DOI : https://doi.org/10.7186/wg492202302

Soil moisture retention characteristics of saprock in a weathering profile over rhyolite in Peninsular Malaysia

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Abstract: Three broad zones can be differentiated at the weathering profile; an upper 3.9 m thick pedological soil (zone I), an intermediate 21.4 m thick saprock (zone II), and the underlying bedrock (zone III). To determine the soil moisture retention characteristics of saprock, samples were collected at vertical depths of 5.7 m (sample A), 9.1 m (sample B), 12.7 m (sample C) and 16.9 m (sample D). Samples A and B with porosities of 39% and 48%, had 7% and 6% gravel fractions, 48% and 57% sand fractions, 32% and 30% silt fractions, and 13% and 7% clay fractions, respectively. Samples C and D with similar porosities of 46%, had 6% and 17% gravel fractions, 56% and 45% sand fractions, 32% silt fractions, and 6% clay fractions, respectively. Laboratory determinations employing the pressure plate method show increasing suctions from 0 kPa through 0.98 kPa and 9.8 kPa to 33 kPa and 1,500 kPa to result in gravimetric soil moisture retentions of 28.3% through 24.0% and 19.2% to 15.0% and 5.7% for sample A, and from 21.7% through 21.1% and 17.8% to 11.9% and 3.8% for sample B. Similarly increasing auctions yield gravimetric soil moisture retentions of 28.3% through 34.7% and 29.1% to 23.2% and 7.0% for sample C, and from 28.4% to 28.1% and 23.4% to 18.6% and 5.0% for sample D. Regression analyses of gravel, sand and clay fractions plotted against moisture contents retained at large suctions (33 kPa and 1500 kPa) yield variable trends with low correlation coefficients (R^2<0.179), though plots involving silt contents yield positive trends with larger correlation coefficients (R^2 >0.525). It is concluded that the adsorption of water on the surfaces of silt particles that most likely results in retention of soil moisture by saprock.

Keywords: Rhyolite, weathering profile, saprock, soil moisture retention, silt content

INTRODUCTION

Deep weathering profiles (several tens of meters thick) are found in Peninsular Malaysia as a result of favorable tectonic and environmental factors that have facilitated pervasive chemical weathering during a larger part of the Cenozoic era (Raj, 2009). The profiles are developed over a variety of bedrock and characterized by the indistinct to distinct preservation of the minerals, textures and structures of the original bedrock material and mass. As the earth materials of the profiles are often “able to be removed by commonly accepted excavating methods”, they are known as residual soils in geotechnical literature in the Peninsula (USBR, 1974; JKR, 2007). These residual soils are considered to be unsaturated soils for unconfined groundwater tables are only found towards the base of weathering profiles in the hilly to mountainous terrain of the Peninsula (Faisal *et al.*, 2005; Bujang *et al*., 2005a; Raj, 2009).

Unsaturated soils are characterized by the presence of negative pore water pressures; the relationship between negative pore pressure and moisture content best expressed by the soil water characteristic curve (Agus *et al*., 2001). The soil water characteristic curve or soil moisture retention curve is considered to be a fundamental relationship that should be determined in investigations of unsaturated soils (Vanapalli *et al*., 1996). The soil moisture retention curve is also of importance in agriculture where it is essential to the development of effective irrigation and plant stress management techniques as suction/water relationships directly affect the yield and quality of crops (Scherer *et al*., 1996).

In Peninsular Malaysia, there is limited published data on the soil moisture retention characteristics of its unsaturated residual soils, especially those over granitic bedrock. In a study to evaluate the hydraulic conductivity

0126-5539; 2682-7549 / Published by the Geological Society of Malaysia.

of saprolite (IC soil horizon), samples were collected from 16 locations in the Peninsula and their soil moisture retention curves determined with the pressure plate method (Hamdan *et al*., 2006). Increasing suctions from 0 kPa to 1,500 kPa resulted in decreasing volumetric soil moisture retentions from 60% to 11% in the case of a granite saprolite, from 47% to 19% in the case of a schist saprolite, from 82% to 30% in the case of a shale saprolite, and from 94% to 35% in the case of a basalt saprolite (Hamdan *et al*., 2006).

In another study, also employing the pressure plate method, saprolite (IC soil horizon) samples from a weathering profile over porphyritic biotite granite experienced decreasing gravimetric moisture contents from 34.5% through 29.3% and 27.4% to 20.2% and 18.0% with increasing suctions from 0 kPa through 0.98 kPa and 9.8 kPa to 33 kPa and 1500 kPa (Raj, 2010). Under similar increasing suctions, saprock samples from the same profile experienced decreasing moisture contents on average from 27.9% through 25.3% and 16.9% to 12.6% and 5.2% (Raj, 2010).

Saprock samples from a weathering profile over biotite-muscovite granite also experienced decreasing moisture contents from 31.9% through 27.9% and 24.0% to 19.4% and 7.9% with increasing suctions from 0 kPa through 0.98 kPa and 9.8 kPa to 33 kPa and 1,500 kPa (Raj, 2021). Regression analyses of gravel, sand and clay contents plotted against moisture contents retained at large suctions (33 kPa and 1,500 kPa) yielded negative trends with variable low to moderate correlation coefficients ($R^2<0.500$), though plots involving silt contents yielded positive trends with large correlation coefficients ($R^2 >0.997$). It was concluded that the retention of soil moisture was due to absorption of water onto the surfaces of silt particles (Raj, 2021).

