

## Physico-chemical properties of serpentinite soils in the Kuala Pilah area, Negeri Sembilan

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**Abstract:** Residual soils of serpentinite in the Kuala Pilah area, Negeri Sembilan, have been analysed for their physico-chemical properties. Results indicate that the serpentinite soils are characterised by their predominantly clayey nature, high plasticities, generally low compacted densities, slightly acidic pore fluids, and non-dispersive nature.

**Abstrak:** Tanah baki serpentinit di kawasan Kuala Pilah, Negeri Sembilan, telah diuji sifat fiziko-kimianya. Hasil kajian menunjukkan bahawa tanah baki serpentinit dicirikan oleh sifat berlempung, keplastikan tinggi, ketumpatan pemadatan rendah, air liang sedikit berasid dan sifat tidak dispersif.

### INTRODUCTION

Residual soils of serpentinite origin occur as limited, isolated patches in the Kuala Pilah area, Negeri Sembilan. 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 serpentinite soils in the Kuala Pilah area was completed recently (Eng, 2002). This paper presents a summary of the results of this study. Previous publications on the physico-chemical properties of residual soils include, among others, Tan (1994, 1996, 2000), Tan and Tai (1999), Tan and Zulhaimi (2000), Tan and Azwari (2001), and Tan and Yew (2002). The 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 12 soil samples (SP1-SP12) were taken from cut slopes in serpentinite soils in the Kuala Pilah area and its vicinity. The cut slopes sampled were mainly along parts of the trunk roads in the vicinity of Kuala Pilah, as well as in housing development schemes in the area. The serpentinite soils are easily recognized by their dark red to brown colours.

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 reference can be made in the thesis quoted above (Eng, 2002).

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 (BSI, 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 (e.g. Moh and Mazhar, 1969; Brand and Hongsnoi, 1969), all samples were tested after air-drying in the laboratory.

### RESULTS AND DISCUSSIONS

The results for the physico-chemical properties of the serpentinite soils are summarised in Tables 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.

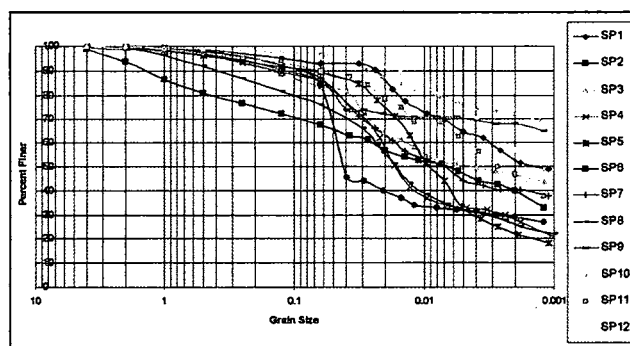


Figure 1. Grain size distribution curves of serpentinite soils.

**Table 1.** Physical properties of serpentinite soils.

No.	Wo (%)	Gs	Grain Size				Atterberg Limits			Compaction	
			G (%)	S (%)	M (%)	C (%)	LL (%)	PL (%)	Ip (%)	Wopt (%)	D <sub>dmax</sub> (g/cm <sup>3</sup> )
SP1	53.3	3.14	0	1	46	53	94.5	58.6	35.9	41.0	1.27
SP2	26.2	2.79	6	26	30	38	58.0	45.7	12.3	22.0	1.57
SP3	69.0	2.94	0	2	52	46	87.5	70.0	17.5	39.0	1.27
SP4	28.0	3.65	0	65	7	28	49.0	37.9	11.1	30.5	1.71
SP5	32.7	3.33	0	10	69	21	54.0	41.6	12.4	25.5	1.58
SP6	26.1	2.99	0	12	59	29	57.5	31.3	26.2	28.7	1.64
SP7	29.7	3.10	0	11	49	40	53.0	33.5	19.5	29.0	1.58
SP8	34.9	3.55	0	23	51	26	37.0	30.9	6.1	28.5	1.68
SP9	35.6	2.92	1	2	19	68	85.0	47.9	37.1	35.5	1.40
SP10	42.6	2.77	0	1	27	72	96.0	48.1	47.9	37.0	1.24
SP11	38.0	2.77	0	2	51	47	79.3	34.1	45.2	35.5	1.40
SP12	52.0	2.77	0	1	42	57	91.5	60.8	30.7	31.5	1.27

