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Physico-chemical properties of andesitic soils in the Kg. Awah area, Pahang

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Abstract: Residual soils of andesite in the Kg. Awah area, Pahang, have been analysed for their physico-chemical properties. Results indicate that the andesitic soils are characterised by their predominantly clayey nature, high plasticities, generally low compacted densities, slightly acidic pore fluids, and intermediate dispersivity behaviour.

Abstrak: Tanah baki andesit di kawasan Kg. Awah, Pahang, telah diuji sifat fiziko-kimia. Hasil kajian menunjukkan bahawa tanah baki andesit dicirikan oleh sifat berlempung, keplastikan tinggi, ketumpatan pemadatan rendah, air liang sedikit berasid dan sifat dispersif perantaraan.

INTRODUCTION

Residual soils of andesite occur widely in the Kg. Awah area, Pahang. As part of a systematic programme of study on the various types of residual soils in Peninsular Malaysia, a study on the physico-chemical and mineralogical properties of the andesitic soils in the Kg. Awah area was completed recently, Yew (2002). This paper presents a summary of the gist of the results of this recent study. Previous publications on the physico-chemical properties of residual soils include, among others, Tan & Tai (1999), Tan & Zulhaimi (2000) and Tan & Azwari (2001), and this present paper continues the effort in publishing data on the physico-chemical properties of various types of residual soils in Peninsular Malaysia.

MATERIALS AND METHODS

A total of 11 soil samples (AN1–AN11) were taken from cut slopes in andesitic soils in the Kg. Awah area and vicinities. The cut slopes sampled were mainly along parts of the trunk roads in the vicinity of Kg. Awah, as well as in housing development schemes in the area. The andesitic soils are easily recognised 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, Yew (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 (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 & 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 andesitic soils are summarised in Table 1 and 2. Figures 1–5 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 high, ranging from 16–51%. The high water content is related to the significantly high clay contents of the soils, thus high adsorption or retention of soil moisture.

Specific Gravity (Relative Density), Gs

Gs values are mostly centred around 2.7, with some minor variations of up to ~3. The higher G_s values are attributed to iron oxide contents.

Table 1. Physical properties of andesitic soils (AN).

	Wo (%)	Gs	Grain Size Distribution				Atterberg Limits			Compaction Characteristic	
			G (%)	S (%)	M (%)	C (%)	LL (%)	PL (%)	PI (%)	W_{opt} (%)	γ_{dmak} (g/cm^3)
AN 1	39.0	2.76	22	35	15	28	99.0	53.5	45.7	28.5	1.48
AN 2	16.3	2.99	38	26	16	20	81.5	61.2	20.3	14.5	1.96
AN 3	45.8	2.75	0	3	34	63	68.5	47.3	21.2	40.5	1.24
AN 4	45.3	2.67	0	8	46	46	73.5	50.0	23.5	35.5	1.20
AN 5	49.0	2.76	0	4	24	72	80.0	59.8	20.2	44.5	1.16
AN 6	46.0	2.71	0	3	50	47	77.0	51.5	25.5	43.5	1.76
AN 7	49.0	2.71	0	3	18	79	79.0	58.1	20.9	47.5	1.15
AN 8	37.0	2.70	0	4	33	63	67.5	46.5	21.0	31.5	1.35
AN 9	50.6	2.74	0	3	20	77	96.0	64.9	31.1	38.5	1.21
AN 10	25.8	2.85	15	51	16	18	94.0	85.1	8.9	29.0	1.59
AN 11	33.8	2.74	1	21	53	25	57.5	42.1	15.4	34.5	1.37

Table 2. Pore fluid chemistry of andesitic soils (AN).

