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Physico-Chemical Properties of Graphitic Schist Soils in the Rawang Area, Selangor

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Abstract

Graphitic schist soils in the Rawang area have been analysed for their physico-chemical properties. Results indicate that the graphitic schist soils are characterised by their silty nature, low plasticities, generally low compacted densities, highly acidic pore fluids (low pH's), and dispersive behaviour. These results support the previous findings on graphitic schist soils conducted in other areas such as the Melaka and South Johore areas.

Sifat Fiziko-Kimia Tanah Syis Grafit di Kawasan Rawang, Selangor

Abstrak

Analisis sifat fiziko-kimia tanah syis grafit kawasan Rawang telah dilakukan dan hasilnya menunjukkan tanah ini berlodak dengan keplastikan dan ketumpatan mampatan yang rendah, cecair ruang berasid yang tinggi (pH rendah), serta bersifat menyebar. Hasil ini menyokong jumpaan awal tanah syis grafit yang telah dilakukan di kawasan Melaka dan Selatan Johor.

INTRODUCTION

Graphitic schist soils are rather interesting materials not only for academic pursuits, but they are also notorious as they form problematic soils in numerous civil or geotechnical works. Cut slopes in graphitic schist soils associated with highways, urban development schemes, and other projects as well as fill-ground employing graphitic schist soils have caused problems such as slope failures and ground settlement. Some actual case studies of these problems and related studies on graphitic schist soils include Tan (1992), Tan and Tai (1999) and Tai (1999).

As part of a systematic programme of study on the graphitic schist soils in Peninsular Malaysia, a study on the physico-chemical and mineralogical properties of the graphitic schist soils in the Rawang area was completed recently (Zulhaimi Abdul Rahman, 2000). This paper presents a summary of the results of this recent study.

MATERIALS AND METHODS

Soil samples were taken from cut slopes in graphitic schist soils in the Rawang area and vicinities. The cut slopes sampled were mainly along parts of the North-South Expressway in the vicinity of Rawang and Bt. Beruntung, as well as in housing development schemes in these areas. As a matter of practical interest, one of the major slope failures involving graphitic schist soils occurred along the Rawang stretch of the North-South Expressway, and it continues to "bug" the highway/geotechnical engineer till today!

As most samples were taken from shallow depths from the ground surface, they are generally of weathering grade VI (residual soils) (Little, 1967). A few deeper samples may represent weathering grade V (completely weathered) materials. For simplicity of discussion, however, the materials are not differentiated in terms of weathering grades in this paper. For the interested reader, further reference can be made in the thesis quoted above (Zulhaimi Abdul Rahman, 2000).

The physical properties tested are: natural water content, specific gravity (relative density), Atterberg limits, grain size distribution, and compaction characteristics. The chemical properties studied involve pore fluid 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 (Moh and Mazhar, 1969; Brand and Hongsnoi, 1969), all samples were tested after air-drying in the laboratory.

RESULTS AND DISCUSSION

The physico-chemical properties of the graphitic schist soils are summarised in Table 1. Figures 1 to 4 provide some illustrations of some of the physico-chemical properties.

Physical Properties

Water Content, Wo - Natural water contents are generally low, ranging from 9 - 24 %. The low water content is related to the low clay content of the soils, thus resulting in low adsorption or retention of soil moisture.

SpecificGravity (Relative Density), Gs - Gs values are mostly centred around 2.6, with minor variations.

Atterberg Limits, LL and PL - Being predominantly silty soils, the plasticities are low. Liquid limits range from 28 - 51 %, with all values but one below 50 %. PI values are also low, mostly < 10 %. Figure 1 shows the data plotted as mostly ML soils, i.e. silts with low plasticities. Note also that the natural water contents fall below the PL and LL values, as is generally the case for residual soils. The low plasticities are in part due to the predominantly kaolinitic nature of the clay minerals in the soils, as confirmed from XRD analyses.