There is also limited published data on the soil moisture retention characteristics of earth materials in neighboring, humid tropical areas. A study involving residual soils over the sedimentary Jurong Formation and the Bukit Timah Granite in Singapore Island concluded that the depth of weathering did not have a consistent effect on their soil water characteristic curves, though soils over granite had a wider range of pore sizes (Agus *et al*., 2001). Several multi-variate empirical equations using a number of basic soil properties were also proposed in the study to describe the soil water characteristic curves of the soils (Agus *et al*., 2001).

Published literature on topics related to soil moisture retention characteristics in Malaysia include a paper that discusses modifications to the standard shear box that allowed testing of samples under unsaturated conditions (Bujang *et al*., 2005a). Results of a series of direct shear tests with fixed suction on samples of saprolite (soil horizon IC) from a weathering profile over porphyritic biotite granite led to the conclusion that suction played a role in increasing the shear strength of unsaturated soil, though there was a non-linear failure envelope due to the non-linear soil water characteristic curve (Bujang *et al*., 2005b; Thamer *et al*., 2006).

As a part of a study to characterize weathering profiles in Peninsular Malaysia (Raj, 1983) was investigated the profile developed over rhyolite at Km 38.2 of the Kuala Lumpur - Karak Highway. This short-note discusses the results of laboratory tests carried out to determine the soil moisture retention characteristics of saprock from the profile; physical characterization of the profile having been discussed earlier (Raj, 2018).

GEOLOGICAL SETTING OF INVESTIGATED WEATHERING PROFILE

The weathering profile, exposed at the slope cut at Km 38.2 of the Kuala Lumpur - Karak Highway, is developed over rhyolite that forms part of a broad, approximately north-south trending belt of acid volcanics within the Main Range of Peninsular Malaysia (Figure 1). The acid volcanics comprise rhyolitic to dacitic flows with minor tuffs and tuff breccias and are considered to be contemporaneous with the Sempah Conglomerate

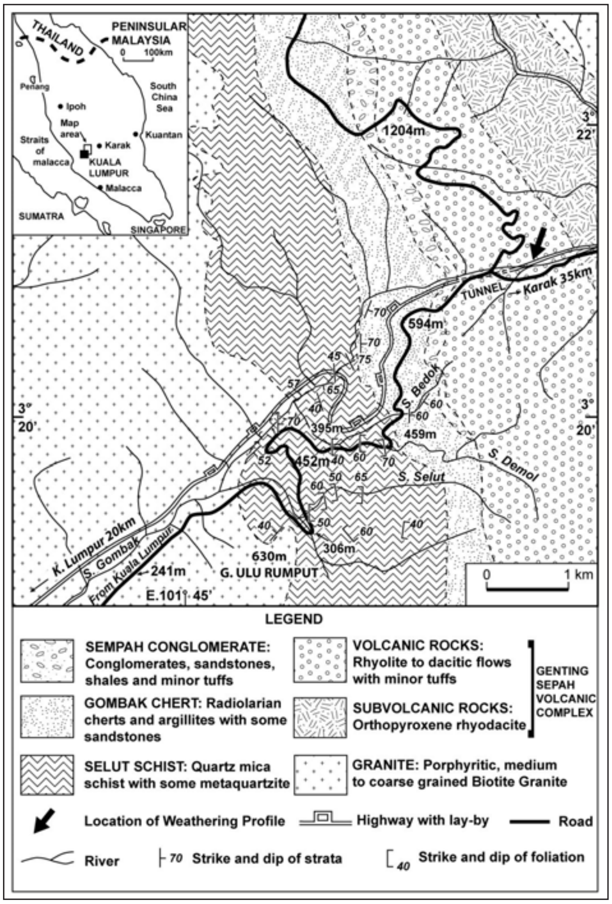

Figure 1: Geology map of the G. Ulu Rumput area (after Haile *et al*., 1977; Azman & Singh, 2005).

which outcrops to their immediate west (Haile *et al.*, 1977). Towards the east, however, the volcanics appear to be faulted against micro-granodiorite with an unusual mineralogy; consisting of abundant quartz, orthoclase, andesine and biotite together with orthopyroxene and labrodorite (Liew, 1977). Cobbing & Mallick (1987) consider this micro-granodiorite to be a subvolcanic rock that together with the acid volcanics constitutes their Genting Sempah Micro-granodiorite Pluton.

Chakraborty (1995), and Singh & Azman (2000), however, consider the acid volcanics (which they call 'orthopyroxene lacking rhyodacitic rocks' or 'rhyodacite') and the micro-granodiorite (which they call 'orthopyroxene bearing rhyodacite porphry' or 'orthopyroxene rhyodacite') to constitute their Genting Sempah Volcanic Complex. Azman & Singh (2005) furthermore, defined the Genting Sempah Volcanic Complex as consisting of two distinctive porphyry sub-volcanic units, i.e. rhyolite, and orthopyroxene rhyodacite, with minor tuffs and lavas. The Genting Sempah Volcanic Complex is considered to be one of the few examples of acid volcanism that is related, both temporally and spatially to the Triassic Main Range Granite; radiometric dating (U-Pb zircon data) yielding an age range between 211 and 219 Ma (million years) (Liew & Page, 1985).