**Table 2.** Pore fluids chemistry of serpentinite soils.

No.	Saturation Wo (%)	pH	Conductivity (mS/cm)	Na <sup>+</sup>		K <sup>+</sup>		Ca <sup>2+</sup>		Mg <sup>2+</sup>		SO <sub>4</sub> <sup>2-</sup> ppm	Cl <sup>-</sup> ppm	SAR	Cation mono/di
				ppm	meq/l	ppm	meq/l	ppm	meq/l	ppm	meq/l				
SP1	99.43	5.50	0.056	1.93	0.08	0.00	0.00	1.18	0.094	0.53	0.026	12.5	7.5	0.34	0.69
SP2	67.48	5.43	0.051	1.49	0.06	0.00	0.00	0.67	0.054	0.17	0.008	12.5	6.3	0.37	1.05
SP3	93.80	5.35	0.060	1.82	0.08	0.00	0.00	1.19	0.096	0.33	0.016	12.5	117.5	0.33	0.71
SP4	57.94	5.80	0.020	8.23	0.36	6.44	0.16	2.81	0.225	3.57	0.178	12.5	32.5	0.80	1.29
SP5	54.03	5.64	0.123	4.97	0.22	7.31	0.18	2.43	0.194	1.09	0.054	12.5	7.5	0.61	1.60
SP6	52.97	5.66	0.065	2.80	0.12	2.69	0.07	0.80	0.064	0.07	0.004	12.5	7.5	0.66	2.80
SP7	57.78	5.54	0.166	6.49	0.28	4.56	0.11	1.29	0.104	0.62	0.031	12.5	37.5	1.09	2.95
SP8	62.12	5.58	0.211	7.14	0.31	0.19	0.00	2.63	0.211	1.41	0.071	12.5	50.0	0.83	1.12
SP9	71.07	5.59	0.106	2.25	0.10	0.06	0.00	1.32	0.106	0.30	0.015	12.5	8.8	0.40	0.83
SP10	94.7	5.77	0.052	1.82	0.08	0.00	0.00	1.23	0.099	0.13	0.006	12.5	6.3	0.34	0.75
SP11	93.16	5.21	0.224	4.53	0.20	1.06	0.03	3.97	0.318	2.57	0.129	12.5	10.0	0.42	0.50
SP12	98.48	5.50	0.036	0.08	0.00	0.00	0.00	1.19	0.096	0.07	0.003	12.5	2.5	0.02	0.04

## Physical Properties

### Water Content, Wo

Natural water contents are generally high, ranging from 26–69%. The high water content is related to the significantly high clay contents of the soils, causing high adsorption or retention of soil moisture.

### Specific Gravity (Relative Density), Gs

Gs values are mostly high, ranging from 2.77–3.65. The higher Gs values are attributed to iron oxide contents.

### Grain Size Distribution

The residual soils are developed from fine-grained rocks (serpentinite) with unstable minerals which readily weathers into clay minerals. Hence, the particle size distributions are dominated by fine-grained components with clay slightly predominating over silt-size particles in general (Figure 1). Clay contents range from 21–72%, while silt contents range from 7–69%. The coarse fractions (G + S) are generally low, i.e. < 10%, with some exceptions (SP2, SP4, SP8) which show higher sand contents of 23–65%. The higher coarse fractions are due to the presence of lateritic bands or iron concretions in the residual soils.

### Atterberg Limits, LL & PL

Being predominantly clayey soils, the plasticities are high. Liquid limits range from 37–96%, with practically all but one being above 50%. PI values show a broad range from 6–48%. Figure 2 shows practically all the data plotted as MH soils, i.e. silts with high plasticities. Note also that the natural water contents mostly fall below the PL and LL values, as is generally the case for residual soils. The high plasticities are in part due to the predominantly clayey nature of the soils (In comparison, graphitic schist soils have low LL of < 50%).

### Compaction Characteristics

Fine-grained soils dominated by clays in general will yield low compacted densities. Compacted maximum dry densities show a wide range of values from ~1.2 g/cm<sup>3</sup> to ~1.7 g/cm<sup>3</sup>. The higher values, i.e. > 1.6 g/cm<sup>3</sup>, are attributed to the higher coarse fractions (higher sand contents) in the residual soils due to the presence of iron concretions (e.g. SP4, SP8). Optimum moisture contents show relatively high values corresponding to the low dry densities with W<sub>opt</sub> ranging from 22–41%. Figure 3 shows the compaction curves of the soil samples tested. The compaction curves show two clusters, one with relatively

higher compacted densities of  $> 1.6 \text{ g/cm}^3$ , and the other cluster with low compacted densities of  $< 1.4 \text{ g/cm}^3$ .