	pH	Conductivity (mS/cm)	Na^+		K^+		Mg^{2+}		Ca^{2+}		SO_4^{2-} (ppm)	Cl^- (ppm)	SAR	Mono Di
			ppm	Meq/l	ppm	Meq/l	ppm	Meq/l	ppm	Meq/l				
AN 1	6.30	0.065	4.22	0.183	0.29	0.007	0.04	0.003	0.00	0.000	5	6.0	4.73	112.75
AN 2	6.15	0.189	6.56	0.285	4.13	0.106	0.42	0.035	1.80	0.090	15	8.5	1.14	4.82
AN 3	6.00	0.058	4.06	0.177	0.71	0.018	0.08	0.007	0.82	0.041	10	9.0	1.14	5.30
AN 4	5.93	0.133	5.89	0.256	3.91	0.100	0.66	0.054	0.24	0.012	35	4.5	1.41	10.89
AN 5	6.10	0.082	5.06	0.220	1.57	0.040	0.10	0.008	0.61	0.030	15	16.5	1.60	9.34
AN 6	6.00	0.078	4.64	0.202	0.07	0.002	0.21	0.017	0.61	0.030	20	8.0	1.32	5.74
AN 7	5.98	0.078	4.47	0.194	0.07	0.002	0.15	0.012	0.00	0.000	15	8.5	2.50	30.27
AN 8	5.90	0.064	4.56	0.198	0.07	0.002	0.12	0.010	0.00	0.000	10	9.5	2.80	38.58
AN 9	5.73	0.240	8.90	0.387	11.17	0.286	0.84	0.069	3.68	0.184	10	41.5	1.09	4.44
AN 10	5.90	0.057	4.14	0.180	0.05	0.001	0.08	0.007	0.00	0.000	15	9.5	3.04	52.38
AN 11	5.68	0.247	8.32	0.362	9.25	0.237	1.56	0.128	3.68	0.184	20	5.5	0.92	3.35

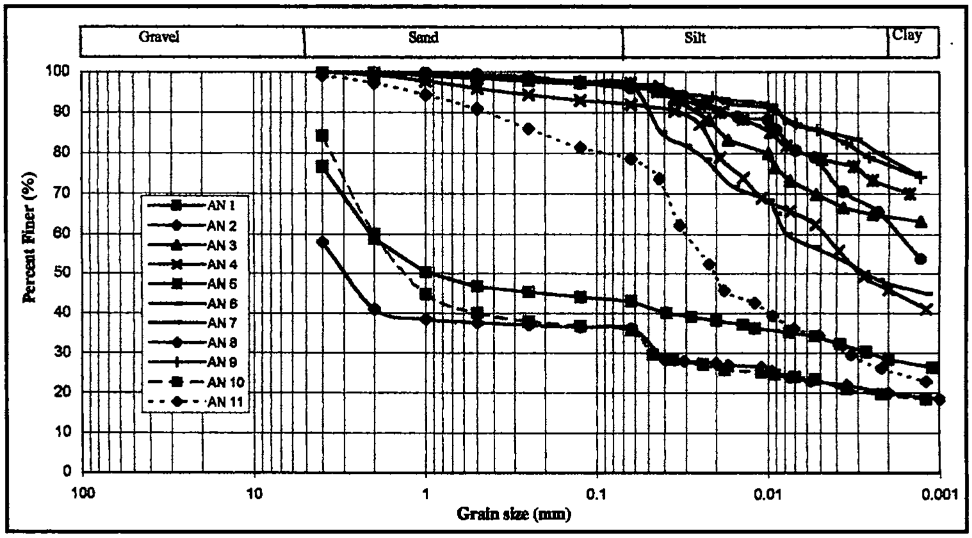

Figure 1. Grain size distribution curves.