The bedrock exposed at the bottom bench of the cut is bluish-grey in color and occurs as a massive, apparently structureless outcrop, though aligned biotite flakes (striking north-south and dipping 40^{o} east) suggest magmatic flow. The bedrock is moderately to strongly jointed (with fracture spacings between 0.2 and 0.7 m) and often contains epidote along joint planes. In thin-sections, the rhyolite is seen to be hypidomorphic holocrystalline with phenocrysts (40-60 %) of quartz, plagioclase (andesine), biotite and alkali-feldspar set in an aphanitic, essentially quartzo-feldspathic groundmass (Liew, 1977). The groundmass shows minor variations in grain size with that surrounding most phenocrysts being finer grained than that not associated with reaction rims (Azman & Singh, 2005). Detailed descriptions of the mineralogy as seen in thin-sections have been published by Azman & Singh (2005).

Seepage along discontinuity planes is seen throughout the exposed bedrock at the foot of the cut and indicates the presence of an unconfined groundwater table just above the bedrock zone.

METHODOLOGY

Tape and compass traverses were first carried out along all berms of the cut to describe the exposed earth materials in terms of the Soil Survey Manual for Malayan Conditions (Leamy & Patton, 1966) and the Guidelines for Soil Description of the Food and Agriculture Organization (FAO, 2006). Pedological features that were described included the colour, consistency and soil structure of the earth materials as well as their content of concretions, stains and organic matter. Geological features were also mapped and described, in particular the minerals, textures and structures of the original bedrock material and mass now indistinctly to distinctly preserved in the earth materials. Lateral similarity in pedological and geological features was then used to distinguish weathering zones and sub-zones, i.e. layers of earth materials with similar morphological features as color, relict bedrock textures and structures as well as litho-relicts (core-stones and core-boulders) (Table 1 and Figure 2).

Brass rings of 4 cm length and 7.6 cm internal diameter were then used to collect constant volume samples from *in situ* weathered rhyolite (saprock) at depths of 5.7 m, 9.1 m, 12.7 m and 16.9 m (Figure 3). The rings had a constant wall thickness of 0.3 cm except at one end where the lower half tapered to 0.15 cm thick to provide a cutting edge. A brass ring was first driven into the soil by hammering gently on its top until the top was flush with the ground surface. A second brass ring, with its cutting

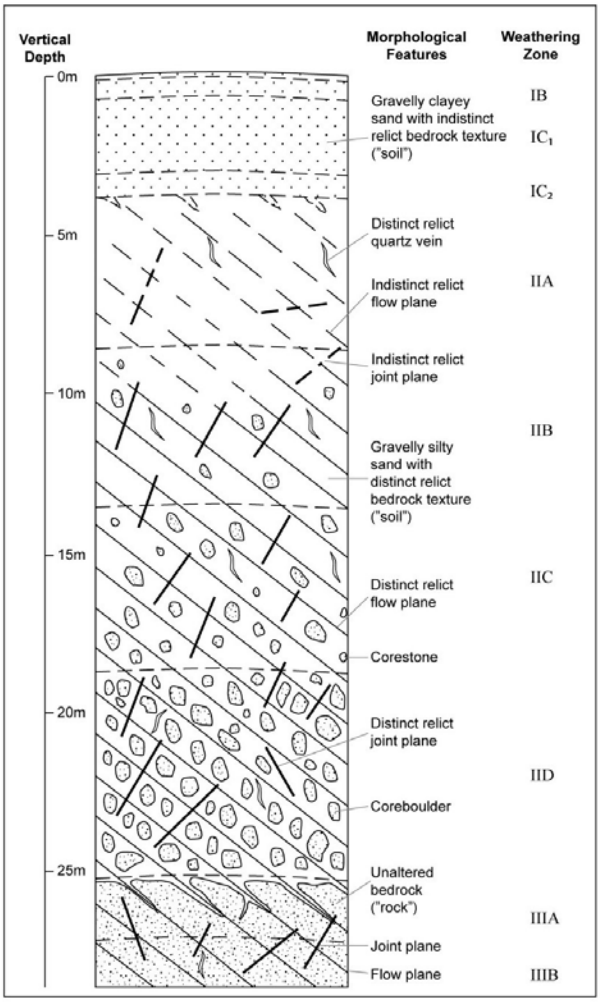

Figure 2: Schematic sketch of morphological features at the weathering profile (Raj, 2018).

Table 1: Morphological features of weathering zones and sub-zones (Raj, 2018).

