The Hardness of Lateritic Concretions and Its Influence in the Performance of Soil Mechanics Tests

La Dureté des concrétions latéritiques et son influence sur les essais géotechniques

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SUMMARY

The preparation of samples of lateritic materials for soil mechanics tests is discussed, and a method of separating the clayey materials adherent to the concretions described. It is observed that the recommended treatment does not alter the properties of the different fractions, but effects the desired separation. A granulometric modulus (M_G) and a hardness index of the concretions (I_{HC}) are defined, which are useful to differentiate soft laterites from the hard ones, more suitable for road pavements.

SOMMAIRE

On discute de la préparation d'échantillons des matériaux latéritiques pour les essais géotechniques et on indique une méthode de séparation des matériaux argileux adhérents aux concrétions. On vérifie que le traitement préconisé n'altère pas les propriétés des diverses fractions, mais réalise la séparation désirée. On définit un module granulométrique (M_G) et un indice de dureté des concrétions (I_{HC}), qui sont utiles pour différencier les latérites tendres des latérites dures, lesquelles conviennent mieux pour les travaux routiers.

COMPONENT PARTS OF A LATERITIC SOIL

THREE TYPES of concreted lateritic materials* have been found in Angola: (*a*) lateritic gravel (LG);† (*b*) hard lateritic crusts (cuirasses) (HLC); and (*c*) soft lateritic crusts (SLC).‡

The tests hitherto carried out with lateritic gravel (Laboratório Nacional de Engenharia Civil (L.N.E.C.), 1959) have shown its heterogeneity; its three main elements are (Fig. 1, Table I): (*a*) the coarse fraction (of which the fraction retained on the ⅜ in. sieve is typical) characterized by a maximum iron content and specific gravity, and, in certain cases a high content of alumina; (*b*) the intermediate fraction (from which it is difficult to indicate a typical fraction although the fraction retained on the No. 200 sieve seems the most representative) characterized by a maximum of silica content and a minimum of loss on ignition, and constituted fundamentally of fine sand; (*c*) the clay fraction, characterized by a maximum of alumina and loss on ignition and a low iron content.

These tests, partially confirmed in Lisbon, have still shown that the coarse fraction could be fairly hard, this hardness being associated with the iron content. A coarse fraction rich in iron appears hard, but when the amount of alumina is high, the hardness tends to decrease considerably. Therefore, it seems that it is presence of iron that confers hardness on the concretion.§ A correlation also appears between the specific gravity of the material reduced to power (Fig. 2) and the iron content (compare Figs. 1 and 2). If lateritic crusts are crushed and the crushed product is sieved the obtained grain size fractions also show the characteristics noted before (Fig. 1, Table I).* These results are in agreement with those obtained by other experimenters (Central Road Resarch Institute, India; Oertel, 1955).

The consistency limits of the material when reduced to powder (Fig. 3) show three types of differentiated materials: (*a*) material proceeding from the coarse fractions—as a rule intermediate w_L and w_P, with the lowest plasticity and shrinkage; (*b*) material proceeding from intermediate fractions—as a rule, the liquid and plastic limits are very low with poor plasticity and shrinkage; (*c*) fine material, with higher limits of plasticity and shrinkage.

*"Materials" rather than "soils" is used because the study is done not from the pedologic point of view, but from the civil engineering standpoint. "Lateritic Concretions" could be used in place of "lateritic materials."

†*Tout-venant* lateritic in French terminology.

‡According to Maignien (1958), p. 13, *cuirasses* and *carapaces*.

§It is not meant that it is the exclusive concreting element, but only the one which confers the greatest hardness on the concretions.

PREPARATION OF SAMPLE

Experience shows that: (*a*) the handling of samples and the performance of tests increase significantly the percentage of the fine materials (L.N.E.C., 1959); (*b*) adherent to the concretions or involved by the concreted material is a lighter and soft material of different chemical composition (Oertel, 1955); (*c*) even in the case of the lateritic gravel with hard pisolites, grains are sometimes found which do not resist the action of water and/or disintegrate under a little pressure of the fingers after immersion (L.N.E.C., 1959).

Three methods were used to separate in a dry way the soft and adherent material. (1) manual—A test sample of 250 grams of material passing through the ⅜ in. sieve was separated; this sample was introduced into a 1 liter bottle with a wide mouth. The bottle was sealed and agitated at a rate of about eighty agitations per minute, for 5 minutes. (2) The material was rotated for a certain period of time in a porcelain ball-mill jar, 22-cm diameter model, but without balls.

*More detailed individual results are kept in the L.E.A. (Laboratório de Engenharia de Angola).

