GEOTECHNICAL CHARACTERISTICS OF OXISOL B HORIZONS

L. M. G. Motta,[1] J. Medina,[2] J. L. R. Souza,[3] and J. Olmos I. L.[4]

The opportunity to determine a few geotechnical characteristics of samples taken from B horizons of Oxisol pedons thoroughly studied by soil scientists seemed to the authors to be a valid exercise. The plan of study included the use of new testing techniques and the engineering soil classification system developed in Brazil by Nogami and Villibor called MCT (miniature compacted tropical) classification.

Materials and Methods

From the 23 pedons described and collected for the VIIIth International Soil Classification Workshop (ISCW), 9 of them were selected for the realization of this study.

Sample	Pedon	Horizon	*Soil Taxonomy*
P1	ISCW 1	Bo2	Typic Eutrorthox
P4	ISCW 4	Bo2	Typic Hapludox
P7	ISCW 7	Bo2	Typic Acrudox
P11	ISCW 11	Bo3	Rhodic Hapludox
P13	ISCW 13	Bo2	Acrudox
P18	ISCW 18	Bo	Typic Acrudox
P20	ISCW 20	Bo2	Rhodic Eutrustox
P22	ISCW 22	Bo1	Typic Acrorthox
Extra	ISCW Extra II	Bo1	Typic Acrorthox

In Table 1 are the comparative properties of soil groups obtained in miniature compacted specimens (MCT). The lateritic engineering behavior is distinguished from the nonlateritic behavior. The method was developed for soils of grain-size less than 2 mm.

The mini-CBR (California bearing ratio miniaturized) is a penetration test (piston of 1.6 cm diameter) of a sample that has been compacted with the mini-MCV rammer, at a constant compaction effort of 10 blows. Specimens were not soaked, and a surcharge weight of 490 g was placed on the top surface during the penetration.

Results

Determinations made at EMBRAPA are in Table 2. The parameters from mini-MCV tests, together with grain-size data, liquid limit and plasticity index (classes according to U.S. Highway Research Board Unified Soil Classification System) and miniature compacted specimens (MCT) are presented in Table 3. These tests were conducted at the Soil Mechanics Laboratory of COPPE/UFRJ. Test results of mini-CBR are shown in Table 4, and the graphs of compaction curves (γ_d, w) and CBR curves (mini-CBR, w) are in Figure 1. In Figure 2 were also plotted the points representative of the nine samples.

Discussion

All soil samples plot on the lateritic behavior part of the chart for classification purposes (Fig. 2). Those of high immersion loss are near the borderline of classes LG' and NG'. Soil samples P4 (Typic Hapludox) and P22 (Typic Acrorthox) have immersion losses of 10 percent and zero respectively. Sample P13, an Acrudox, is more sandy than the previous ones and has an immersion loss of 100 percent, which means lack of strong cementation when saturated.

The usual testing procedures of SNLCS laboratories were applied to determine grain-size distribution, silt to clay ratio, and CEC k_i and k_r. The mini-MCV (moisture condition value) test is described by Nogami and Villibor (1981, 1985). A sample of soil weighing about 200 g is compacted in miniaturized equipment similar to that developed by Parsons and Boden (1976). The rammer weight is 2740 g, the height of drop 305 mm, and the diameter of mold 50 mm (Fig. 3).

The difference to the traditional Proctor compaction test much used in earthworks throughout the world is that instead of applying a standardized compactive effort to the moistened mass of soil, successive blows are applied while the decreasing height of the compacted soil sample is measured. This procedure is repeated for different water contents. The MCV value is defined:

[1] Assistant Professor at COPPE/UFRJ.
[2] Professor at COPPE/UFRJ.
[3] Researcher at Serviço Nacional de Levantamento e Conservação de Solos, Empresa Brasiliera de Pesquisa Agropecuária (SNLCS,EMBRAPA),Brazil.
[4] Researcher, SNLCS, EMBRAPA, Brazil.