Sub-zone	Thickness (m)	Sub-zone	Morphological Features	RMWG
IA	0.1 m	IA	Yellow to dark brown, porous, friable, clayey sand; some roots, boundary wavy, clear.	VI (6)
IB	0.6 m	IB	Red, firm, clayey sand; subangular blocky, moist; friable, dry; boundary irregular, gradual	
IC$_1$	2.4 m	IC$_1$	Red, stiff, gravelly clayey sand; some yellow brown mottles; friable, granular, dry; boundary irregular, diffuse	
IC$_2$	0.8 m	IC$_2$	Red, stiff, gravelly clayey; indistinct relict rhyolite texture & quartz veins; friable granular dry; boundary irregular, diffuse	
IIA	4.7 m	IIA	Red, friable, gravelly silty sand with yellow mottles; distinct relict rhyolite texture & quartz veins; some indistinct relict joint & flow planes; some core stones; boundary irregular, diffuse.	V (5)
IIB	4.9 m	IIB	Red, friable, gravelly silty sand; distinct relict rhyolite texture, quartz veins, joint & flow planes; several angular, core-stones; a few core-boulders (about 10% of sub-zone); boundary irregular, diffuse.	
IIC	5.1 m	IIC	Broad bands of friable, red, gravelly silty sand with distinct relict rhyolite texture, quartz veins, joint & flow planes in-between angular, core-stones & core-boulders (≈20-40% by area of sub-zone); boundary irregular, diffuse.	IV (4)
IID	6.7 m	IID	Predominantly angular to subrounded, core-stones & core-boulders (>50% by area of sub-zone) with thin to broad bands of friable, red, gravelly silty sand with distinct relict rhyolite texture, quartz veins, joint & flow planes; boundary irregular, sharp.	III (3)
IIIA	2.2 m	IIIA	Continuous bedrock outcrop with thin wedges & bands of red, gravelly silty sand with distinct relict rhyolite textures & structures, along & between discontinuity planes; boundary broken, diffuse.	II (2)
IIIB	>2 m	IIIB	Continuous bedrock outcrop with thin strips of red, gravelly silty sand with distinct relict rhyolite textures & structures along discontinuity planes only.	I (1)

Note: RMWG = Rock Mass Weathering Grade

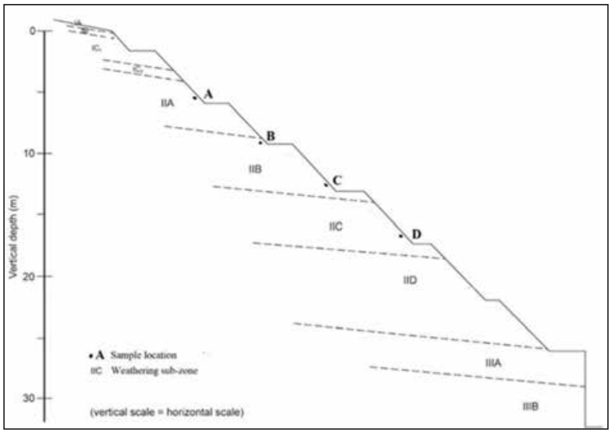

Figure 3: Sample locations and lateral extensions of weathering sub-zones.

edge facing upwards, was then placed on the top of the first ring which was then driven deeper into the soil by gently hammering on the top of the second ring; a piece of wood placed over the second ring to minimize damage and disturbance of the sample. Both rings were then dug out from the ground by excavating the surrounding and underlying soil. The sample in the upper ring was discarded whilst the sample in the lower ring was trimmed and sealed with rubber discs that were held in place by screwed-on metal plates. Prior to sampling, the rings were externally greased to facilitate entry into the soil, whilst materials on the slope were excavated to a depth of some 0.5 m to minimize surface disturbance. Prior to sampling, the soil was also trimmed into an approximately cylindrical shape, slightly larger than the ring diameter, to reduce lateral compaction. Two constant volume samples were collected at each sampling point; one for determination of its physical and soil index properties, and the other for determination of its soil moisture retention characteristics.

The sample rings were taken to the laboratory where the moisture content, unit weight and density of one set of samples was determined before the specific gravity of the constituent mineral grains was measured using a pycnometer (ASTM, 1970). Porosities, void ratios and degrees of saturation of the samples were then calculated before the plastic limits of the fine fractions (<0.42 mm size) were determined (ASTM, 1970). The particle size distributions of the samples were next determined using the sieving, and sedimentation, methods for the coarse (>0.0625 mm diameter), and fine (<0.0625 mm), grained fractions respectively (ASTM, 1970). The main minerals present in the gravel, sand and silt sized fractions were then identified with the aid of a binocular microscope, whilst X-ray diffractograms of the clay fractions were prepared under normal, glycolated, and 500^{o}C heated, conditions to identify the minerals present (Thorez, 1975; Poppe *et al.*, 2001). It is to be noted, that the size limits for soil particles are based on the Wentworth (1922) Scale.

Samples from the second set of brass rings were extracted in the laboratory and cut into five pieces of about similar volumes which were then saturated by allowing them to stand in water overnight. The moisture content of one of the five saturated samples was determined, whilst the remaining samples were placed on water saturated ceramic porous plates in four separate chambers. The air pressures in the pressure chambers were then adjusted to subject the samples to different pressures; the lower side of the porous plates being exposed to atmospheric pressure. The pressures were kept constant for one week until the overflow of excess water had stopped. After release of the pressures, the samples were removed and their moisture contents determined. The pressure plate tests were carried out at the Soils Laboratory of Universiti Pertanian Malaysia (now Universiti Putra Malaysia) where such tests were being routinely carried out for agricultural soil surveys.

