younger Schist Series (Lower Devonian). The Older Schist Series consists of two main lithological subunits; a dominant light grey to grey quartz-mica schists intercalated with quartz-schist and a minor dark to very dark grey graphite and quartz-graphite-mica schist. The dominant subunit is considered equivalent to the Dinding Formation (Pre-Silurian) of the Kuala Lumpur area while the minor subunit is considered equivalent to the Hawthornden Formation (Silurian). The Older Schist Series is also similar to the Pilah Schist. The Younger Schist Series consist of immature to moderately mature sandstone with minor intercalations of light grey shale and is variably metamorphosed to metaquartzite and slate or phyllite. The Younger Schist Series is found to be similar to the Kenny Hill Formation (Lower Devonian) of the Kuala Lumpur area. Quartz-mica schists studied in the study area are part of the dominant subunit of the Older Schist Series (Silurian-Ordovician) and is found towards the north, northwest, west and southwest of the study area. A total of seven existing cut slopes (S1-S7) and three existing failures (F1-F3) are identified in the quartz-mica schist. These features are all found only along the Seremban-Mambau-Siliau and Siliau-Rantau-Seremban roads.

Based on the weathering profiles exposed on the quartz-mica schist outcrops in the study area, a complete weathering profile of vertical zonation of laterally similar properties is identified and it consists of Soil, Pedoplasation Zone, Saprolite, Saprock and Rock. The complete weathering is divided into three main distinct morphological zones, namely ZI, ZII and ZIII. ZI consists of Soil and Pedoplasation Zone, ZII of Saprolite and Saprock, and ZIII of Rock. ZI is pedologically and geochemically altered while ZII is only geochemically altered. ZIII is unaltered and fresh. These morphological zones can be further divided into smaller subzones or horizons. ZI is divided into horizons IA, IB and IC based on their hardness and grain size distribution. Horizon IA, IB and IC are yellowish red, red and reddish yellow in colour respectively. Horizons IA and IB make up Soil and horizon IC make up Pedoplasation Zone. ZII is divided into horizons IIA, IIB and IIC based on the degree of weathering or alteration from the original bedrock. Horizon IIC is the least weathered (α), horizon IIB is the less weathered (β) and horizon IIA is the most weathered (γ) of the ZII horizons. Horizon IIA and upper horizon IIB make up Saprolite while lower horizon IIB and horizon IIC make up Saprock. The weathering front is between zones ZIII (Rock) and lower ZII (Saprock) while the pedoplasation front is between zones upper ZII (Saprolite) and lower ZI (Pedoplasation Zone). Only zones ZI and ZII are found exposed in the study area.

As weathering progresses, variations are observed in the inherent and engineering properties of the slope forming materials. The inherent properties considered are the grain size distribution, Atterberg limits and activity index (*Ia*). The engineering properties are the shear strength parameters, *C* (cohesion) and ϕ (angle of internal friction). The variations observed are both vertical and lateral.

The vertical variations are apparent in the inherent and engineering properties of zones of the same cut. The grain size distribution shows a vertical variation from that of siltier least weathered lower zones to a clayey more weathered upper zones with a general increase in clay content and a relative drop in sand content. As the clay content increases with weathering, there is also vertical variation in the clay type. The least weathered lower zones have high concentrations of mainly illite. The less weathered intermediate zones have less concentrations of illite and more of interstratified illite-montmorillonite. The more weathered upper zones have a lesser concentration of illite, less of interstratified illite-montmorillonite and more of kaolinite. This variation is due to the main clay mineral in the lower zones of a weathering profile, illite, which alters first into interstratified illite-montmorillonite and subsequently into kaolinite as the degree of weathering progresses. There is also a general vertical increase in the plasticity index (I_p) as weathering progresses. The vertical variations noted in the undisturbed C and ϕ values are a generally increase with weathering. The remoulded C value which is smaller than its undisturbed value and the remoulded ϕ value which is larger than its undisturbed value too show an increase as weathering advances. Vertical variations in the inherent and engineering properties within the same zone of a weathering profile is very slight, almost non-existent and is insignificant.

