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PHYSICO-CHEMICAL PROPERTIES OF RESIDUAL SOILS OF THE KENNY HILL FORMATION IN THE SHAH ALAM AREA, SELANGOR

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Abstract: Residual soils of the Kenny Hill formation in the Shah Alam area, Negeri Selangor, have been analysed for their physico-chemical properties. Since the Kenny Hill formation comprises two distinct lithologies, namely phyllite and quartzite, the residual soils derived need to be differentiated accordingly. Test results indicate that the residual soils of phyllite (as compared to quartzite) are characterised by their more clayey nature, higher plasticities and lower compacted densities. In terms of pore fluids chemistry, both types of soils show similar results, namely: slightly acidic pore fluids, low cations and anions contents, and non-dispersive nature.

INTRODUCTION

The Kenny Hill formation is a major geologic unit in the Kuala Lumpur area and its vicinity. It is encountered in many civil engineering and construction works in the area. Both weathered rocks and residual soils of the Kenny Hill formation feature prominently in numerous earthworks, foundations, cut-slopes, etc. in the Klang valley and adjacent areas. As part of a systematic programme of study on the various types of tropical residual soils in Peninsular Malaysia, a study on the physico-chemical and mineralogical properties of the residual soils of the Kenny Hill formation in the Shah Alam area was completed recently, Siti Farah (2005). This paper presents the results of this recent study. Previous publications on the physico-chemical properties of various residual soils include, among others, Tan (1994, 1996, 2000, 2004), Tan & Tai (1999), Tan & Zulhaimi (2000), Tan & Azwari (2001), Tan & Yew (2002)., Tan & Eng (2004). This present paper continues the effort in publishing data on the physico-chemical properties of various types of tropical residual soils in Peninsular Malaysia.

MATERIALS AND METHODS

A total of 14 soil samples (Py1-Py5 and Q1-Q9) were taken from cut slopes in residual soils of the Kenny Hill formation in the Shah Alam area and its vicinity. The cut slopes sampled were mainly along main roads in the vicinity of Shah Alam, as well as in new housing development schemes in the area. The Kenny Hill formation and its residual soils are easily recognised by their bedded or stratified nature. Since the Kenny Hill formation comprises phyllite and quartzite, the residual soils collected are differentiated as such (Py for phyllite soils, and Q for quartzite soils).

As most samples were taken from shallow depths from the ground surface, they are generally of weathering grade VI (Residual Soils), Little (1969). A few deeper samples may represent weathering grade V (Completely Weathered) materials. For simplicity of discussions, however, the materials are not differentiated in terms of weathering grades in this paper. For the interested reader, further details including sampling and sample locations can be referred to in the thesis quoted above, Siti Farah (2005).

The physical properties tested are: natural water content, specific gravity (relative density), grain size distribution, Atterberg limits and compaction characteristics. The chemical properties studied involve the pore fluids chemistry, namely pH, conductivity, pore fluid soluble cation and anion contents.

The test methods adopted are in accordance with the British Standards BS1377 (1975) and the Geotechnical Research Centre (GRC) Laboratory Manual (1985), McGill University, Montreal, Canada. Pore fluids of the soil samples were extracted using the "Saturation Extract" method involving vacuum suction, GRC Manual (1985).

As the method of preparation of the soil samples prior to testing has an effect on the index properties and compaction characteristics of lateritic or tropical residual soils, eg. Moh & Mazhar (1969), Brand & Hongsnoi (1969), all samples were tested after air-drying in the laboratory.

RESULTS AND DISCUSSIONS

The results for the physico-chemical properties of the residual soils of the Kenny Hill formation are summarised in Table 1 and 2. Figures 1-4 provide some illustrations of some of the physico-chemical properties. Some discussions of the physico-chemical properties are provided below.

Physical Properties

Water Content, Wo - Natural water contents are generally higher for the phyllite soils, ranging from 26-35 %. For the quartzite soils, the water contents range from 10-26%. The higher water content in the phyllite soils is related to the significantly higher clay contents of the soils, thus high adsorption or retention of soil moisture.

Specific Gravity (Relative Density), Gs - Test results of the specific gravity or relative density of the soil solids, Gs, show values which are higher for the quartzite soils, ranging from 2.50-2.69. The phyllite soils have lower G_s values of 2.40-2.52, reflecting differences in soil mineralogy.