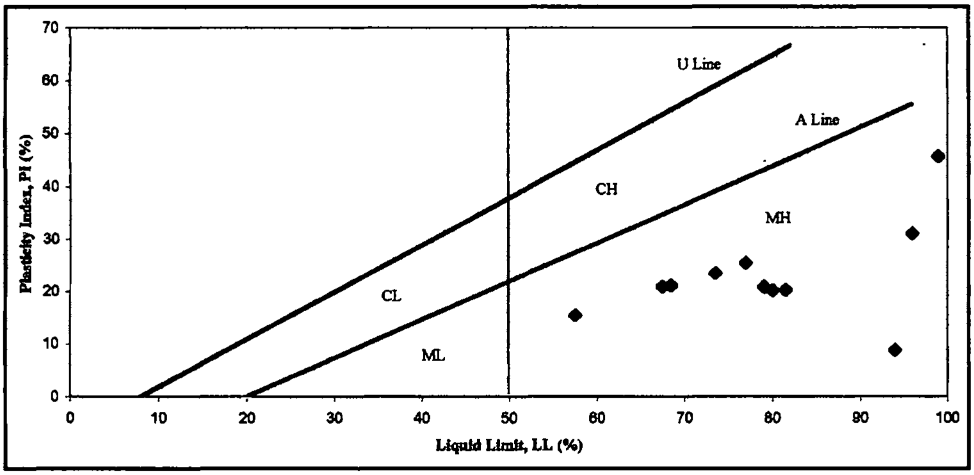

Figure 2. Plasticity chart.

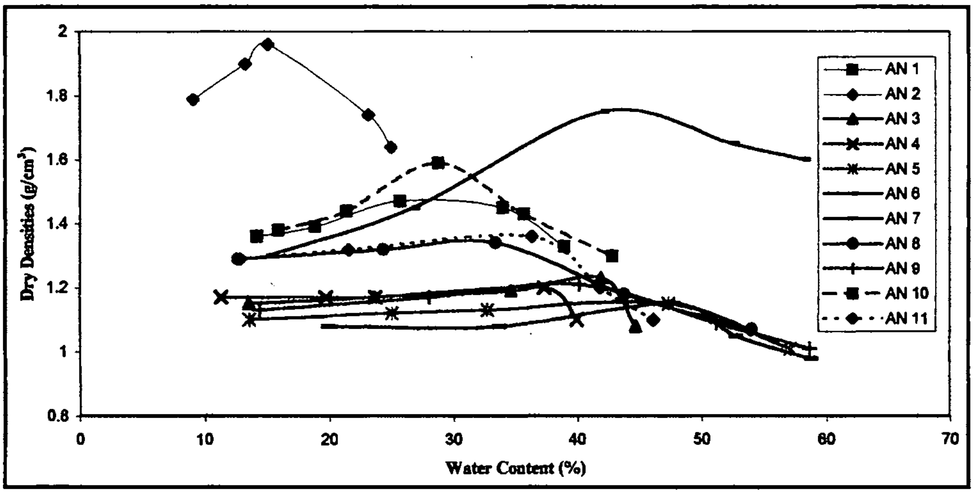

Figure 3. Compaction characteristic.

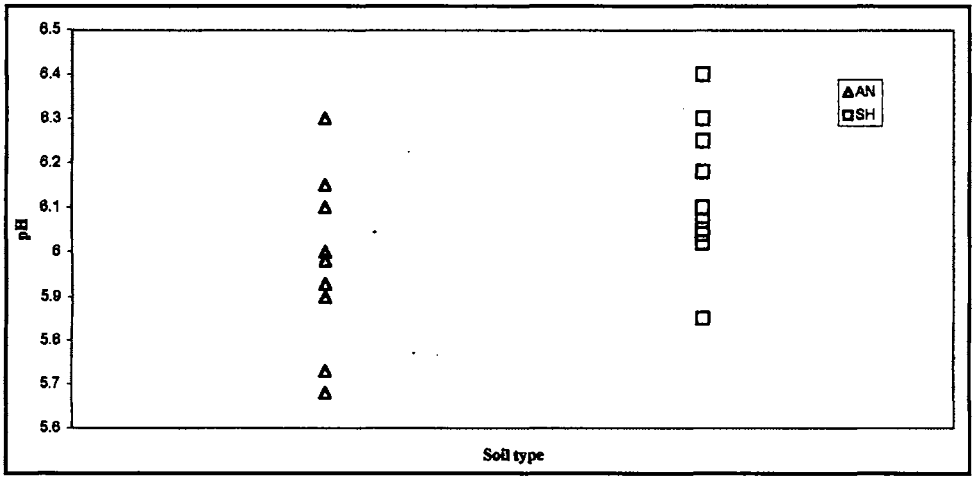

Figure 4. pH of pore fluids.