The lateral variations are noted in the inherent and engineering properties of similar zones of adjacent cuts. The grain size distribution shows lateral variations which differ within their respective soil classification. Other inherent and engineering properties too show lateral variations which correspond with the lateral variation in grain size distribution. The smaller remoulded C value and larger remoulded ϕ too show slight lateral variations to this effect. Lateral variations of inherent and engineering properties within the same zone of a weathering profile is very slight and insignificant.

The stability analysis using the SLOPE/W programme calculates the minimum factor of safety as well as the respective critical failure surface. Based on this existing cut slopes and existing failures are ranked in the stability status which are categorized as I-‘failed’, II-‘soon to fail’, III-‘possibility of failing’ and IV-‘very stable’. Existing failure F1 shows the potential to fail again real soon and is ranked in category II. Existing failure F2 which has a strong possibility to failing again sometime in the future is in category III. The others, S1, S2, S3, S4, S5, S6, S7 and F3 which have very high factors of safety are very stable and unlikely to fail; therefore are categorized in category IV. These existing cut slopes and existing failures are then ranked on the risk categories based on the danger towards road users and adjacent premise. There are four risk categories and they are the RI-‘very dangerous’, RII-‘dangerous’, RIII-‘less dangerous’ and RIV-‘not dangerous’. Of the seven existing cut slopes, S1, S2, S4, S6 and S7 are ranked as RIV-‘not dangerous’. This is because the computed critical failure surface in case of a failure does not involve the adjacent road or premise and the expected debris will not spill onto the road causing obstruction to the traffic. The cut slopes S3 and S5, though very stable, are ranked under RIII-‘less dangerous’. This is due to the fact that the computed critical failure surface which does not affect the adjacent road or premise but may spill onto the road and cause minor hindrance to road users. Of the three existing failures, all are ranked in the RIV-‘not dangerous’. Though F1 and F2 are expected to fail again, the computed critical failure surfaces do not involve adjacent road or premise. Moreover, the expected failure debris is minimal

and will not spill over onto the road. F3 which is ranked as stable has a computed critical failure surface that does not involve any adjacent road or premise and no debris spillage onto the road.

Therefore, it can be stated that these existing cut slopes in quartz-mica schist are of danger to neither road users nor property in the vicinity and are of no hindrance to the traffic on the Seremban-Mambau-Siliau road. The existing instabilities along the Seremban-Mambau-Siliau and Siliau-Rantau-Seremban roads are mainly due to unsuitable slope geometry, seasonal fluctuation in total rainfall, exposed slope surfaces and the presence of poorly preserved relict structures such as foliation and joints which on weathering become weak zones that serve as potential failure surfaces.

CONTENTS

Page

ABSTRACT

SUMMARY

CONTENTS

LIST OF FIGURES

LIST OF PLATES

LIST OF TABLES

CHAPTERS

CONTENTS

1. INTRODUCTION

- 1.1 Objectives
- 1.2 Study area
- 1.3 Previous work in the study area
- 1.4 Literature review
- 1.5 Methodology
- 1.6 Organization of thesis

2. ENVIRONMENTAL SETTING OF THE STUDY AREA

- 2.1 Introduction
- 2.2 Topography
- 2.3 Drainage
- 2.4 Climate
- 2.5 Temperature
- 2.6 Humidity
- 2.7 Summary

CONTENTS

	<u>Page</u>
ABSTRACT	i
SUMMARY	ii
CONTENTS	v
LIST OF FIGURES	ix
LIST OF PLATES	xiii
LIST OF TABLES	xvi

CHAPTERS:

1.0	INTRODUCTION	1
1.1	Objectives	1
1.2	Study area	1
1.3	Previous work in the study area	2
1.4	Literature review	4
1.5	Methodology	7
1.6	Organization of thesis	15
2.0	ENVIRONMENTAL SETTING OF THE STUDY AREA	17
1.7	Introduction	17
1.8	Topography	18
1.9	Drainage	20
1.10	Rainfall	21
1.11	Temperature	24
1.12	Groundwater	24
1.13	Summary	26a