Table 1. Comparative Properties of Soil Groups

A = sand (Arena)
A′ = sandy
G = clay (Argilla)
G′ = clayey
S = silt
S′ = silty
k = kaolinitic
m = micaceous
q = quartzose

h = high
l = low
m = medium
v = very
/ = to

		NA	NA′	NS′	NG′	LA	LA′	LG′
	Class	Nonlateritic (N) behavior				Lateritic (L) behavior		
	Group	NA	NA′	NS′	NG′	LA	LA′	LG′
	Typical grain size	A S′A S(q)	S′A G′A	S(km) A′S G′S	G A′G S′G	A	G′A A′G	G A′G
Mini-CBR*	Soaked	h/m	h/m	m/h	h	h	h/vh	h
Mini-CBR*	Decrease by soaking	m/l	l	h	h	l	l	l
	Swelling *	l	l	h	h/m	l	l	l
	Shrinkage *	l/m	l/m	m	h/m	l	l/m	m/h
	Permeability*	m/h	l	m/l	l/m	m/l	l	l
	Plasticity	l/NP	m/NP	m/h	h	NP/l	l/m	m/h

* Specimens compacted at optimum of standard compactive effort.

Table 2. Soil Parameters and Geotechnical Classification of Oxisols Studied

Sample	% Pass. 200	WL/I_P	c'	d'	P_i	e'	Classification HRB	USCS	MCT
P1	<50	58/14	1.5	77	0	0.64	A-7-5	SM	LA′/LG′
P4	>50	64/21	1.7	67	10	0.74	A-7-5	MH	LG′
P7	>50	45/12	2.1	27	80	1.13	A-7-5	ML	LG′
P11	>50	39/9	2.6	15	30	1.18	A-4	ML	LG′
P13	<50	47/11	0.6	10	60	1.37	A-2-7	SM	LA
P18	>50	46/10	1.8	57	100	1.11	A-5	ML	LG′
P20	>50	32/11	2.0	32	100	1.18	A-6	CL	LG′
P22	>50	36/NP	2.0	40	0	0.79	A-4	ML	LG′
Extra II	>50	52/28	2.2	44	20	0.87	A-7-6	CH	LG′

Note: WL = liquid limit; I_P = plasticity index; c', d', P_i, e' = parameters defined in text.

Table 3. Testing Data of Samples from EMBRAPA

Sample	CEC	k_i	k_r	Silt/Clay (%)	Grain size (%)		
					Sand	Silt	Clay
P1	2.9	1.40	1.22	15	53	6	41
P4	2.8	1.78	1.39	13	14	10	76
P7	1.3	0.71	0.41	18	10	14	76
P11	1.3	0.37	0.27	11	3	10	87
P13	1.3	1.82	1.28	39	75	7	18
P18	1.8	0.91	0.69	10	12	8	80
P20	2.4	0.71	0.55	9	13	7	80
P22	4.9	1.53	1.20	38	34	18	48
Extra II	2.8	0.43	0.25	18	11	14	75

Note: Sand 2-0.05 mm; silt 0.05-0.002 mm; clay <0.002 mm.