Grain Size Distribution - Comparing the residual soils derived from phyllite and those developed from quartzite, the effect of different source rock is obvious. The residual soils developed from the finer-grained phyllite that contains relatively unstable minerals that readily weather into clay minerals and clay-size particles are thus more clayey in nature. Hence, the particle size distributions for the phyllite soils are dominated by fine-grained components with clay slightly predominating over silt-size particles in general, Fig. 1. Clay contents range from 41 – 60 %, while silt contents range from 20 – 45 %. The sand fractions are generally low, i.e., generally < 30 %, with the exception of Py2, which shows higher sand content of 39 %.

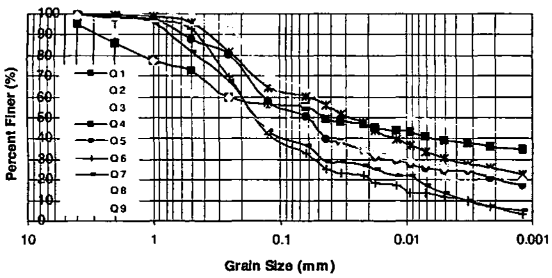

Fig. 1 b. Grain size distribution curves of quarzite soils

On the other hand, the quartzite residual soils show higher sand contents ranging from 37-67%, and lower clay contents of 6-43 %, mostly < 20 %. These differences in grain size distributions are clearly shown in the grain size curves of Fig. 1.

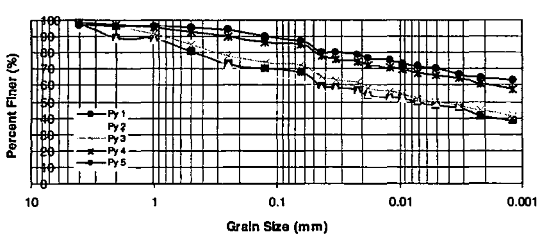

Fig.1a. Grain size distribution curves of phyllite soils

Atterberg Limits: Liquid Limit (LL) & Plastic Limit (PL) - Being predominantly clayey soils, the plasticities are higher for the phyllite soils. Liquid limits for the phyllite soils range from 42 - 73 %, while that for the quartzite soils range from 24-72%. Plasticity Index (PI) values show a higher range for the phyllite soils from 12 –17 % compared to 5- 16 % mostly for the quartzite soils. Fig. 2 shows the differences in plasticities of the two types of residual soils. Note also that the natural water contents mostly fall below the PL and LL values, as is generally the case for residual soils.

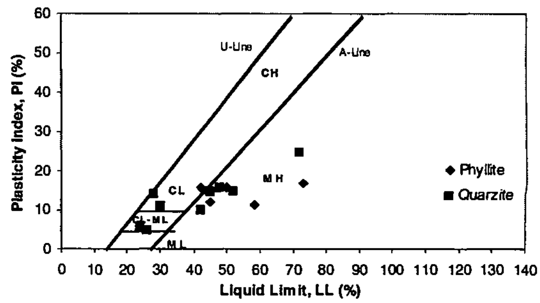

Fig. 2. Plasticity chart, phyllite & quarzite soils

Compaction Characteristics - Fine-grained soils dominated by clays in general will yield low compacted densities. The values for the compacted maximum dry densities for the phyllite soils show a lower range of values from ~1.6 g/cm^3 to ~ 1.7 g/cm^3 (mostly ~ 1.6 g/cm^3). The quartzite soils, on the other hand, show higher compacted maximum dry densities of ~ 1.7-1.9 g/cm^3. The higher values for the quartzite soils, i.e. > 1.6 g/cm^3, are attributed to the higher coarse fractions (higher sand contents) in the residual soils of the quartzite. For the phyllite soils, optimum moisture contents show relatively higher values corresponding to the lower dry densities, with W_{opt} ranging from 17 – 22 %. Fig. 3 shows the compaction curves of the soil samples tested.