	<u>Page</u>
3.0 GENERAL GEOLOGY	27
3.1 Lithology	27
3.1.1 The Older Schist Series (Silurian-Ordovician)	27
3.1.2 The Younger Schist Series (Lower Ordovician)	33
3.2 Petrology of the lithological units	33
3.2.1 The Older Schist Series	33
3.2.2 The Younger Schist Series	37
3.3 Structural geology of the study area	37
3.4 Correlation	39
3.5 Brief geological history of the study area	39
4.0 WEATHERING OF QUARTZ-MICA SCHIST	41
4.1 Introduction	41
4.2 Weathering of quartz-mica schist	43
4.2.1 Introduction	43
4.2.2 Physical weathering	43
4.2.3 Chemical weathering	44
4.2.4 Mineralogical Alteration	46
4.2.5 Pedoplasation	48
4.3 Weathering profiles	49
4.3.1 Introduction	49
4.3.2 Criteria for differentiating the weathering zones	50
4.3.3 Zonation of weathering profile	50
4.3.4 Weathering profile	52
4.4 Mineralogy of quartz-mica schist	66
4.5 Chemical properties	67
4.5.1 CEC	67
4.3.4 pH and abrasive pH	67
4.6 Summary	70
5.0 CHARACTERISTICS OF WEATHERING PROFILES OVER QUARTZ-MICA SCHISTS	71
5.1 Introduction	71
5.2 Saprock	76
5.2.1 General	76
5.2.2 Geotechnical properties	76

	<u>Page</u>
5.2.2.1 Inherent properties	77
5.2.2.2 Engineering properties	80
5.3 Saprolite	83
5.3.1 General	83
5.3.2 Geotechnical properties	84
5.3.2.1 Inherent properties	84
5.3.2.2 Engineering properties	88
5.4 Pedoplasation Zone	93
5.4.1 General	93
5.4.2 Geotechnical properties	93
5.4.2.1 Inherent properties	94
5.4.2.2 Engineering properties	97
5.5 Soil	102
5.5.1 General	102
5.5.2 Geotechnical properties	102
5.5.2.1 Inherent Properties	103
5.5.2.2 Engineering Properties	105
5.6 Summary	112
 6.0 SLOPE STABILITY ANALYSIS	 117
6.1 Introduction	117
6.1.1 Aim of slope stability analysis	118
6.1.2 Principles of stability analysis	119
6.2 Slope/W	119
6.2.1 Introduction	119
6.3 Stability analysis	122
6.3.1 Existing cut slopes	122
6.3.2 Existing failures	131
6.3.2.1 F1	134
6.3.2.2 F2	134
6.3.2.3 F3	137
6.4 Factors affecting stability	139
6.5 Recommendation	141
6.5.1 Reduction of pore-pressure	141
6.5.2 Reduction of destabilizing forces	143
6.5.3 Increasing of stability forces	143
6.5.4 Support for unstable areas	144
6.6 Summary	145
 7.0 CONCLUSSION & SUMMARY	 146

REFERENCES

APPENDIXES:

- I Records of monthly rainfall amount
(Source: Malaysian Meteorological Department)
- II Records of Number of Rainy Days
(Source: Malaysian Meteorological Department)
- III Records of Minimum mean Temperature (Taken at 8.00am)
(Source: Malaysian Meteorological Department)
- IV Records of Maximum mean Temperature (Taken at 2.00pm)
(Source: Malaysian Meteorological Department)
- V Grain Size Analysis (ASTM D8080)
(BS 1377 Pt 2 : 1990, Pg 26)
- VI Particle Density (Specific Gravity)
 – Small pyknometer (density bottle) method
(BS 1377 Pt 2 : 1990, Pg 26)
- VII Atterberg Limits
(BS 1377 Pt 2 : 1990, Pg 6, 13, 14)
- VIIIa Direct Shear Box Method
(BS 1377 Pt 2 : 1990, Pg)
- VIIIb Ring Shear Method
(BS 1377 Pt 2 : 1990, Pg)
- IX pH and Abrasive pH
- X Moisture Content and Organic Content
- XI X-ray Diffraction (XRD)
- XII SLOPE/W