Table 4. Compaction Parameters (γ_d, w) and Mini-CBR Values

Sample		Specimen										
		1	2	3	4	5	6	7	8	9	10	Wo
P1	w%	16.91	17.21	19.28	22.06	22.75	12.38	14.24	16.44	17.61	19.92	18
	MCBR	25	18	7	6	3	31	26	25	17	10	16
	γ_d	17.51	17.64	16.91	16.52	16.10	15.23	15.87	17.32	17.84	17.07	17.8
P4	w%	26.06	27.88	30.65	31.49	35.35	25.64	28.44	30.39	31.80	34.13	28.5
	MCBR	20	17	9	8	3	20	16	13	9	5	16
	γ_d						14.24	14.73	14.37	14.07	13.59	14.7
P7	w%	24.71	26.14	27.80	30.51	32.23	22.90	25.05	26.66	29.38	31.29	27
	MCBR	20	16	9	5	3	22	18	11	7	4	10
	γ_d						15.66	16.35	16.55	15.74	15.20	16.6
P11	w%	27.01	31.29	32.20	33.97	36.56	23.18	26.34	29.47	29.72	34.47	30
	MCBR	21	14	10	7	4	35	27	21	19	9	20
	γ_d						11.99	13.14	14.16	13.98	13.71	14.3
P13	w%	8.87	10.91	13.36	15.05	17.60	9.00	10.95	12.39	14.34	17.35	11
	MCBR	25	20	16	7	3	33	27	14	5	2	25
	γ_d						18.78	18.99	18.93	18.17	17.19	19.0
P18	w%	28.09	28.95	30.79	33.01	34.55	20.43	21.94	23.71	25.54	26.47	28
	MCBR	14	15	8	4	3	35	35	25	21	18	16
	γ_d						12.26	12.28	12.81	13.77	14.42	14.7
P20	w%	26.84	28.94	31.25	33.73	35.33	16.61	19.92	20.11	22.49	24.71	26
	MCBR	18	15	9	6	3	38	34	33	29	21	20
	γ_d						12.06	11.98	12.04	12.22	13.48	14.1
P22	w%	15.84	17.58	20.16	21.61	24.00	14.37	16.83	18.97	18.86	22.64	19
	MCBR	23	16	14	8	4	25	21	20	19	7	20
	γ_d						15.41	16.28	16.68	16.54	16.03	16.6
Extra II	w%	26.01	28.14	30.08	32.08	34.28	20.08	22.45	23.47	25.65	27.49	28
	MCBR	10	16	9	5	2	36	20	22	20	19	16
	γ_d						13.23	13.89	14.27	15.16	15.58	15.6

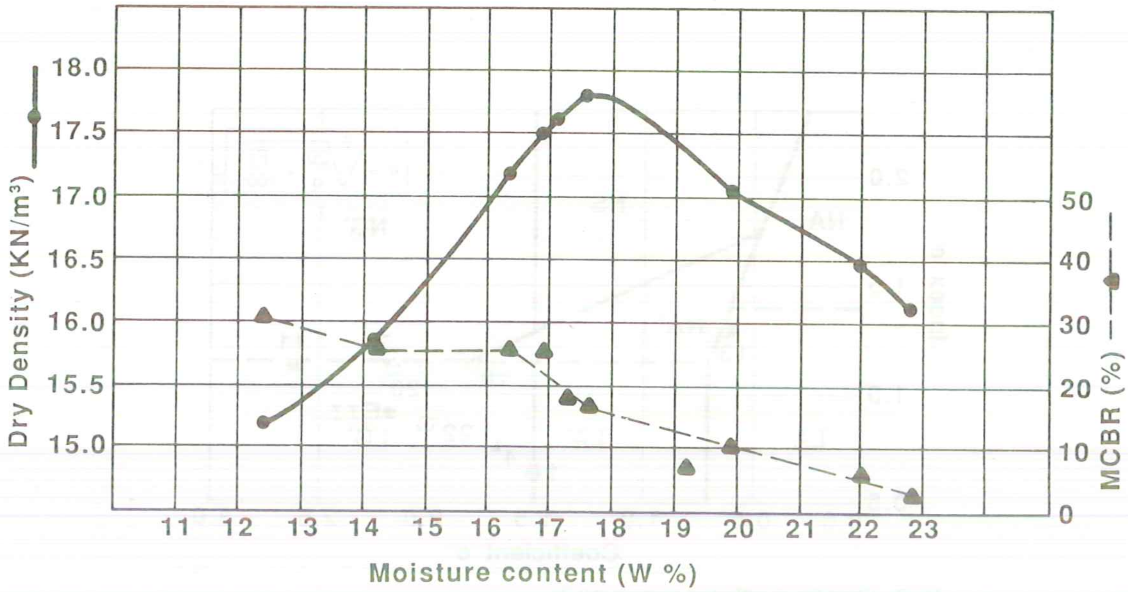

Fig. 1. Example of compaction and mini-CBR curves (sample P20).