Grain Size Distribution

The residual soils are developed from fine-grained volcanic rocks (andesite). Hence, the particle size distributions are dominated by fine-grained components with clay predominating over silt-size particles, Figure 1. Clay contents range from 18–79%, while silt contents range from 15–53%. The coarse fractions (G + S) are generally < 10%, (AN3–AN9). However, the presence of lateritic bands or iron concretions in the residual soils can contribute to significantly higher amounts of sand- and gravel-sized particles in the andesitic soils, e.g. AN1 and AN2.

Atterberg Limits, LL & PL

Being predominantly clayey soils, the plasticities are high. Liquid limits range from 58–99%, with all the values being above 50%. PI values show a broad range from 9–46%. Figure 2 shows the data plotted as mostly MH soils, i.e. silts with high plasticities. Note also that the natural water contents all 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.

Compaction Characteristics

Fine-grained soils dominated by clays in general will yield low compacted densities. The values for the compacted maximum dry densities show mostly low values from ~1.2 g/cm^3 to ~1.4 g/cm^3, (AN3–AN9). Some of the values, however, are high, i.e. > 1.6 g/cm^3, and they are attributed to the higher coarse fractions in the residual soils due to the presence of iron concretions (e.g. AN2 and AN10). Optimum moisture contents show relatively high values corresponding to the low dry densities, W_{opt} ranging from 15–48%. Figure 3 shows the compaction curves of the soil samples tested. Except for the "anomalous" AN2 and AN6, the compaction curves show low compacted densities and high optimum moisture contents.

Pore Fluids Chemistry

pH

pH is a measure of the acidity of the pore fluids. The andesitic soils are characterised by slightly acidic pore fluids, with pH values of around 6. Figure 4 shows the slightly more acidic values of andesitic soils in comparison to residual soils of shales in the Kg. Awah area.

Conductivity

Conductivity is a measure of the total cations content in the pore fluids. The values obtained range from ~0.1 to 0.2 mS/cm. These low values are comparable to other soil types studied such as granitic, quartz-mica schist, basaltic soils, etc. e.g. Tan (1996), Tan (2000). The close similarity of the conductivity values between the andesitic soils in the Kg. Awah area and basaltic soils in Kuantan is indeed striking — the basaltic soils in Kuantan have conductivity values of 0.050–0.229 mS/cm, Tan (1994). 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 (Na^+, K^+, Mg^{2+}, Ca^{2+})

The cations contents of andesitic soils are low in general (< 10 ppm). Again, there is close similarity in cations contents compared to basaltic soils of Kuantan, Tan (1994). 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 ~3–53. Predominance of monovalent cations, in particular Na^+, can contribute to the dispersivity of the soil. The values for the sodium adsorption ratio (SAR) show some values of > 2, as well as some values of < 2. Values of SAR > 2 would indicate dispersive soils. Figure 5

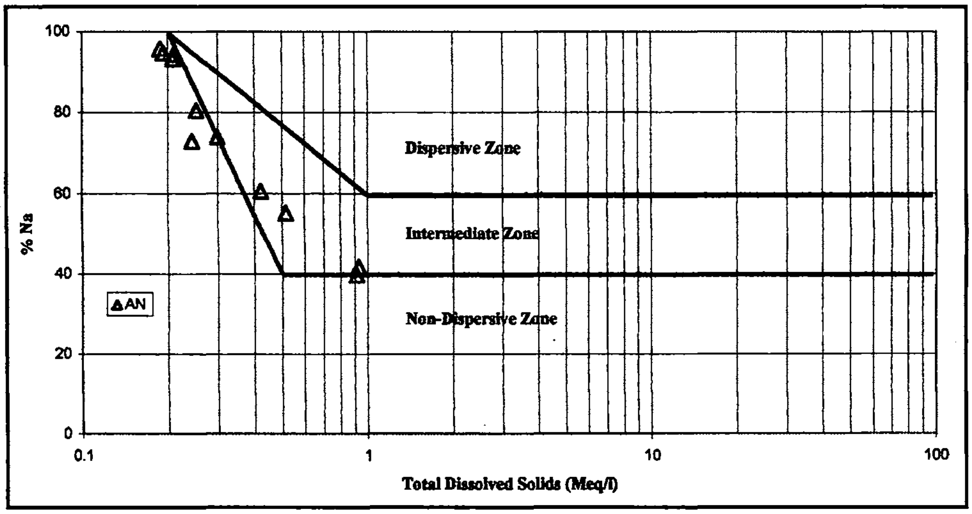

Figure 5. Dispersivity plot (Sherard *et al.*, 1976).

shows the Sherard's plot for dispersivity of soils, Sherard *et al.* (1976), and some of the data indicate the intermediate dispersivity nature of the andesitic soils. The other data fall close to the boundary between non-dispersive and intermediate zones. 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 are low, with both SO_4^{2-} and Cl^- contents ranging mostly around 10–20 ppm. Comparing the two anions, $SO_4^{2-} > Cl^-$ in general.