List of Figures

1.1	Location map of the study area	1
1.2	Order of work on the proposed study	2
1.3	The assigning of weathering grades based on the degree of weathering	13
2.1	Topography and drainage of the study area	18
2.2	Monthly rainfall chart for Samsan (1981-1995)	22
2.3	Number of Monthly and Annual rainy days chart for Samsan (1981-1995)	23
2.4a)	Maximum mean temperature chart (above 30°C) for Samsan (1981-1995)	24
2.4b)	Minimum mean temperature chart (below 10°C) for Samsan (1981-1995)	28
3.1	Geological map showing the distribution of lithological units and the location of sampling stations	29
4.1	Distribution of quartzite (Adapted from Raj, 1993)	32
4.2	Physical weathering of quartzite rocks (Adapted from Desai, 1979 & Zeynep, et al., 1976)	35
4.3	The effect of weathering on the concentration of certain oxides in the soil (Adapted from Zeynep, 1985)	37
4.4	Mineral formation due to weathering (Adapted from Zeynep, 1976)	47
4.5	Weathering profile showing transformation of rock to soil (pedological profile) (Adapted from Zeynep, 1985)	49
4.6	Dividing of weathering profile into three main zones (Carroll, 1970 in Zeynep, 1985)	51
4.7	Morphological homogeneity of residual soil over metamorphic bedrock (Raj, 1993)	53

LIST

OF

FIGURES

LIST OF FIGURES

List of Figures

<u>Figure</u>	<u>Pg</u>
1.1 Location map of the study area	3
1.2 Order of work on the proposed study	9
1.3 The assigning of weathering grades based on the degree of weathering	13
2.1 Topography and drainage of the study area	19
2.2 Monthly rainfall chart for Seremban (1981-1995)	22
2.3 Number of Monthly and Annual rainy days chart for Seremban (1981-1995)	23
2.4a) Minimum mean temperature chart (taken at 8.00am) for Seremban (1981-1995)	25
2.4b) Maximum mean temperature chart (taken 2.00pm) for Seremban (1981-1995)	26
3.1 Geological map showing the distribution of existing lithological units and the location of sampling stations	28
4.1 Distribution of quartz-mica schist in Peninsula Malaysia (Adapted from Raj, 1983)	42
4.2 Physical weathering of quartz-mica schist (Adapted from Dearman 1978 & Brenner <i>et al</i> , 1978)	45
4.3 The effect of weathering on the concentration of certain oxides in the the soil (Adapted from Zauyah, 1986)	45
4.4 Mineral alteration due to weathering (Adapted from Zauyah, 1986)	47
4.5 Weathering zones showing transformation of rock to soil (pedological profile) (Adapted from Zauyah, 1986)	47
4.6 Dividing of weathering profile into three main zones (Carrol, 1970 in Zauyah, 1986)	51
4.7 Morphological horizonation of residual soil over metamorphic bedrock (Raj, 1983)	53

4.8	Morphological zonation of regoliths over rocks in the Tropics (Zauyah, 1986)	53
4.9	Scale of weathering grades of rock mass (BS 5936, 1981)	54
4.10	Complete weathering profile and morphological zones over quartz-mica schist in the Seremban-Siliau area	64
5.1	Morphological zoning and horizoning criteria for the weathering profile exposed on cut slopes in Quartz-Mica Schists in the Seremban-Siliau area	72
5.2	Inherent and engineering properties of the weathering profile exposed over cut slopes in Quartz-mica schists in the Seremban-Siliau area	78
5.3	Grain size distribution of samples from the morphological Saprock zone	79
5.4	X-ray diffraction results on tests run on samples from the morphological Saprock zone	81
5.5	Shear strength parameters determined using the Shear Box apparatus on samples (S5II & S6IIL) taken from Saprock exposed on cut slopes in the Seremban-Siliau area	82
5.6	Grain size distribution of samples from the morphological Saprolite zone	85
5.7	X-ray diffraction results on tests run on samples from the morphological Saprolite zone	87
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	89
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	90
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	91
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	92
5.9	Grain size distribution of samples from the morphological Pedoplasation Zone	95