### Pore Fluids Chemistry

#### pH

pH is a measure of the acidity of the pore fluids. The serpentinite soils are characterised by slightly acidic pore fluids, with pH values of 5.2–5.8.

#### Conductivity

Conductivity is a measure of the total content of cations in the pore fluids. The values obtained range from  $\sim 0.02$  to  $0.2 \text{ mS/cm}$ . These low values reflect low dissolved cation contents in the pore fluids. As is the general case with residual soils on cut slopes which are subject to continuous leaching by percolating water, the total cations content (hence conductivity) is low.

#### Soluble Cations ( $\text{Na}^+$ , $\text{K}^+$ , $\text{Mg}^{2+}$ , $\text{Ca}^{2+}$ )

The cations contents of serpentinite soils are low in general (mostly  $< 10 \text{ ppm}$ ). The soluble cations are dominated by  $\text{Na}^+$ , with the general order of abundance as follows:  $\text{Na}^+ > \text{K}^+ \sim \text{Ca}^{2+} > \text{Mg}^{2+}$ . Since  $\text{K}^+ \sim \text{Ca}^{2+}$  or  $\text{K}^+ < \text{Ca}^{2+}$  in some of the samples, there is no predominance of monovalent cations over divalent cations. Predominance of monovalent cations, in particular  $\text{Na}^+$ , can contribute to dispersivity of the soil. The sodium adsorption ratio (SAR) show values of  $< 2$ , i.e. indicating non-dispersive soils. Figure 4 shows the Sherard's plot for dispersivity of soils, Sherard *et al.* (1976), and the data indicate the non-dispersive nature of the serpentinite 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.

## CONCLUSIONS

Detailed study of the physico-chemical properties of soil is essential in understanding the behaviour of the soil. Serpentinite soils are characterised by clayey content, high plasticities, low compacted densities, slightly acidic pore fluids and non-dispersive nature. The physico-chemical properties, coupled with the clay mineralogy, would dictate the behaviour of the soil. This is a useful contribution in studying stability problems in engineering work.

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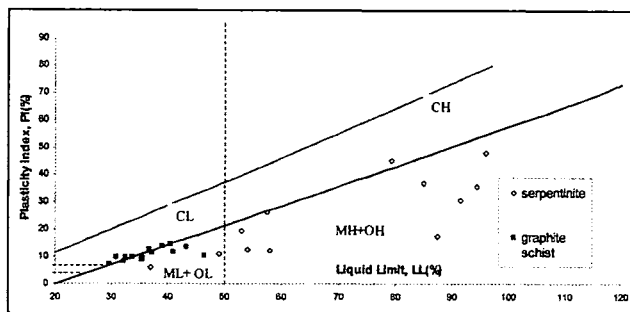


Figure 2. Plasticity chart, serpentinite soils.

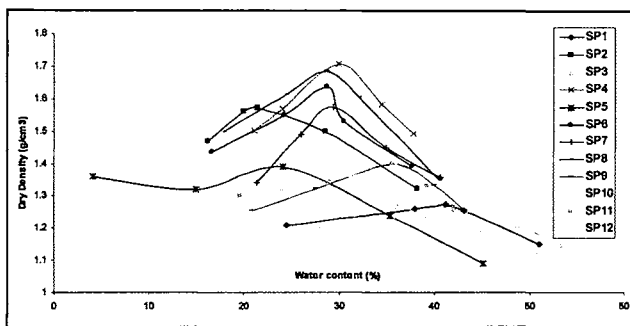


Figure 3. Compaction curves, serpentinite soils.

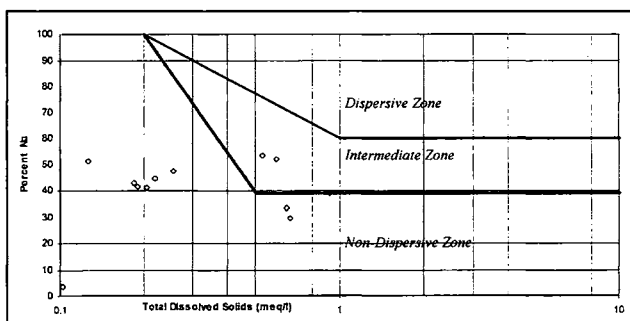


Figure 4. Dispersivity plot (Sherard *et al.*, 1976).

*Engineering, Mexico City, vol. 1, 107–116.*

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*Manuscript received 12 March 2004*