CHAPTER 1
INTRODUCTION

1. Objectives

Rising incidences of slope failures of late have raised great concern to all the parties involved, especially with regard to the loss of life and property. This is particularly true in Myanmar, where slopes are found along many transportation routes including roads and railways, where little has been done towards understanding the various physical properties and features of the weathered material.

The study also aims to identify the various factors influencing the stability of cut slopes excavated in the said bedrock.

1.1 Study Area

The study area which is bounded by latitudes, 19° 34' 5" N - 2° 59' 36" N and longitudes 101° 52' 3" E - 101° 59' 3" E, is situated to the southeast of Sagaing town.
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The objectives of this study are to characterize the weathering patterns and profiles developed over weathered schistose bedrock in the Seremban-Siliau area and to determine the various physical properties and features of the weathered materials. The study also aims to identify the various factors influencing the stability of cut slopes excavated in the said bedrock.

1.2 Study Area

The study area which is bordered by latitudes 2° 34.5’N - 2° 40’N and longitudes 101° 52.5’E - 101° 57.5’E, is situated to the southwest of Seremban town.
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1.2 Study Area

The study area which is bordered by latitudes 2° 34.5’N - 2° 40’N and longitudes 101° 52.5’E - 101° 57.5’E, is situated to the southwest of Seremban town.
The cut slopes studied are located along the road heading southwest from Seremban and passing through Mambau, Siliau and Rantau before returning to Seremban (see Fig 1.1).

Cut slopes along the solitary railway track going through the area were also studied (Fig 1.1) to determine the geological distribution of the study area. This track heads southeast from Seremban to Kuala Sawah where it then turns southwest towards Siliau. The study area covers a total area of some 110 square kilometres.

1.3 Previous Work In The Study Area

Early geological work including geochemical surveys were carried out by Khalid & Derksen (1971) to the west of the Kuala Kelawang-Seremban-Tampin road in the early 1970s. Khalid (1972) then conducted a brief geological study of the Seremban area (Map Sheet 103), followed by geological surveys of the Seremban-Tampin and Seremban-Labu areas. Khalid (1973) carried out geological mapping of Seremban town. A follow-up study in these areas by Sunthralingam (1977) included identification of areas with the potential for economic minerals. Mohd Sidi (1988) conducted a geochemical survey of the Seremban area. Tan (1988) focused on possible quarry sites and the general excavation requirements.
Figure 1.1 Location map of the study area
No work to date, however, has been carried out on the weathering patterns and profiles nor the stability of cut slopes in the quartz-mica schist.

1.4 Literature Review

Included in the many early works on slopes is the study on the hydraulics of overland flow on hillslopes in the United States by Emmett (1970) which emphasized the importance of slope stability. This was especially so if slopes were along important roads (Binnie & Partners, 1979). Over the years, much stress has been put on slope maintenance and stability monitoring (Lumb, 1975; Au et al, 1994).

Numerous slope failures in tropical areas have also indicated that several failure inducing processes need to be considered (Lumb, 1975; Heath & Saroso, 1988; Othman, 1989). A similar observation was made by Ching & Fredlund (1984) in their survey of slopes in Hong Kong where steep slopes with factors of safety of less than one remained stable and showed no sign of movement. Among the additional factors to be considered is the influence of negative soil water pressure on soil strength.

Besides shear strength (Chandler, 1977; Spain et al, 1990 (in Fredlund & Krahm, 1977)), the influence of rainfall intensity on surface runoff and infiltration (Nassif & Wilson, 1975) has opened doors towards work on elements of soil suction which started as early as 1978 in Hong Kong (Anderson, 1984). It involved
establishing suction levels in various materials under different types of surface cover i.e. chunam and grass. Though initially slope hydrology was taken into consideration (Lumb, 1975; Anderson & Pope, 1984; Anderson & Howes, 1985; Lloyd, 1990), it was established later that soil suction did indeed have a strong effect on slope stability (Sweeny & Robertson, 1979). Mc Farlane (1976) has established a statistical programme for suction prediction. Chipp, Clare, Henkel & Pope (1982) set-up a similar system to record field measurement of suction in colluvium covered slopes in Hong Kong. Fredlund (1980) and Brand (1982) also looked into the influence of soil suction on slope failure.