RESULTS

Descriptions of saprock samples

Binocular microscope examinations show the gravel and sand sized fractions to consist almost entirely of quartz grains with a few altered (whitish) and fresh (cloudy) feldspar grains, whilst the silt sized particles consist entirely of sericite flakes. X-ray diffractograms of the clay fractions show kaolinite and illite to be the clay minerals present (Table 2).

Physical properties of saprock samples

As the samples were collected at different depths, there are some variations in physical properties (Table 3). Sample A from sub-zone IIA has a dry density of 1586 kg/m^3 and dry unit weight of 15.56 kN/m^3, whilst sample B from upper sub-zone IIB has corresponding values of 1364 kg/m^3 and 13.39 kN/m^3, respectively. Samples C, and D, from sub-zones IIB and IIC have dry densities of 1410, and 1399, kg/m^3, and dry unit weights of 13.83 and 13.72, kN/m^3, respectively.

The specific gravity of soil particles shows little variation, ranging from 2.59 to 2.61, though this is to be expected in view of the similarity in mineral compositions (Table 2). Values of porosity are somewhat variable; sample A with a porosity of 39% and the other samples with porosities of 46% and 48%. Void ratios are similarly variable with sample A having a value of 0.65, and the other samples with values of 0.85 and 0.91. Field moisture contents are variable; samples A and B with contents of 5.1%, and 4.0%, and samples C and D with contents of 3.8%, and 8.9%, respectively.

Table 2: Descriptions of saprock samples.

Sample	Sub-zone	Vertical Depth	Description
A	IIA	5.7 m	Red, friable, gravelly silty sand with yellow mottles; distinct relict rhyolite texture. Coarse fraction of quartz grains & sericite flakes with some altered feldspar fragments. Clay fraction of kaolinite & illite.
B	IIB	9.1 m	Red, friable, gravelly silty sand with distinct relict rhyolite texture. Coarse fraction of quartz grains & sericite flakes with some altered feldspar fragments. Clay fraction of kaolinite & illite.
C	IIB	12.7 m	Red, friable, gravelly silty sand with distinct relict rhyolite texture. Coarse fraction of quartz grains & sericite flakes with some unaltered feldspar fragments. Clay fraction of illite.
D	IIC	16.9 m	Red, friable, gravelly silty sand with distinct relict rhyolite texture. Coarse fraction of quartz grains & sericite flakes with some unaltered feldspar fragments. Clay fraction of illite.

Soil index properties of saprock samples

Differences in depth result in some variations in soil index properties; samples A, B and C with gravel contents of 6% to 7% and sample D with a gravel content of 17% (Table 4). Sand contents are more variable; A, B, C and D having contents of 48%, 57%, 56% and 45%, respectively. Total sand and gravel contents in samples A, B, C and D are thus 55%, 63%, 62%, and 62%, respectively (Table 4). Silt contents are surprisingly of little variation; samples A, C and D with 32%, and sample B with 30% (Table 4) Clay contents are more variable; samples A and B with 13%, and 7%, and samples C and D with 6%, respectively (Table 4).

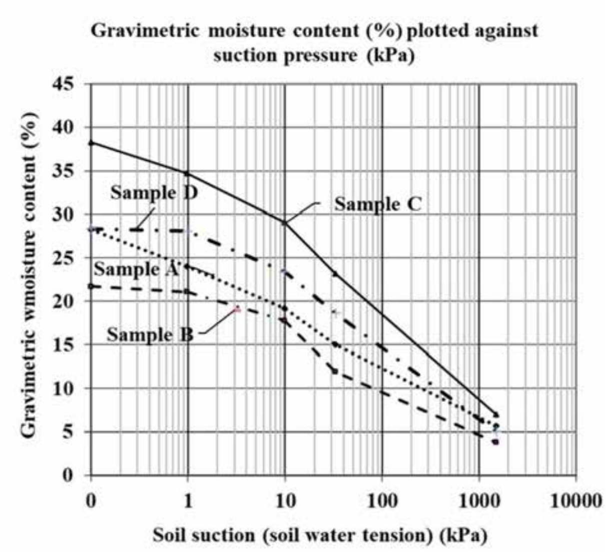

Figure 4: Gravimetric moisture retention curves of saprock samples.

Soil moisture retention under different suction pressures

The pressure plate tests show gravimetric moisture contents of the samples to decrease with increasing suctions (Figure 4). In samples A and B, gravimetric moisture contents decrease from 28.3% through 24.0% and 19.2% to 15.0% and 5.7%, and from 21.7% through 21.2% and 17.8% to 11.9% and 3.8%, respectively under increasing suctions from 0 kPa through 0.98 kPa and 9.8 kPa to 33 kPa and 1,500 kPa (Table 5). Exactly similar increasing suctions furthermore, result in decreasing gravimetric moisture from 38.3% through 34.7% and 29.1% and 23.2% and 7.0% in sample C, and from 28.4% through 28.1% and 23.4% to 18.6% and 5.0% in sample D (Table 5).