$$\text{mini-MCV} = 10 \log_{10} (B_n). \quad (1)$$

B_n is the intersection of mini-MCV curves shown in Figure 4 with a straight line corresponding to a_n equal to 2 mm.

$$a_n = A_n - A_{4n}. \quad (2)$$

A_n is the height for n blows and A_{4n} for 4n blows.

The parameter c' is picked up from the mini-MCV curves.

After compaction the soil sample is partially extruded from the mold so that a part 1 cm long becomes salient. Then the mold with the extruded sample is flooded until the water level comes at least 1 cm above the mold. The loss of weight by immersion (P_i) is determined. Its plot is shown in the same figure. From the compaction curves, where dry density of compacted soil is plotted against moisture content the d' parameter (average slope of 12-blows curve in the dry side) is determined. To enter the classification chart (Fig. 2) two parameters are needed: c' and e'. The latter is defined as:

$$e' = \left(\frac{Pi}{100} + \frac{20}{d'}\right)^{1/3} \quad (3)$$

It can be observed that soils having a high value of P_i (immersion loss) are Acrox ones; they are old soils with little CEC. However, data are not enough for a tentative correlation of P_i with CEC (or with k_i or k_r).

Soil P_i is at the borderline LA/LG′. It has approximately the same amounts of sand and clay fractions.

With data from Tables 2 and 3 some correlations were tested:

1. Parameter c'

$c' = 2.6023 - 0.0475$ (silt/clay, %); $r = 0.773$ (4)

$c' = 2.3414 - 0.0203$ (sand, %); $r = 0.882$ (5)

$c' = 0.5397 + 0.0200$ (clay, %); $r = 0.836$ (6)

$c' = 2.6577 - 0.7681\ (k_i)$; $r = 0.779$ (7)

$c' = 2.5321 - 0.8663\ (k_r)$; $r = 0.720$ (8)

These correlations are reasonably good.

2. Parameter d'

$d' = -13.85 + 26.49$ (CEC); $r = 0.790$ (9)

3. Parameter e'

$e' = 0.2284 + 0.0103$ (clay, %); $r = 0.779$ (10)

$e' = 1.29 - 0.36\ (k_i)$; $r = 0.750$ (11)

$e' = 1.23 - 0.37\ (k_r)$; $r = 0.770$ (12)

$e' = 1.3713 - 0.1150$ (CEC); $r = 0.729$ (13)

The parameter P_i does not correlate with the variables considered. The d' value correlates only with the CEC. But as e' is an empirical function of P_i and d', some kind of correlation might be tried. More data are needed.

The classical soil classification systems used in Brazil for engineering purposes—HRB (now TRB) or AASHTO classification and the USCS—do not detect the so-called lateritic behavior. One soil may be classified in a weak category as subgrade material, yet may behave very well because of its structure and the cementing effect of iron oxides. CBR values are sometimes surprisingly high for what could be expected from a clayey soil, or a fine lateritic sand, according to above mentioned classifications. Therefore, the attempt to translate pedological data into engineering information cannot be accomplished by performing a few extra tests such as the Atterberg limits and the compaction tests. What should be done