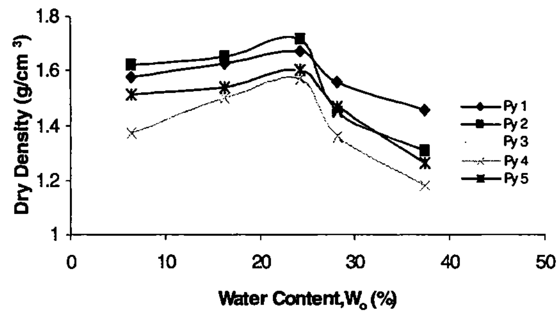

Fig. 3a. Compaction curves, phyllite soils

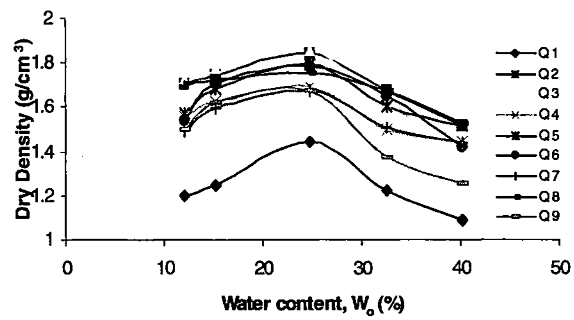

Fig. 3b. Compaction curves, quarzite soils

Pore Fluids Chemistry

pH - pH is a measure of the acidity of the pore fluids. The residual soils tested are characterised by slightly acidic pore fluids, with pH values of quartzite soils (5.08-6.00) being slightly lower than the phyllite soils (5.98-6.47).

Sample	Water Content, W_o (%)	Specific Gravity, Gs	Liquid Limit, LL (%)	Plastic Limit, PL (%)	Plasticity Index, IP (%)	Symbols	Sand (%)	Silt (%)	Clay (%)	W_{opt} (%)	γd_{maks} (g/cm^3)
Py 1	35.49	2.47	73	56	17	MH	31	28	41	17	1.67
Py 2	31.63	2.52	45	33	12	ML	39	20	41	19	1.63
Py 3	29.92	2.42	59	47	12	MH	29	27	44	22	1.72
Py 4	27.30	2.40	50	34	16	MH	16	24	60	20	1.57
Py 5	26.48	2.41	42	26	16	CL	12	45	42	21	1.61
Q 1	26.01	2.56	72	47	25	MH	44	20	36	25	1.44
Q 2	21.77	2.50	30	19	11	CL	37	20	43	14	1.84
Q 3	20.76	2.61	24	18	6	CL-ML	52	32	16	13	1.86
Q 4	17.26	2.60	45	30	15	CL	48	36	16	20	1.69
Q 5	16.26	2.71	48	32	16	ML	67	27	6	26	1.79
Q 6	13.66	2.69	42	32	10	ML	66	28	6	18	1.78
Q 7	12.91	2.52	26	21	5	CL-ML	39	37	24	15	1.67
Q 8	11.36	2.56	28	15	14	CL	43	39	18	14	1.75
Q 9	10.34	2.63	52	37	15	MH	57	20	23	26	1.67

TABLE 1: Physical properties of phyllite & quartzite soils

Sample	Saturation (%)		pH	Conductivity (mS/cm)	Na^+		K^+		Ca^{2+}		Mg^{2+}		SO_4^{2-} ppm	Cl^- ppm	SAR	Cation mono/dwi valen
ppm		meq/l			ppm	meq/l										
Py 1		75.41	6.28	0.09	7.50	0.33	1.50	0.04	5.17	0.26	0.26	0.02	0.40	5.00	2.36	1.66
Py 2		86.17	6.01	0.10	5.50	0.24	4.00	0.10	4.57	0.23	0.52	0.04	0.40	3.25	1.78	1.87
Py 3		73.31	6.29	0.08	5.25	0.23	4.25	0.11	2.90	0.14	0.15	0.01	0.40	3.00	2.88	3.11
Py 4		92.77	5.98	0.11	6.25	0.27	4.25	0.11	3.32	0.17	0.20	0.02	1.00	2.00	2.84	2.98
Py 5		71.94	6.47	0.07	5.50	0.33	2.50	0.06	2.43	0.12	0.14	0.01	0.65	2.50	3.69	3.11
Q 1		56.49	5.26	0.16	4.50	0.19	1.00	0.03	2.68	0.13	0.25	0.02	5.00	3.25	2.67	1.88
Q 2		34.25	5.76	0.12	5.25	0.23	2.00	0.05	2.42	0.12	0.26	0.02	2.15	3.75	3.29	2.71
Q 3		31.07	5.75	0.12	7.50	0.33	3.00	0.08	3.11	0.16	0.35	0.03	2.04	3.75	3.47	3.03
Q 4		60.79	5.33	0.14	4.50	0.19	1.50	0.04	3.47	0.17	0.51	0.04	0.62	3.00	1.90	1.51
Q 5		58.49	5.84	0.14	5.50	0.24	3.75	0.10	9.14	0.46	1.63	0.13	1.24	5.00	0.81	0.86
Q 6		71.94	5.08	0.19	5.50	0.24	3.25	0.08	7.02	0.35	1.06	0.09	5.25	5.25	1.09	1.08
Q 7		61.68	5.53	0.13	3.25	0.14	0.75	0.02	2.53	0.13	0.28	0.02	1.52	2.50	1.87	1.42
Q 8		39.31	6.00	0.10	5.50	0.24	3.75	0.10	4.31	0.22	0.55	0.05	0.30	4.50	1.78	1.90
Q 9		69.73	5.84	0.10	3.00	0.13	2.25	0.06	2.69	0.13	0.31	0.03	3.25	3.25	1.63	1.75