Storage and drainage pores in saprock samples

In agriculture, soil suction or soil moisture tension is considered to be the most important soil moisture characteristic for a growing plant and is usually defined in units of bars (where 1 bar = 100 kPa). A saturated soil has a soil moisture tension of about 0.1 kPa or less, whilst at field capacity, most soils have a soil moisture tension between 5 kPa and 33 kPa; field capacity defined as the level of soil moisture left in the soil after drainage of gravitational water which frequently takes a few days

Table 3: Physical properties of saprock samples.

Sample	Depth (m)	Dry Unit Weight (kN/m^3)	Dry Density (kg/m^3)	Mineral Grain SG	Porosity (%)	Void Ratio	Moisture Content (%)
A	5.7	15.56	1586	2.61	39	0.65	5.1
B	9.1	13.39	1364	2.60	48	0.91	4.0
C	12.7	13.83	1410	2.61	46	0.85	3.8
D	16.9	13.72	1399	2.59	46	0.85	8.9

Note: SG refers to specific gravity

Table 4: Soil index properties of saprock samples.

Sample	Depth (m)	Sub-zone	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Gravel & Sand (%)
A	5.7	IIA	7	48	32	13	55
B	9.1	IIB	6	57	30	7	63
C	12.7	IIB	6	56	32	6	62
D	16.9	IIC	17	45	32	6	62
Average	-	-	9	52	32	6	61

Table 5: Gravimetric moisture contents retained under different suction pressures.

Sample	Vertical Depth	Gravimetric Moisture Content (%)				
		0 kPa	0.98 kPa	9.8 kPa	33 kPa	1500 kPa
A	5.7 m	28.3	24.0	19.2	15.0	5.7
B	9.1 m	21.7	21.1	17.8	11.9	3.8
C	12.7 m	38.3	34.7	29.1	23.2	7.0
D	16.9 m	28.4	28.1	23.4	18.6	5.0
Average	-	29.2	27.0	22.4	17.2	5.4

Table 6: Different sized pores in saprock samples.

Sample	Vertical Depth	Quick Drainage Pores (%)	Slow Drainage Pores (%)	Total Drainage Pores (%)	Storage Pores (%)
A	5.7 m	9.1	4.2	13.3	9.3
B	9.1 m	3.9	5.9	9.8	8.1
C	12.7 m	9.2	6.0	15.2	16.2
D	16.9 m	5.0	4.8	9.8	13.6
Average	-	6.8	5.2	12.0	11.8

to drain through the soil profile. The wilting point, which is defined as the soil moisture content where most plants cannot exert enough force to remove water from small pores in the soils, is at about 1,500 kPa soil moisture tension for most agronomic crops. Water, held between field capacity and the wilting point is available for plant use, whilst capillary water held in the soil beyond the wilting point can only be removed by evaporation (Scherer *et al.*, 1996). In view of these relationships, results of soil water retention curves are often expressed in terms of 'quick' and 'slow' drainage pores as well as 'storage' pores; these values being determined from the following equations, i.e.

Quick drainage pores (%) =
moisture content (0.0 kPa) - moisture content (0.98 kPa)
Slow drainage pores (%) =
moisture content (9.8 kPa) - moisture content (33 kPa)
Storage pores (%) =
moisture content (33 kPa) - moisture content (1,500 kPa)

Percentages of quick and slow drainage pores in the samples are quite variable, though the total drainage pores of samples B and D are exactly similar with a value of 9.8%, and those of samples A, and C, some 13.3%, and 15.2%, respectively (Table 6). The total percentage of storage pores is more variable with samples A and B having values of 9.3%, and 8.1%, and samples C and D having values of 16.2% and 13.6%, respectively (Table 6).

DISCUSSION

Comparison with published data

In earlier publications, it has been emphasized that there are variations with depth in the textures and compositions of the earth materials of weathering profiles as well as differences in the extent of preservation of the original bedrock minerals and structures (Raj, 1985; Raj, 2018). Discussions on the physical and soil index properties of these earth materials as well as their soil moisture retention characteristics must therefore, be carried out with reference to the locations of samples. Results of the present study can therefore, only be compared with those involving saprock samples from the weathering profile over porphyritic biotite granite (Raj, 2010) and that over biotite-muscovite granite (Raj, 2021).

In the present study, gravimetric moisture contents of the saprock samples decrease on average from 29.2% through 27.0% and 22.4% to 17.2% and 5.4% with increasing suctions from 0 kPa through 0.98 kPa and 9.8 kPa to 33 kPa and 1,500 kPa (Table 5). These values are quite similar with those of saprock samples from the weathering profile over biotite-muscovite granite where increasing suctions from 0 kPa through 0.98 kPa and 9.8 kPa to 33 kPa and 1,500 kPa result in decreasing moisture contents on average from 31.9% through 27.9% and 24.0% to 19.4% and 7.9% (Raj, 2021). A similar pattern is shown by saprock samples from the weathering profile over porphyritic biotite granite where increasing suctions from 0 kPa through 0.98 kPa and 9.8 kPa to 33 kPa and 1,500 kPa result in decreasing moisture contents on average of 27.9% through 25.3% and 16.9% to 12.6% and 5.2% (Raj, 2010). Decreasing moisture contents with increasing suctions amongst the individual saprock samples from the different weathering profiles are, however, not exactly identical for there are differences in their textures and mineral compositions.