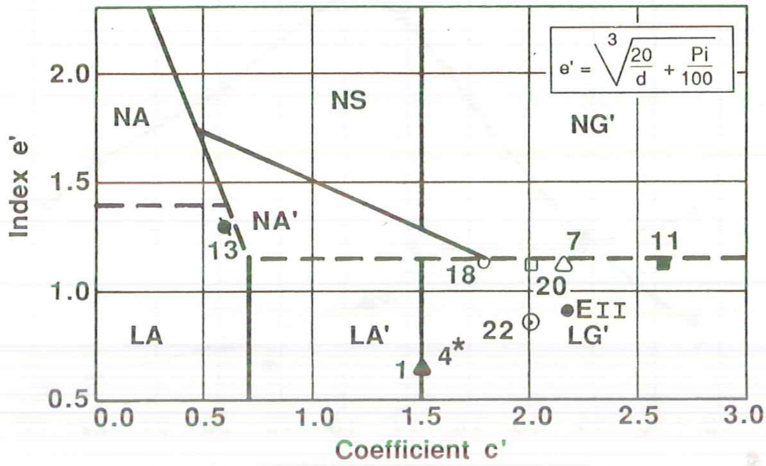

Fig. 2. Chart for classification purpose (MCT).

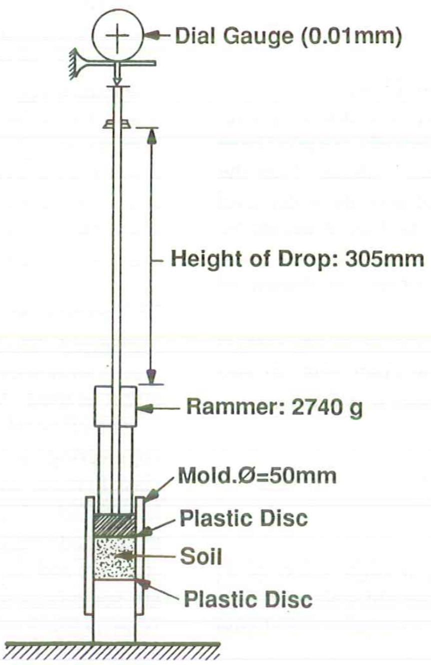

Fig. 3. Schematic Mini-MCV compaction apparatus.

