CHAPTER 7

CONCLUSION & SUMMARY

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The study area is situated in an undulating terrain of low hills of about 160m high surrounded by lower hills of about 80m – 40m. The Seremban-Mambau-Siliau and Siliau-Rantau-Seremban roads cut through areas of lower hills of about 40m or less. The study area is of warm and humid climate with a seasonal fluctuation in its total rainfall.

Two lithological units have been identified 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 subunits; a dominant light greenish to grey quartz-mica schist 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 is made up 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. Existing cut slopes and slope failures in the Older Schist Series were studied in this project and are found along the Seremban-Mambau-Siliau and Siliau-Rantau-Seremban roads. No cut slopes along the railway track was studied as these cut slopes were not on quartz-mica schists.

The quartz-mica schists in the study area is a metamorphic rock with a primary content of quartz and micaceous minerals which influences its weatherability. A complete weathering profile over quartz-mica schists is characterized by horizontal zones of laterally similar visible textures and properties. It consists of Rock, Saprock, Saprolite, Pedoplasmation Zone and Soil which can be divided into three distinct morphological zones. They are the ZI, ZII and ZIII zones. ZI is made up of Soil and Pedoplasmation Zone, ZII is made up of Saprolite and Saprock. ZIII is made up of Rock. The weathering front is between Rock (ZIII) and Saprock (lower ZII) while the pedoplasmation front is between Saprolite (upper ZII) and Pedoplasmation Zone (lower ZI). These morphological zones, with the exception of ZIII, can be further divided into smaller morphological horizons based on their degree of alteration. ZI (Soil & Pedoplasmation Zone) is divided into three morphologically distinct horizons. They are the yellowish red IA and the red IB which make up Soil and the reddish yellow IC which makes up Pedoplasmation Zone. Zone II (Saprolite & Saprock) is also divided into three morphologically distinct horizons. They are the most weathered IIA (γ) and the less weathered IIB (β) which make up Saprolite and the least weathered IIC (α) which makes up Saprock.

In the course of weathering, the fresh bedrock has undergone various physical and chemical alterations. These alterations can be categorized into two main types of alteration, namely the geochemical and pedological alterations. In the beginning, the unaltered fresh bedrock is geochemically altered to form firstly Saprock ('rotten rock') (lower ZII) and subsequently Saprolite (upper ZII). Then at the pedoplasmation front, the geochemically altered bedrock undergoes pedological and further geochemical alterations to form the Pedoplasmation Zone (lower ZI) and Soil (upper ZI) of the weathering profile.

It is noted that no complete weathering profile was found exposed in the study area nor any fresh bedrock (ZIII) exposed at any of the existing cut slopes or failures along the Seremban-Mambau-Siliau and Siliau-Rantau-Seremban roads. Most existing cut slopes and failures only expose zones ZI and ZII. The thickness of zones ZI and ZII vary from one cut slope to another. As weathering increases, vertical and lateral variations are noted. The vertical variations are especially distinct in the various horizontal morphological zones of weathering profiles exposed on a cut slope. It is especially so in the inherent properties and the engineering properties of the slope forming material. The inherent properties considered are the grain size distribution, Atterberg limits and activity indexes; and the engineering properties considered are the shear strength parameters, cohesion (C) and angle of internal friction (ϕ).

There is a very distinct change in grain size distribution and soil type from the silty least weathered lower ZII (Saprock) to the clayey more weathered upper ZI (Soil). The Atterberg limits too show variations which corresponds to the aforementioned variations, especially the plasticity index (*Ip*) which increases with weathering. The vertical variations noted in the activity index (*Ia*) are further supported by the X-ray Diffraction test results which indicate that illite (found in lower zones of the weathering profile) alters into inter-stratified illite-montmorillonite (found in intermediate zones of the weathering profile) which then alters into kaolinite (found in upper zones of the weathering profile). The vertical variations in the engineering properties are especially obvious in the generally higher C and ϕ values of ZI (Soil and Pedoplasmation Zone) compared to that of ZII (Saprolite and Saprock).

Lateral variations, though slight, are also apparent in the inherent and engineering properties of similar zones of adjacent cuts. The grain size distributions of adjacent cuts, though they vary, remain within its respective soil classification. Other inherent properties such as the *Ip* and *Ia* and the engineering properties, C and ϕ, too exhibit variations which correspond to the variation in the grain size distribution.

Remoulding too has its effect on the shear strength parameters, C and ϕ. The remoulded value of C is generally smaller than its undisturbed value and the remoulded ϕ is generally larger than its undisturbed value. Lateral and vertical variations are present in the remoulded values too. Remoulded values of C and ϕ of samples from similar zones of adjacent zones exhibit lateral variations while the remoulded values of C and ϕ of the various zones of the same cut slope exhibit vertical variations.

The slope stability analyses using the SLOPE/W programme have shown minimum factor of safety values which categorize the seven existing cut slope (S1-S7) and the three existing failures (F1-F3) into four main categories. They are the categories I-'failed', II-'soon to fail', III-'possibility of failing' and IV-'very stable'. F1 falls under the category II. S5 and F2 fall under the category III. S1, S2, S3, S4, S6, S7 and F3 are under category IV. Those with very high factors of safety are very stable as no rise of groundwater table will cause failure. The critical slip surfaces computed in case of a failure show that any possible failure will neither involve the road nor hinder road users. In the cases of the 'soon to fail' F1 and the 'possibility of failing' S5 & F2, no danger will come to road users or properties since the potential failures do not involve the road nearest to them. Though the resulting debris may spill over on to the road, it will be of no major hindrance to road users since the spillage will only be of small quantity. Therefore, on the risk ranking which is based on the danger towards road users and nearby premises, S1, S2, S4, S6, S7, F1, F2 and F3 are ranked as RIV-'not dangerous' since the computed failure surface does not involve the nearby road or premises nor will its debris spill on to the road. S3 and S5 are ranked as RIII-'less dangerous' because the expected failure debris may spill on to the road nearest to it but be of small hindrance to road users and of no danger nearby premises.

In conclusion, it can be stated that the currently existing cut slope and failures in the quartz-mica schist in the Seremban-Siliau area which are found exposed only along the main Seremban-Mambau-Siliau and the Siliau-Rantau-Seremban roads of danger to neither road users nor nearby properties.

Since the Older Schist Series is similar to the Dinding and Hawthornden Formations as well as the Pilah Schist, the findings of this study can be applied or used as a guide or reference where these aforementioned lithological units are concerned.