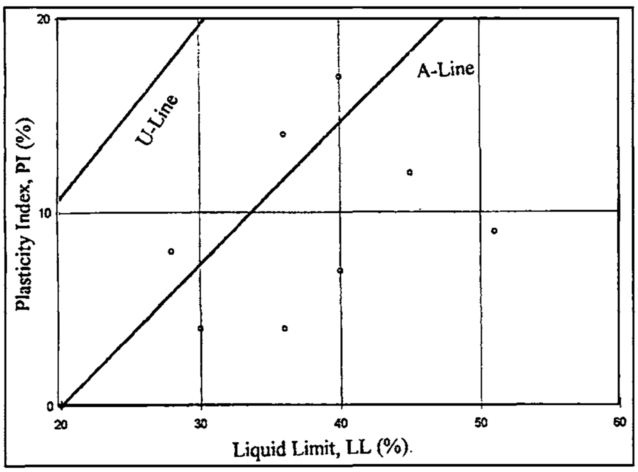

Figure 1: Plasticity chart.

Grain Size Distribution - Since the residual soils are developed from fine-grained rocks (schists), the particle size distributions are dominated by fine-grained components with silt predominating over clay-size particles. However, the presence of vein quartz and lateritic bands in the parent rock has contributed to significantly high amounts of sand- and gravel-sized particles in the graphitic schist soils. Nonetheless, in truly graphitic schist soils, silt predominates. The results show silt ranging from 22 up to 70 %. In the previous study on graphitic schist soils in the Melaka area, the silt content achieved a high value of ~ 98 % (Tan and Tai, 1999). Figure 2 shows some grain size distribution curves for the graphitic soils studied, indicating high fines contents as mentioned.

Compaction Characteristics - Silty soils in general cannot be compacted properly and will yield low compacted densities. The values for the compacted maximum dry densities range from a low of 1.34 g/cm^3 to a high of 1.86 g/cm^3. Most values, however, are low, i.e. < 1.8 g/cm^3, as would be expected from the silty nature of the graphitic schist soils. The higher values are attributed to the higher sand- and/or gravel-size components in some of the soil samples. It is interesting to note that the low compacted density of 1.34 g/cm^3 corresponds to the maximum value for optimum moisture content of 28.6 % in the data obtained.

The rather high carbon contents of the graphitic schist soils is another factor contributing to the low compacted densities of graphitic schist soils. Yet another factor is the micaceous nature of the graphitic schist soils which also hinders compaction efforts. Thus, graphitic schist soils are poor candidates for use in fill embankments, and in fact have given rise to problems in highway embankments (Tan, 1992).

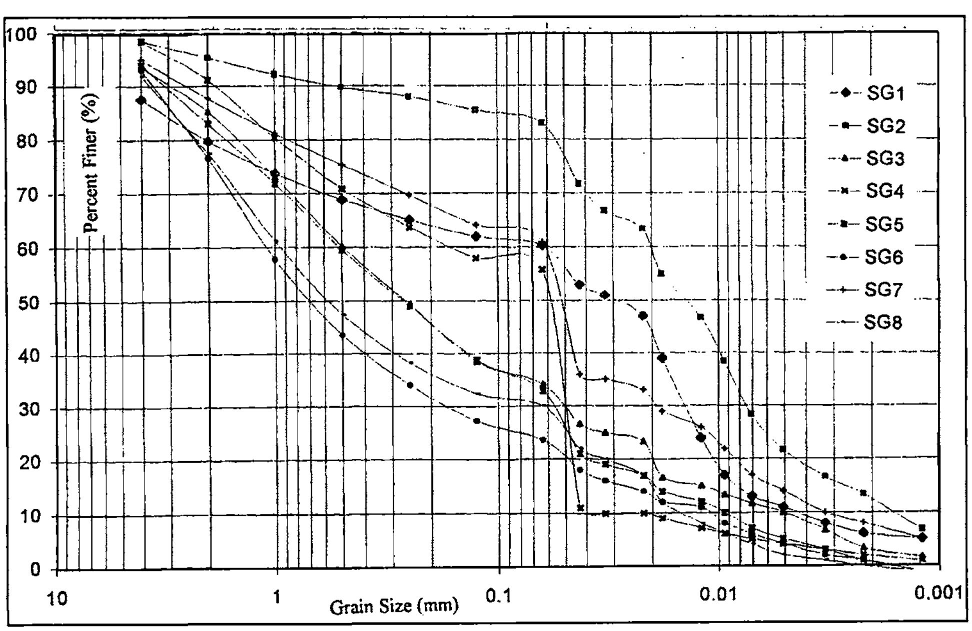

Figure 2: Grain size distribution curves.