<u>Figure</u>	<u>Pg</u>
5.10 X-ray diffraction results on tests run on samples from the morphological Pedoplasation Zone	96
5.11a Shear strength parameters determined using the Shear Box apparatus on samples (S21C & S31C) taken from Pedoplasation Zone exposed on cut slopes in the Seremban-Siliau area	98
5.11b Shear strength parameters determined using the Shear Box apparatus on samples (S41C & S51C) taken from Pedoplasation Zone exposed on cut slopes in the Seremban-Siliau area	99
5.11c Shear strength parameters determined using the Shear Box apparatus on samples (S61C & F21C) taken from Pedoplasation Zone exposed on cut slopes in the Seremban-Siliau area	100
5.11d Shear strength parameters determined using the Ring Shear apparatus on samples (F11C & F31C) taken from Pedoplasation Zone exposed on cut slopes in the Seremban-Siliau area	101
5.12 Grain size distribution of samples from the morphological Soil zone	104
5.13 X-ray diffraction results on tests run on samples from the morphological Soil zone	106
5.14a Shear strength parameters determined using the Shear Box apparatus on samples (S11 & S21) taken from Soil zone exposed on cut slopes in the Seremban-Siliau area	107
5.14b Shear strength parameters determined using the Shear Box apparatus on samples (S31 & S41) taken from Soil zone exposed on cut slopes in the Seremban-Siliau area	108
5.14c Shear strength parameters determined using the Shear Box apparatus on samples (S51 & S61) taken from Soil zone exposed on cut slopes in the Seremban-Siliau area	109
5.14d Shear strength parameters determined using the Ring Shear apparatus on samples (S71 & F11) taken from Soil zone exposed on cut slopes in the Seremban-Siliau area	110
5.14e Shear strength parameters determined using the Shear Box and Ring Shear apparatus on samples (F21 & F31) taken from Soil zone exposed on cut slopes in the Seremban-Siliau area	111
6.1 Cut slope S1 (2km from Mambau)	126

Figure**Pg**

6.2	Cut slope S2 (4.5km from Mambau)	127
6.3	Cut slope S3 (7km from Mambau)	128
6.4	Cut slope S4 (100m from S3)	129
6.5	Cut slope S5 (7.5km from Mambau)	130
6.6	Cut slope S6 (4.5km from Siliau)	132
6.7	Cut slope S7 (4km from Siliau)	133
6.8	Failed Cut slope F1 (4.1km from S1)	135
6.9	Failed Cut slope F2 (3.35km from S1)	136
6.10	Failed Cut slope F3 (3km from Seremban)	138

List of Plates

Plate		Page
2.1	Graphitic biotite in over-bedded quartz-graphitic mica schist outcropping along the railway line (Location: ST1 - 3km from Mambou)	26
2.2	Light greenish weathered quartz-grap/mica-schist outcropping along the railway line (Location: ST1 - 5km from Mambou)	28
2.3	Weathered graphitic schist exposed on embankments along the railway line (Location: ST3 - 5km from Mambou)	29
2.4	Weathered graphitic schist outcropping along the railway line (Location: ST6 - 5km from Mambou)	31
2.5	Light greenish and foliated quartz-mica schist exposed along the Rarua (Rarua) road (Location: 5km from Rarua)	32
2.6	Brownish (due to secondary iron oxidation) quartz-mica schist outcropping along the railway line (Location: ST3 - 7.5km from Mambou)	32
2.7	Light grey to whitish, quartzite and exposed along the railway line (Location: ST1 - 1.5km from Mambou)	33
2.8	Blocks of light grey to whitish, weathered metaquartzite exposed along the railway line (Location: ST3 - 12km from Mambou)	34
2.9	Outcrops of moderately metamorphosed (light grey) with minor intercalation of light grey shale (darker bands) (not to scale) at the bottom (Location: 3km from ST3)	35
2.10	Variously metamorphosed metaquartzite, slate and phyllite (Location: Signs from ST3)	35