Other stability factors such as the prediction of pore water pressures (Anderson & Kneale, 1987) and topography (Anderson & Mc Nicholl, 1983) in cut slopes were also given equal importance. Greenway (1987), Collison (1993), Styczen & Morgan (1995) and Wu (1995) (in Hartshorne, 1996) stressed the impact of vegetation on slope stability especially on soil moisture regime and its influence in evapotranspiration as well as the interception regimes of a slope.

In geotechnical engineering, emphasis has been placed on slope stability analysis as seen in the various approaches and techniques found in Fredlund & Krahn (1977), Chowdhury (1978), Morgenstern & Sangrey (1978), Kenney (1956), Bromhead (1986) and Nash (1987), most of which, however, are only two dimensional analyses. In the case of three-dimensional analysis, though the theory has been available for years (Hovland, 1977), it was Hungr (1987), Xing (1987) (in Hartshorne, 1996)
and Fredlund & Lam (1993) (in Hartshorne, 1996) who have made considerable progress in the theory of the three dimensional analyses of slopes. The applicability of these methods of analysis, however, has many problems, some of which were looked into by Shasko & Keller (1991) (in Hartshorne, 1996). The two main problems faced are the choice of the suitable analytical technique and the difficulties encountered in providing sufficient data for the many parameters involved.

Studies on weathering and soil formation in Malaysia were first cited in the Malayan Geological Survey Memoirs by Roe (1951) who differentiated morphological characteristics of weathering profiles developed over phyllites, arenaceous rocks and granite. Further research involved study of the chemical, mineralogical and micromorphological changes as well as, stages of weathering and slope stability. Yeow (1975) in Peninsula Malaysia, studied weathering profiles over granite, gneiss, phyllite, tuff and schist, and identified the influence of parent rock and topography on weathering as well as the overall stability sequence of minerals and the formation of clay minerals. Eswaran & Wong (1977) researched physico-chemical and micromorphological properties as well as the mineralogy of a deep weathering profile over granite and its evolution to soil. Other research on soil genesis includes the work by Lim (1977), Paramananthan (1977), Nordin (1975) (in Zauyah, 1986), Loh (1981), Zainol (1984), Zauyah et al (1984) all of which mainly concentrated on soil profiles with emphasis on agricultural soil classification. Zauyah (1986) concentrated on studying the weathering profile distribution over graphitic quartz-mica schist while Raj
(1988) identified morphological zones in weathering profiles over various bedrock
types in Peninsula Malaysia.

Studies on the stability of slope cuts in Malaysia were first carried out by
Mohd Rasid Muda & Komoo (1984) and involved the slope stability mapping of the
Bangi area. Raj (1986) studied the stability of slope cuts along the KL-Karak
Highway while a study on determining the various types of failures as well as their
causal factors along the Jeli-Seri Banding stretch of the East-West Highway was
carried out by Abdul Ghani Rafiek & Komoo (1987). Slope failures along the Paloh-
Kluang Bypass Highway in central Johor were found by Raj (1986) to be partly due to
the presence of swelling clay minerals in the slope cuts. Further research on slope
failures was by Komoo (1988) along the East-West Highway where it was found that
the types of failure were related to the engineering geological characteristics of the
respective slopes. Little work has been done on the stability of slope cuts in the
Seremban-Siliau area, especially along the more recently built roads and railway tracks.

1.5 Methodology

The present study covers all exposed cut slopes located along the two major
roads from Seremban to Siliau. One route is from Seremban to Siliau through Mambau
to the west while the other is through Rantau to the east. All cuts along smaller roads
and tracks within the general area were also studied. Upon having identified the
distribution of quartz-mica schist bedrock in the study area, only cut slopes and failures exposed on quartz-mica schist were chosen for purpose of the study.

Exposed weathered and unweathered bedrock outcrops at selected sites and in adjacent areas were studied to identify various stages of weathering of the quartz-mica schist bedrock. Morphological horizons were also determined in order to correlate the results of shear strength determination for discussion on slope stability and factors of safety. The SLOPE/W software by GEO-SLOPE International Limited (Calgary, Alberta, Canada) was utilized to undertake the slope stability analysis. Stability analysis was also carried out on existing failures to identify the causes of failure. Upon determination of the factors causing these failures, recommendations and possible solutions are proposed.