Quick and slow drainage pores in the present saprock samples are on average, 6.8%, and 5.2%, respectively, whilst the total drainage porosity is 12.0%, and total storage porosity 11.8% (Table 6). These values are very similar to those from the profile over biotite-muscovite granite where quick and slow drainage pores are on average some 7.8%, and 4.7%, respectively, and the total drainage porosity 12.5%, and the total storage porosity 11.5% (Raj, 2021). These results are also quite similar to those of saprock samples from the weathering profile over porphyritic biotite granite where quick and slow drainage pores were found on average to be 9.7%, and 4.1%, whilst the total drainage porosity was 13.8%, and the total storage porosity 11.0% (Raj, 2010). Volumes of drainage and storage pores in the individual samples from the different weathering profiles are, however, not exactly identical for there are differences in textures and mineral compositions.

Reason for retention of soil-moisture

The pressure plate tests show the soil moisture contents retained under different suctions to be variable with particle size distributions (Tables 4 and 5). Regression analyses of sand and gravel contents plotted against moisture contents retained at different suctions, however, yield extremely low correlation coefficients ($R^2<0.098$), whilst similar plots involving clay contents yield low correlation coefficients ($R^2<0.273$). Regression analyses of silt contents plotted against moisture contents retained at low suctions (0.98 and 9.8 kPa) furthermore, yield positive trends with moderate correlation coefficients ($R^2=0.441$ and $R^2=0.361$), whilst those involving large suctions (33 and 1500 kPa) yield positive trends with larger correlation coefficients ($R^2=0.525$ and $R^2=0.616$).

Adsorption of water onto the surfaces of silt particles thus appears to be most likely responsible for the retention of soil moisture in the saprock samples; the silt particles having relatively large specific areas. Van der Waal forces furthermore, have been considered to be primarily responsible for such particle surface hydration (Lu, 2016). A similar conclusion was reached in the earlier study involving saprock samples from the weathering profile over biotite-muscovite granite where regression analyses of silt contents plotted against moisture contents retained at large suctions (33 kPa and 1,500 kPa) yielded positive trends with very large correlation coefficients ($R^2>0.9966$) (Raj, 2021).

CONCLUSION

Three broad zones were differentiated at the weathering profile; an upper 3.9 m thick pedological soil (zone I), an intermediate 21.4 m thick saprock (zone II), and the underlying rhyolite (zone III). Laboratory determinations with the pressure plate method show increasing suctions from 0 kPa through 0.98 kPa and 9.8 kPa to 33 kPa and 1,500 kPa to result in gravimetric soil moisture retentions of 28.3% through 24.0% and 19.2% to 15.0% and 5.7% for sample A (collected at a depth of 5.7 m), and from 21.7% through 21.1% and 17.8% to 11.9% and 3.8% for sample B (collected at a depth of 9.1 m). Similarly increasing suctions yielded gravimetric moisture contents of 28.3% through 34.7% and 29.1% to 23.2% and 7.0% for sample C (collected at a depth of 12.7 m), and from 28.4% to 28.1% and 23.4% to 18.6% and 5.0% for sample D (collected at a depth of 16.9 m).

Regression analyses of silt fractions plotted against moisture contents retained at large suctions (33 and 1500 kPa) yield positive trends with moderate correlation coefficients ($R^2=0.525$ and $R^2=0.616$) indicating that adsorption of water on the surfaces of silt particles that results in the retention of soil moisture.

ACKNOWLEDGEMENTS

The study was supported by an F-Vote Research Grant from the University of Malaya. Grateful thanks are extended to the anonymous reviewers for their valuable comments.

CONFLICT OF INTEREST

The author has no conflicts of interest to declare that are relevant to the content of this article

REFERENCES

Agus, S.S., Leong, E.C. & Rahardjo, H., 2001. Soil-water characteristic curves of Singapore residual soils. Geotechnical & Geological Engineering, 19, 285-309.

ASTM, American Society for Testing Materials, 1970. Special procedures for testing soil and rock for engineering purposes. Special Publication 479. American Society for Testing Materials, Philadelphia. 630 p.

Azman, A.G. & Singh, N., 2005. Petrology and geochemistry of the Sempah Volcanic Complex. Bulletin of the Geological Society of Malaysia, 51, 103-121.

Bujang, B.K.H., Faisal Hj. Ali & Hashim, S., 2005a. Modified shear box test apparatus for measuring shear strength of unsaturated residual soil. American Journal of Applied Sciences, 2(9), 1283-1289.

Bujang, B.K.H., Faisal Hj. Ali & Affendi Abdullah, 2005b. Response of suction, moisture and temperature of unsaturated residual soil to rainfall. Electronic Journal of Geotechnical Engineering (EJGE), 10, D, Paper 2005-0545.

Chakraborty, K.R., 1995. Genting Sempah Volcanic Complex: Genetic implications for the Main Range Granite. Warta Geologi, 21, 216-217.

Cobbing, E.J. & Mallick, D.I.J., 1987. Southeast Asia Granite Project – Field Report for Peninsular Malaysia. Overseas Directorate, British Geological Survey, Report No. MP/87/19R. 29 p.