TABLE 2: Pore fluids chemistry of phyllite & quartzite soils

Conductivity - Conductivity is a measure of the total cations content in the pore fluids. The values obtained for both types of soils are similar, namely ranging from 0.07-0.11 mS/cm for phyllite soils, and 0.10-0.19 mS/cm for the quartzite soils. These low values reflect low dissolved cations contents in the pore fluids. As is the general case with residual soils on cut slopes that are subject to continuous leaching by percolating water, the total cations content (hence conductivity) is low.

Soluble Cations (Na^+, K^+, Mg^{2+}, Ca^{2+}) – The cations contents of both types of soils tested are low in general (mostly < 10 ppm). The soluble cations are dominated by Na^+, with the general order of abundance as follows: $Na^+ > Ca^{2+} > K^+ > Mg^{2+}$. Since $Ca^{2+} > K^+$ in most of the samples, there is thus no predominance of monovalent cations over divalent cations. Predominance of monovalent cations, in particular Na^+, can contribute to the dispersivity of the soil. The values for the sodium adsorption ratio (SAR) show values of < 2 or slightly above 2, i.e. indicating mostly non-dispersive soils. Fig. 4 shows the Sherard's plot for dispersivity of soils, Sherard et al. (1976), and the data again indicate the non-dispersive nature of the soils. However, the authors would like to caution that these conclusions are based solely on pore fluids chemistry alone. Further supporting tests, such as the pin-hole test, etc. may be necessary.

Soluble Anions (SO_4^{2-}, Cl^-) - The anions contents of both types of soils tested are low (< 5 ppm), again indicating intense leaching of residual soils in cut slopes.

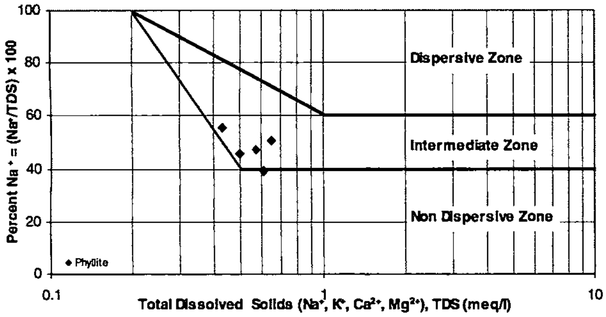

Fig. 4a. Dispersivity plot (Sherard *et al*., 1976)

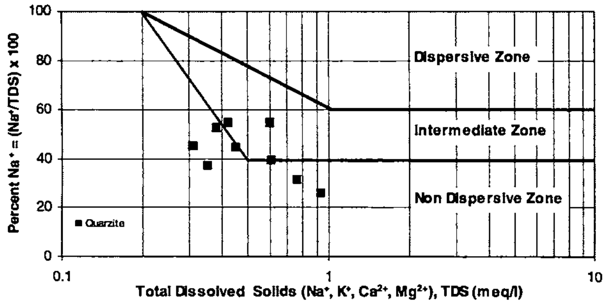

Fig. 4b. Dispersive plot (Sherard *et al*., 1976)

CONCLUSIONS

A detailed study on the physico-chemical properties of a soil is essential in understanding the behaviour of the soil. The residual soils of the Kenny Hill formation show clearly the effect of different parent rock (phyllite versus quartzite) on the properties of the residual soils developed. The phyllite soils, when compared to the quartzite soils, are characterised by their more clayey nature, higher plasticities, and lower compacted densities. In terms of pore fluids chemistry, however, they are similar, namely: slightly acidic pore fluids, low cations and anions contents, and non-dispersive nature. The physico-chemical properties, coupled with the clay mineralogy, would dictate the behaviour of the soil and hence its contribution to stability or problems in engineering works.

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