A systematic approach has been undertaken to ensure that no relevant area of the research was overlooked. The general order of work is as shown in Figure 1.2. Upon submission of the research proposal, a reconnaissance survey was conducted to choose areas where slopes posed potential danger to road users, trains and/or buildings, occupied or otherwise. In the case of the study area, which is located in an undulating terrain, however, most of the buildings are situated in well-levelled ground, and this leads to the absence of slopes in most present-day new residential areas. The few odd slopes found (if any) in such areas are less than 1 metre in height and of a potential low hazard. The railway line passes through for the most part rubber and oil palm plantations on low to moderate hills and it was determined that there was a random combination of
Figure 1.2 Order of work on the proposed study
embankments and cuttings on both sides, beginning some 2 km from Mambau till about 3 km from Siliau. Most of these embankments and cuttings were found to be overgrown with shrubs and secondary natural vegetation.

A random survey of the roads in the area has shown that most of them traverse through estates and areas with slopes of low heights (<1m high) on either side. The paved roads are mainly the Seremban-Mambau-Siliau and the Siliau-Rantau-Seremban dual carriageway as well as some roads in the interiors of Mambau and Rantau. Slopes with potential problems were found on the Seremban-Mambau-Siliau carriageway.

A geological survey was conducted to determine the distribution of quartz-mica schist bedrock in the study area and involved two stages. The first was library research, which involved reviewing previous reports and published work on the area. The findings were then correlated with the second stage, which was fieldwork conducted both on foot and by car. The study area was geologically mapped based on information gathered in both the two stages. Two main lithological units were identified in the area, i.e. the Older Schist Series (Silurian-Ordovician) and the Younger Schist Series (Lower Devonian).

The next step involved identification of cut slopes suitable for study, the suitability being based on its geology, accessibility, location, slope angle and slope height. As quartz-mica schist bedrock is known to be found to the southwest of
Mambau and to the northwest of Siliau (see Figure 3.1), only slopes along the Seremban-Mambau-Siliau highway were found to be most suitable for studies on stability. These slopes are easily accessible, as they are located along the said highway and would also pose a danger to road users should they fail. The choice of slopes therefore also took into account slope angle, slope height and its proximity to the road, as the steeper and higher the cut, the greater are its chances for failure. Steep slopes of more than 30° slope angles and more than 1m in height were thus taken into consideration. Attention was also given to the distance between the toe of the slope and the pavement edge as a distance of less than 1.5m was assumed to be of a higher risk than a distance of more than 1.5m.

Having chosen suitable cut slopes, the next step was to identify the various morphological zones of the weathering profile exposed at each cut. These zones were identified on the basis of criteria such as colour (at the time of sampling), degree of preservation of original bedrock features, cohesiveness and texture (see Table 1.1). Lateral and vertical distributions of various stages of weathering within the weathering profile were also identified to allow for better distinction of the morphological horizons. This information was then used to assign weathering grades to each distinct zone based on its degree of weathering using a scale of I to VI, I for fresh rock and VI for soil material (refer to Table 1.3). Weathered and unweathered bedrock exposures in nearby areas were also studied to assist in identifying the different stages of weathering. This was then followed by in-situ and laboratory (ex-situ) studies of the slope materials.
<table>
<thead>
<tr>
<th>Criteria</th>
<th>Definition / Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>i) Colour (at the time of sampling)</td>
<td>-dominant matrix colour of individual morphological zone (Munsell Soil Colour Chart, 173)</td>
</tr>
<tr>
<td></td>
<td>-colour of mottles &amp; streak</td>
</tr>
<tr>
<td>ii) Preservation of original bedrock features</td>
<td>-preservation of rock fabric as in the spatial arrangement of mineral grains</td>
</tr>
<tr>
<td>characteristics</td>
<td>-rock structures as in different primary and secondary features like bedding, foliation,</td>
</tr>
<tr>
<td>(relict structures)</td>
<td>fracture (joint planes) and quartz veins</td>
</tr>
<tr>
<td>iii) Cohesiveness</td>
<td>-resistance to being crushed under pressure from finger/hammer</td>
</tr>
<tr>
<td>iv) Texture</td>
<td>-grain size distribution and laterally similar features &amp; physical properties</td>
</tr>
</tbody>
</table>

(Coller, 1969 from Thomas, 1974)