Pore Fluid Chemistry

pH - pH is a measure of the acidity of the pore fluid. The graphitic schist soils are characterised by highly acidic pore fluids, with pH values ranging from 1.22 - 4.21, with the majority of values being < 2. The cause of the high acidity of the graphitic schist soils is now well known, even to the highway or geotechnical engineers. Graphitic schists contain a high amount of pyrite, which on exposure to the elements undergoes oxidation and hydrolysis reactions producing sulphuric acid and iron oxides/hydroxides. Typical chemical reactions are as follows:

$$2FeS_2 + 2H_2O + 7O_2 = 2FeSO_4 + 2H_2SO_4$$

$$4FeSO_4 + O_2 + 3H_2SO_4 = 2Fe_2(SO_4)_3 + 2H_2O$$

$$Fe_2(SO_4)_3 + 6H_2O = 2Fe(OH)_3 + 3H_2SO_4$$

The practical implications of these chemical reactions are: failures in turfing of cut slopes due to highly acidic soils, ugly staining (brown/red) of concrete pavements and drains due to the iron oxides/hydroxides released from the reactions, disintegration of the soil structure (hence severe drop in soil shear strength) due to the reactions and further formations of other secondary minerals. Corrosion of steel reinforcements in concrete structures located in close proximity to the graphitic schist soils is also possible. Thus, the acidity of the graphitic schist soils affect engineering works in a direct manner, in particular the stability of the cut slopes.

Figure 3 shows the very low (mostly <2) pH values of graphitic schist soils in comparison to some other soil types in the Rawang area.

Conductivity - Conductivity is a measure of the total cations content in the pore fluid. The values obtained range from 0.35 to 13.98 mS/cm. In comparison to other soil types studied such as granitic, quartz-mica schist, basaltic soils (Tan, 1996), these conductivity values are very much higher. The highest value of 13.98 mS/cm corresponds to the lowest pH value of 1.22, while the lowest value of 0.35 mS/cm corresponds to the highest pH value of 4.21. This indicates, as to be expected, that the more aggressive the soil (lower pH), the greater the amount of cations that is

Table 1: Physico-chemical properties of graphitic schist soils (SG).

	Wo	Gs	Atterberg Limits			Grain Size Distribution(%)				γ_{dmax}	Wopt
			LL (%)	PL (%)	PI	G	S	M	C	(g/cm³)	(%)
SG1	18.05	2.61	51	42	9	12.44	27.29	54.27	6	1.73	15.5
SG2	24.21	2.64	30	26	4	1.5	15.52	69.65	13.33	1.57	21.6
SG3	11.64	2.61	40	33	7	6.45	59.45	30.77	3.33	1.81	12.4
SG4	11.82	2.61	36	32	4	1.58	42.62	53.8	2	1.86	13.7
SG5	18.61	2.62	45	33	12	6.01	61.1	31.89	1	1.6	21.4
SG6	9.22	2.56	28	20	8	6.93	69.45	22.62	1	1.75	16.3
SG7	21.84	2.68	40	23	17	5.06	34.08	52.86	8	1.34	28.6
SG8	13.35	2.43	36	22	14	8.01	62	29.99	0	1.69	15.5

	Na+		K+		Mg2+		Ca2+		SO4		Cl-		pH	konduktiviti	monovalen/	SAR
	(ppm)	meq/l	(ppm)	meq/l	(ppm)	meq/l	(ppm)	meq/l	(ppm)	meq/l	(ppm)	meq/l		mS/cm	dwivalen	
SG1	24.24	1.04	9.8	0.25	0.95	0.08	0.6	0.03	17.5	0.37	39	1.10	4.21	0.35	21.96	4.47
SG2	33.84	1.46	5.66	0.15	0.65	0.05	0.95	0.05	367.5	7.72	24	0.68	1.65	4.54	24.69	6.46
SG3	26.32	1.13	2.88	0.07	2.3	0.19	4	0.20	1980	41.58	34	0.96	1.61	7.2	4.63	2.56
SG4	16.16	0.69	1.35	0.04	3.6	0.30	4.33	0.22	770	16.17	19.5	0.55	1.81	4.5	2.21	1.37
SG5	44.95	1.93	17.12	0.45	0.87	0.07	0.45	0.02	122.5	2.57	58.5	1.65	3.38	0.63	47.02	8.88
SG6	57.87	2.49	16.4	0.43	1.23	0.10	2.57	0.13	1830	38.43	38.5	1.09	1.22	13.98	19.54	7.33
SG7	20.71	0.89	1.54	0.04	2.31	0.19	4.59	0.23	735	15.44	35	0.99	1.67	4.78	3.22	1.94