Faisal, H.A., Bujang, B.K.H. & Low, T.H., 2005. Infiltration characteristics of granitic residual soil of various weathering grades. American Journal of Environmental Sciences, 1(1), 64-68.

FAO, Food and Agricultural Organization, 2006. Guidelines for soil description, 4th edition. Food and Agriculture Organization of the United Nations, Rome. 109 p.

Haile, N.S., Stauffer, P.H., Krishnan, D., Lim, T.P. & Ong, G.B., 1977. Palaeozoic redbeds and radiolarian cherts: reinterpretation of their relationships in the Bentong and Raub areas, West Pahang, Peninsular Malaysia. Bulletin of the Geological Society of Malaysia, 8, 45-60.

Hamdan, J., Ching, L.B. & Ruhana, B., 2006. Saturated hydraulic conductivity of some saprolites from Peninsular Malaysia. Malaysian Journal of Soil Science, 10, 13-24.

JKR, Public Works Department of Malaysia, 2007. Guidelines for hard material/rock excavation. Technical Note (Roads) 24/05. Road Division, Jabatan Kerja Raya Malaysia, Kuala Lumpur. 15 p.

Leamy M.L. & Panton, W.P., 1966. Soil survey manual for Malayan conditions. Division of Agriculture, Malaysia. 22 p.

Liew, T.C., 1977. Petrology and structural relationships of rhyolitic rocks and micro-granodiorite, east of Genting Sempah, Pahang. B.Sc. (Hons) Thesis, Department of Geology, University of Malaya, Kuala Lumpur. 80 p.

Liew, T.C. & Page, R.W., 1985. U-Pb zircon dating of granitoid plutons from the West Coast Province of Peninsular Malaysia. Journal Geological Society, 142, 525-626.

Lu, N., 2016. Generalized soil water retention equation for adsorption and capillarity. Journal of Geotechnical & Geoenvironmental Engineering, 142, 10, 1-15.

Lumb, P., 1975. Slope failures in Hong Kong. Quarterly Journal Engineering Geology, 8, 31-36.

Poppe, L.J., Paskevich, V.F., Hathaway, J.C. & Blackwood, B.S., 2001. A laboratory manual for X-ray powder diffraction. United States Geological Survey Open-File Report 01-041, 88 p.

Raj, J.K., 1983. A study of residual soils and their cut slope stability in selected areas of Peninsular Malaysia. Ph.D. Thesis, Faculty of Science, University of Malaya, Kuala Lumpur. 462 p.

Raj, J.K., 1985. Characterization of the weathering profile developed over a porphyritic biotite granite bedrock in Peninsular Malaysia. Bulletin International Association of Engineering Geology, 32, 121-128.

Raj, J.K., 2000. Rainfall and slope failures in the granitic bedrock areas of Peninsular Malaysia. Proceedings Annual Conference 2000, Penang, Geological Society of Malaysia, 275-282.

Raj, J.K., 2009. Geomorphology. In: Hutchison, C.S. & Tan, D.N.K. (Eds.), Geology of Peninsular Malaysia. University of Malaya and Geological Society of Malaysia, Kuala Lumpur, 5-19.

Raj, J.K., 2010. Soil moisture retention characteristics of earth materials in the weathering profile over a porphyritic biotite granite in Peninsular Malaysia. American Journal of Geosciences, 1(1), 12-20.

Raj, J.K., 2018. Physical characterization of a deep weathering profile over rhyolite in humid tropical Peninsular Malaysia. Geotechnical & Geological Engineering, 36(6), 3793-3809.

Raj, J.K., 2021. Soil moisture retention characteristics of saprock from the weathering profile over a biotite-muscovite granite in Peninsular Malaysia. Warta Geologi, 47(3), 217-225.

Scherer, T.F., B. Seelig & Franzen, D., 1996. Soil, water and plant characteristics important to irrigation. EB-66, www.ag.ndsu.edu/pubs/ageng/ irrigate/eb66w.htm.

Singh, N. & Azman, A.G., 2000. Sempah volcanic complex, Pahang. In: Teh, G.H., Pereira, J.J. & Ng, T.F. (Eds.), Proceedings Annual Conference 2000, Penang, Geological Society of Malaysia, 67-72.

Thamer, A.M., Faisal Hj. Ali, S. Hashim & Bujang, B.K.H., 2006. Relationship between shear strength and soil water characteristic curve of an unsaturated granitic residual soil. American Journal of Environmental Sciences, 2(4), 142-145.

Thorez, J., 1975. Phyllosilicates and clay minerals – A laboratory handbook for their X-ray diffraction analysis. G. Lelotte, Belgium. 582 p.

USBR, United States Bureau of Reclamation, 1974. Earth Manual. United States Government Printing Office, Washington, 810 p.

Vanapalli, S.K., Fredlund, D.G., Pufahi, D.E. & Clifton, A.W., 1996. Model for the prediction of shear strength with respect to soil suction. Canadian Geotechnical Journal, 33, 379-392.

Wentworth, C.K., 1922. A scale for grade and class terms for clastic sediments. Journal of Geology, 30, 377-392.

Manuscript received 17 March 2023;
Received in revised form 20 May 2023;
Accepted 20 May 2023
Available online 30 August 2023