Table 1.1 Criteria for differentiating weathering zones on site

| i) Mass characteristics                      | -field strength (compactness of weathered materials)                                   |
|                                             | -moisture condition                                                                    |
|                                             | -foliation & bedding                                                                   |
|                                             | -discontinuities                                                                      |
|                                             | -state of weathering                                                                  |

| ii) Material characteristics                | -colour                                                                               |
|                                             | -particle shape & composition                                                          |
|                                             | -soil classification, grading & plasticity                                            |

| iii) Geological factors                     | -geological formation                                                                 |
|                                             | -age                                                                                  |
|                                             | -types of deposit                                                                      |

Table 1.2 Sampling site characteristics
<table>
<thead>
<tr>
<th>WEATHERING GRADES</th>
<th>DEGREE OF WEATHERING</th>
<th>DESCRIPTION OF WEATHERED MATERIAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>VI</td>
<td>Residual soil</td>
<td>- Organic matters</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- No relict textures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- No relict structures</td>
</tr>
<tr>
<td>V</td>
<td>Extremely weathered</td>
<td>- No relict structures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Visible relict textures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Discolouration</td>
</tr>
<tr>
<td>IV</td>
<td>Highly weathered</td>
<td>- Visible relict structures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Visible relict textures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Discolouration</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- &gt;35% change in consistency</td>
</tr>
<tr>
<td>III</td>
<td>Moderately weathered</td>
<td>- Visible relict structures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Discolouration</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- &lt;35% change in consistency</td>
</tr>
<tr>
<td>II</td>
<td>Slightly weathered</td>
<td>- Visible relict structures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Discolouration</td>
</tr>
<tr>
<td>I</td>
<td>Fresh bedrock</td>
<td>- No visible sign of weathering</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Hard and fresh</td>
</tr>
</tbody>
</table>

Figure 1.3 The assigning of weathering grades based on the degree of weathering
In-situ studies were undertaken in the field in two parts; the first part involving physical examination of the weathering profile. Observations from all other quartz-mica schist outcrops in the study area were incorporated with that of the chosen slopes to produce a generalized weathering profile over quartz-mica schist. The second part of the in-situ field studies was a slope inventory involving recognition and mapping of parameters such as slope angle, slope height, width, benching, proximity to the road, presence of visible structures such as faults, joints, bedding plane and foliation, any form of stabilization and for signs of seepage. Fundamental parameters such as the distribution of previous landslide deposits and geological characteristics of the bedrock and surficial deposits in the general area were also recorded, as these parameters are important factors pertaining to stability and of significance in regional stability analysis.

For the purpose of the ex-situ (laboratory) studies, samples were taken from sites chosen on the basis of clearly exposed weathering profiles as this allowed collection of appropriate samples. The sampling sites were described in terms of the characteristics shown in Table 1.2 while the samples taken from the morphological zones of each slope were tested to determine their natural moisture content, particle size distribution, chemical composition (using various equipment such as pH, X-ray diffraction, Atomic Absorption Spectrophotometry) and engineering properties (Atterberg Limits and shear strength). Since the prediction of future instability as well as past and present stability conditions are dependent on shear strength, a Shear Box and a Ring Shear apparatus were used to determine the shear strength of samples from different samples zones. The mode of test for both these equipment was based on the
BS 1377 cross-referenced with the ASTM (D 3080). The engineering properties were then incorporated with the slope inventory for stability analyses to calculate a factor of safety and to identify factors affecting the stability of the cut slopes.

The cut slopes in the study area only show parts of weathering profiles, with most cut slopes only exhibiting Grade VI or residual soil zone. As no one cut slope had a perfect weathering profile exposed, the generalized weathering profile over quartz-mica schist bedrock in the study area was derived by correlating profiles identified in previous studies together with observations made in this present study. This generalised weathering profile was also supported by the results of laboratory tests, which were utilized in stability analyses to obtain factor of safety. Results of stability analyses of failed slopes also allowed recommendation of remedial measures to minimize failures of cut slopes in quartz-mica schist.

1.6 Organisation Of Thesis

This thesis comprises a total of seven chapters; Chapter 1 being the introduction. Chapters 2 and 3 discuss the environmental setting and general geology of the study area respectively, whilst Chapter 4 discusses the quart-mica schist bedrock of the study area and its various properties. Chapter 5 reviews the characteristics of weathering profiles over quartz mica schist whilst Chapter 6 reviews and discusses
slope stability analyses and factors affecting the stability of cuts in the study area.

Chapter 7, being the final chapter, concludes and summarizes the work that has been carried out.