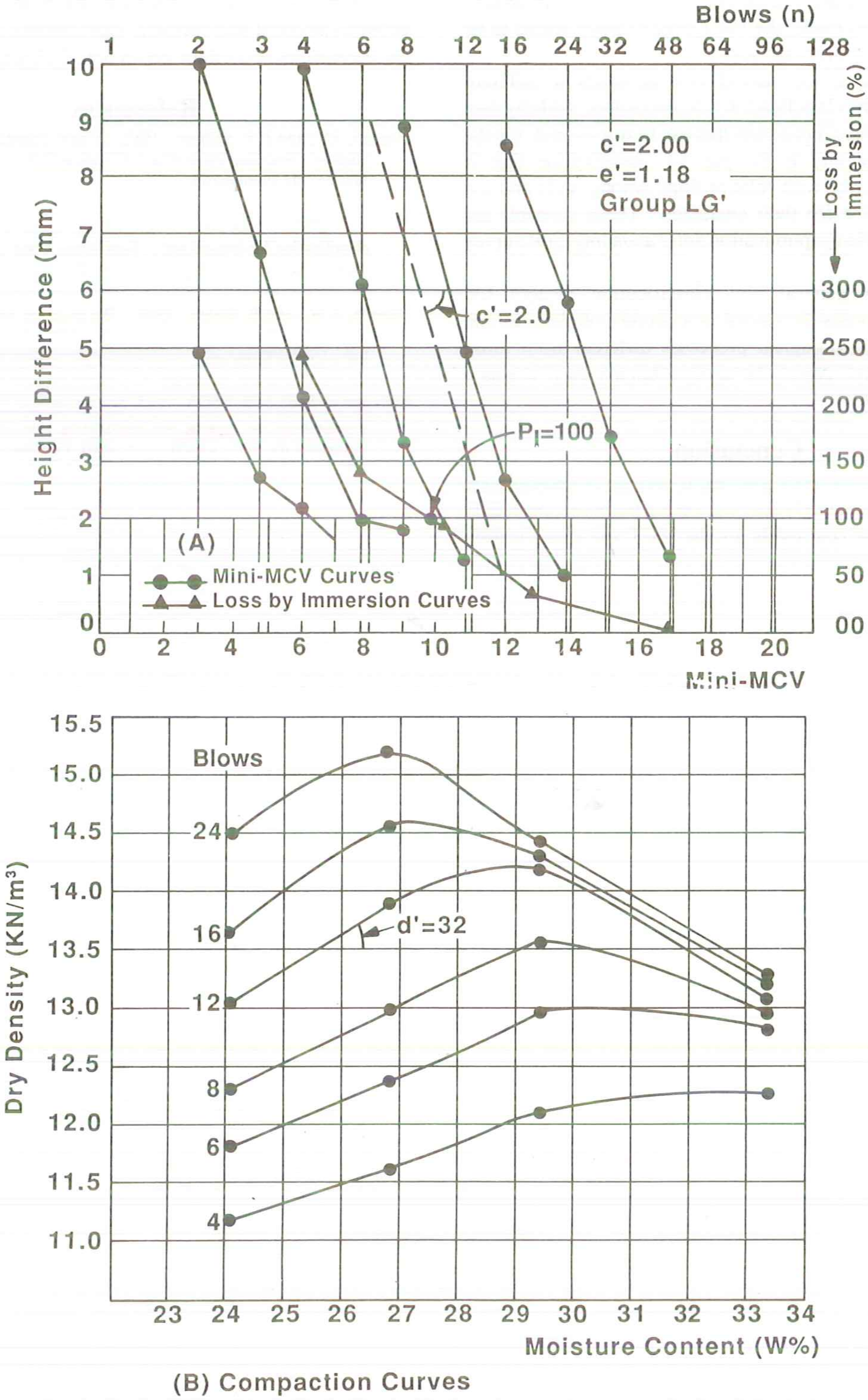

Fig. 4. Graphic representation of test results.

is either to correlate soil series with performance of engineering constructions or to perform more significant testing reflecting properties that explain engineering behavior. For pavement design of low cost roads, the MCT classification seems to be quite adequate for Brazilian soils.

Each purpose to be served best demands a different classification. The classification is a contrivance made by men to suit their purposes, not a truth that can be discovered. On the other hand taxonomy is the part of classification that is concerned primarily with relationships among soils and the factors responsible for their character. These concepts are clearly presented in the publication *Soil Taxonomy* (Soil Survey Staff 1975).

Therefore, a general soil classification system for engineering purposes developed in a country of climates and weathering and pedological processes different from those prevalent in Brazil cannot be applied blindly as if it was a taxonomic system.

Conclusion

The nine samples taken from the B horizon of Oxisols were evaluated more accurately for engineering purposes, especially for paving of low cost roads, by the MCT soil classification system than by simply determining the classes they belong to in the Unified and HRB soil classification systems.

A strong possibility exists for determining relationships between physical and chemical characteristics of Oxisols and the parameters needed for geotechnical classification.

References

Nogami, J.S., and D.F. Villibor. 1981. A new classification for highway purposes. Brazilian Symposium of Tropical Soils in Engineering, Rio de Janeiro. (In Portuguese).

———. 1985. Additional considerations about a new geotechnical classification for tropical soils. First Intern. Conf. on Geomechanics in Tropical Lateritic and Saprolitic Soils, Brasilia.

Parsons, A.W., and B. Boden. 1979. The moisture condition test and its potential applications in earthworks. SR-1522. Transport and Road Res. Lab., United Kingdom.

Soils Survey Staff, SCS, USDA. 1975. Soil taxonomy: A basic system of soil classification for making and interpreting soil surveys. Agriculture Handbook no. 436. USDA. U.S. Govt. Printing Office, Washington, D.C.