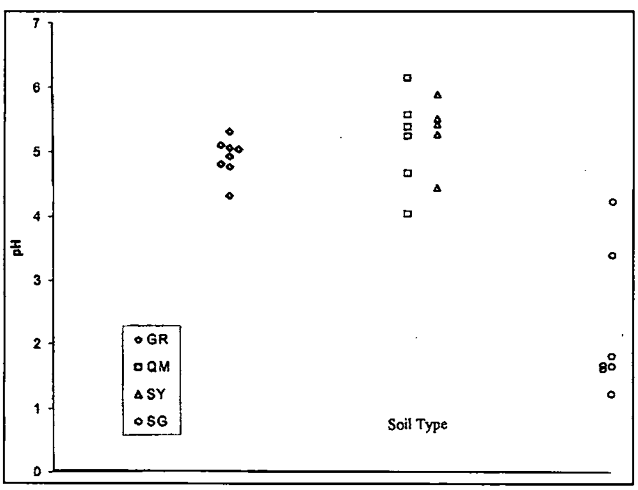

Figure 3: pH, in comparison to other soil types. GR=granitic soils, QM=quartz-mica schist soils, and SY=residual soils of shale.

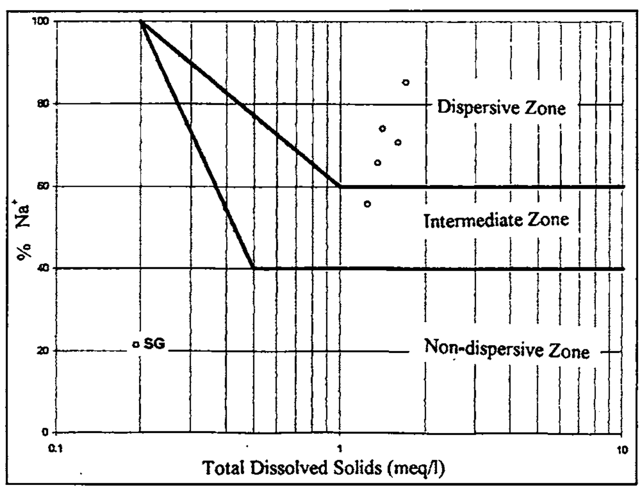

Figure 4: Dispersivity plot, Sherard *et al.* (1976).

leached from the soil. The higher H^+ content of the acidic soils would, of course, also contribute to the higher conductivity values.

Soluble Cations (Na^+, K^+, Mg^{2+}, Ca^{2+}) - The soluble cations are dominated by Na^+, with the general order of abundance as follows: $Na^+ >> K^+ > Ca^{2+} > Mg^{2+}$. The predominance of the monovalent cations ($Na^+ + K^+$) over the divalent cations ($Ca^{2+} + Mg^{2+}$) is also shown by the values for the monovalent/divalent ratios which range from ~2-47. Predominance of monovalent cations, in particular Na^+, can contribute to the dispersivity of the soil. In addition, the values for the sodium adsorption ratio (SAR), also show mostly >2 (range from 1.37-8.88), also indicating the dispersive nature of the graphitic schist soils. Figure 4 shows the Sherard's plot for dispersivity of soils (Sherard *et al.*, 1976), and the data indicate yet again the dispersive nature of the graphitic schist soils. However, the authors would like to caution that these conclusions are based solely on the pore fluid chemistry alone. Further supporting tests, such as the pin-hole test may be necessary.

Soluble Anions (SO_4^{2-}, Cl^-) - The anions are dominated by the SO_4^{2-} as expected, with values reaching as high as ~ 2000 ppm. The SO_4^{2-} is a direct product of the oxidation and hydrolysis process of pyrite. Thus a direct correlation between the anion content and the pH of the soil is observed. High SO_4^{2-} corresponds to low pH and vice versa. Cl^- contents are comparatively low, ranging from ~20-60 ppm.

CONCLUSIONS

A detailed study on the physico-chemical properties of soil is essential in understanding the behaviour of soil. The graphitic schist soils are characterised by their silty nature, low plasticities, low compacted densities as well as highly acidic/low pH and 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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