LIST OF PLATES

List of Plates

<u>Plates</u>	<u>Pg</u>
3.1 Graphite lenses in crenulated quartz-graphitic-mica schist outcropping along the railway line (Location: ST1- 3km from Mambau)	30
3.2 Light greenish weathered quartz-graphitic-mica schist outcropping along the railway line (Location: ST2- 4km from Mambau)	30
3.3 Weathered graphitic schist exposed on embankments along the railway line (Location: ST3- 5km from Mambau)	31
3.4 Weathered graphitic schist outcropping along the railway line (Location: ST6- 9km from Mambau)	31
3.5 Highly crenulated and foliated light greenish grey quartz-mica schist exposed along the Rantau-Seremban road (Location: 8km from Rantau)	32
3.6 Brownish (due to secondary iron oxides) green quartz-mica schist outcropping along the railway line (Location: ST5- 7.5km from Mambau)	32
3.7 Light grey to whitish, highly crenulated metaquartzite found exposed along the railway line (Location: ST7- 11km from Mambau)	34
3.8 Blocks of light gray to whitish, weathered metaquartzite exposed along the railway line (Location: ST8- 13km from Mambau)	34
3.9 Cut slope of moderately mature sandstone (light bands) with minor intercalation of light grey shale (darker bands) (not in-situ) at the bottom (Location: 3km from ST8)	35
3.10 Variably metamorphosed metaquartzite, slate and phyllite (Location: 5km from ST8)	35

<u>Plates</u>	<u>Pg</u>
4.1 Morphological zones, Zone I (soil & pedoplasation zone) and Zone II (saprolite & saprock) exposed on a cut slope (S6) along the road to Siliau (Location: 4.5km from Siliau)	56
4.2 Weathering profile on a cut slope (S5) exposing Zone I (soil & pedoplasation zone) and Zone II (saprolite & saprock) (Location: 7.5km from Mambau)	57
4.3 Weathering profile on a cut slope (S2), exposing complete Zone I and a partial Zone II (saprolite only) (Location: 4.5km from Mambau)	58
4.4 A cut slope (S3) exposing a complete Zone I (soil & pedoplasation zone) and a partial Zone II (saprolite only) of a weathering profile over quartz-mica schist (Location: 7km from Mambau)	59
4.5 Partly obscured morphological horizons, soil & pedoplasation zone (Zone I) and partial Zone II (saprolite only) exposed on a cut slope (S4) (Location: 100m from S3)	60
4.6 Morphological zones, ZI (soil & pedoplasation zone) and Zone II (saprolite only), exposed along the main railway track to Siliau (Location: 4.6km from Mambau)	61
4.7 A failure exposing the soil, pedoplasation and saprolite zones of a weathering profile over quartz-mica schist (Location: 7km from Mambau)	61
4.8 A cut slope (S7) exposing Zone I (soil & pedoplasation zone) and partial Zone II (saprolite only) (Location: 4km from Siliau)	62
4.9 An outcrop exposing only saprolite (except for about 7cm thick soil layer above it) of morphological zone, Zone I (Location: 3km from Seremban)	63
4.10 Only partial Zone I (soil only) is exposed on cut slope S1 (Location: 2km from Mambau)	63
5.1 Bromhead Ring Shear apparatus	74
5.2 Motorised direct residual shear box machine	74

Plates

Pg

- | | | |
|-----|--|----|
| 5.3 | Remoulded soil samples sheared (undrained) in annular ring shear using the motorised Bromhead ring shear apparatus (refer Plate 5.1) | 75 |
| 5.3 | Oven-dried undisturbed samples sheared (undrained) using the motorised Wykeham direct residual shear box apparatus (refer Plate 5.2) | 75 |

List of Tables

Table	Page
1.1	1
1.2	12
1.3	28
1.4	49
1.5	118
1.6	123
1.7	126
1.8	124

LIST OF TABLES

List of Tables

<u>Tables</u>	<u>Pg</u>
1.1 Criteria for differentiating weathering zones at site	12
1.2 Sampling site characteristics	12
4.1 CEC and ECEC (effective CEC) for values of samples taken from cut	68
4.2 pH values of soil samples taken from cut slopes along the Seremban-Siliau road	69
5.1 Characteristics of cut slopes and existing failures in the study area	115
6.1 A summary of the minimum factor of safety obtained for each cut slope (S1-S7) and existing failures (F1-F3) in the study area	123
6.2 Ranking of stability or failure potential and risk categories	124
6.3 Summary of stability/failure potential and risk ranking of existing cut slopes and failures	124