CONCLUSIONS

A detailed study on the physico-chemical properties of a soil is essential in understanding the behaviour of the soil. The andesitic soils are characterised by the clayey nature, high plasticities, low compacted densities, slightly acidic pore fluids and intermediate dispersivity 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.

REFERENCES

BS 1377, 1975. Methods of test for soils for civil engineering purposes. *British Standards Institution*, London.

BRAND, E.W. & HONGSNOI M., 1969. Effects of method of preparation on compaction and strength characteristics of lateritic soils. *Proc. Specialty Session on Engineering Properties of Lateritic Soils, 7th Int. Conf. on Soil Mechanics & Foundation Engineering, Mexico City, vol. 1*, 107–116.

GEOTECHNICAL RESEARCH CENTRE (GRC), 1985. *Laboratory Manual*, GRC, McGill University, Montreal, Canada (unpubl.).

LITTLE, A.L., 1969. The engineering classification of residual tropical soils. *Proc. Specialty Session on Engineering Properties of Lateritic Soils, 7th Int. Conf. on Soil Mechanics & Foundation Engineering, Mexico City, vol. 1*, 1–10.

MOH, Z.C. & MAZHAR, M.F., 1969. Effects of method of preparation on index properties of lateritic soils. *Proc. Specialty Session on Engineering Properties of Lateritic Soils, 7th Int. Conf. on Soil Mechanics & Foundation Engineering, Mexico City, vol. 1*, 109–120.

SHERARD, J.L., DUNNIGAN, L.P. & DECKER, R.S., 1976. Identification and nature of dispersive soils. *ASCE J. Geotech. Eng. Div., 102(GT4)*, 287–301.

TAN, B.K., 1994. Physico-chemical properties of basaltic soils from Kuantan, Pahang. *Warta Geologi, 20(5)*, Geol. Soc. of Malaysia, 347–352.

TAN, B.K., 1996. Physico-chemical properties of some granitic soils from Peninsular Malaysia. *Proc. 12th SE Asian Geotechnical Conf., 6–10 May, 1996, Kuala Lumpur, vol. 1*, 595–600 (4th Int. Conf. on Tropical Soils).

TAN, B.K., 2000. Physico-chemical properties of some residual soils in Peninsular Malaysia. *Proc. GeoEng 2000: Int. Conf. On Geological & Geotechnical Engineering, Nov. 19–24, 2000, Melbourne*, CD-ROM.

TAN, B.K. & AZWARI HUSLAN MOHD, 2001. Physico-chemical properties of carbonaceous shale soils in the Yong Peng area, Johor. *Proc. GSM Annual Geol. Conf. 2001, 2–3 June 2001, Pangkor Island*, 229–232.

TAN, B.K. & TAI, T.O., 1999. Physico-chemical properties of graphitic schist soils from Malacca, Peninsular Malaysia. *Proc. 2nd Asian Symposium on Engineering Geology & Environment, IAEG/IGM, 23–25 Sept., 1999, Bangi*, 2–8 to 2–10 (Abstract).

TAN, B.K. & ZULHAIMI ABDUL RAHMAN, 2000. Physico-chemical properties of graphitic schist soils in the Rawang area, Selangor. *Proc. GSM Annual Conf. 2000, Sept. 8–9, 2000, Pulau Pinang*, 283–286.

YEW, C.K., 2002. Sifat fiziko-kimia dan mineralogi lempung tanah baki sekitar kawasan Kg. Awah, Pahang. *B.Sc. (Hons) thesis*, Program Geologi, FST, UKM, 68p.