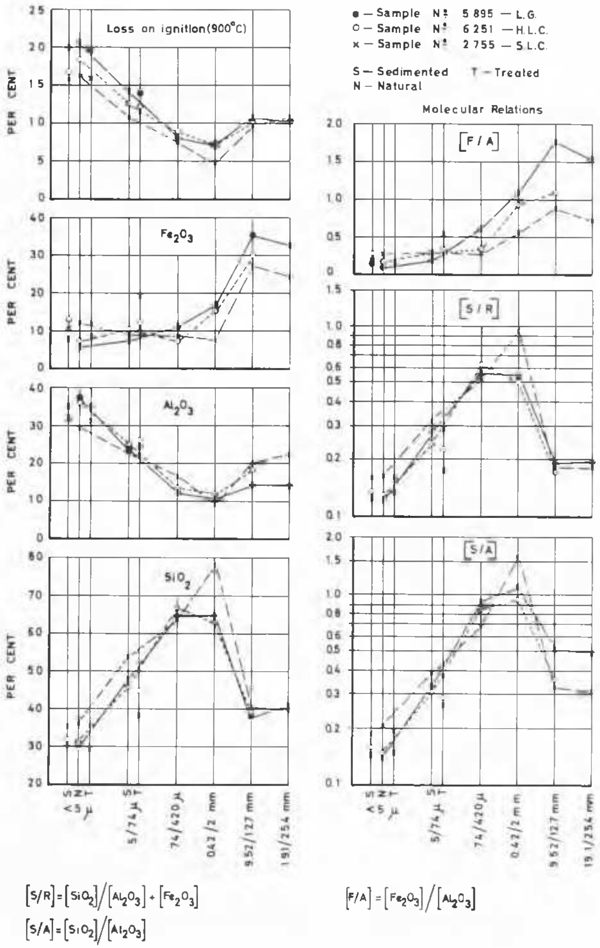

FIG. 1. Chemical composition related to particle size.

(3) In the Los Angeles abrasion machine (AASHO T96) 5 kg of the lateritic material were subjected to a certain number of turns, without using any charge of balls. The results show that the manual method is dependent on the operator, and the second method is inadequate, almost not altering the initial state of the sample. The Los Angeles method proved to be of interest (Fig. 4).

The numeric over-all appreciation of the gradings is difficult. Therefore a similar method to the one used for construction materials (concretes) was adopted. Thus, with the more commonly used sieves in soil tests, the granulometric modulus (M_G) has been defined as the sum of the percentages of material passing the 1-in., ¾-in., ½-in., ⅜-in., No. 4, No. 10, No. 40, and No. 200 ASTM sieves. This index depends on fineness, the smaller the particle sizes the larger the M_G. It has also been defined thusly: hardness index of concretions (I_{HC}) $= M_G$ (in natural state)/M_G (after a standardized treatment) $\leqslant 1$.

Fig. 4 shows the effect of rotation on grain size. The initial increase in the fine particles possibly corresponds to the separation of the materials adherent to but not exactly part of the concretions. It is thus considered advisable not to exceed 200 to 300 turnings—because the wear on the material is small and because the separation of the fines adherent to the concretion surface is practically completed. The number of 200 turnings has been fixed. The statistical results are shown in Tables II and III.

Fig. 1 shows that the chemical composition of the fine materials obtained after treatment (treated material) proved to be analogous to that of the natural fine materials. This is true for the specific gravity as well (Fig. 2). In Fig. 5 some physical properties obtained for different samples are

TABLE I. CHEMICAL COMPOSITION—MEAN AND EXTREME VALUES

Type fraction		Extreme values, percentage					
		LG		HLC		SLC	
		Sedimented	3/8 in.	Sedimented	3/8 in.	Sedimented	3/8 in.
Loss on ignition (900 C)	X_{max}	23.3	12.7	17.9	10.6	16.0	10.4
	$\bar{X}$	16.0	10.0	15.0	9.0	14.0	9.0
	X_{min}	11.4	6.1	11.0	6.0	13.2	6.7
SiO_2	X_{max}	45.2	63.9	45.8	60.1	43.5	65.8
	$\bar{X}$	36.0	40.0	37.0	46.0	38.0	51.0
	X_{min}	23.3	22.1	28.0	37.3	33.9	39.6
Fe_2O_3	X_{max}	19.6	48.2	20.7	40.4	15.4	29.5
	$\bar{X}$	12.0	31.0	15.0	28.0	10.0	22.0
	X_{min}	5.0	15.5	8.1	17.9	4.8	11.9
TiO_2	X_{max}	9.3	7.0	9.6	5.4	6.8	4.5
	X_{min}	3.2	0.9	1.6	1.2	1.9	1.2
MnO	X_{max}	0.84	0.90	0.26	0.68	0.03	0.04
	X_{min}	0.01	0.02	0.01	0.02	0.01	0.01
Al_2O_3	X_{max}	42.0	25.0	36.0	26.0	34.0	20.0
	$\bar{X}$	31.0	16.0	30.0	16.0	33.0	15.0
	X_{min}	23.0	4.0	15.0	9.0	28.0	8.0
Molecular relations [S/R]	X_{max}	2.22	5.40	2.09	5.01	2.17	5.77
	$\bar{X}$	1.6	2.1	1.6	2.5	1.4	3.2
	X_{min}	0.91	0.86	1.14	1.63	1.40	1.80
[S/A]	X_{max}	3.19	20.77	5.18	11.38	2.41	11.18
	$\bar{X}$	2.0	5.0	2.3	6.0	2.0	6.0
	X_{min}	1.12	2.01	1.65	2.84	1.69	3.36
[F/A]	X_{max}	0.48	4.83	0.79	2.09	0.35	2.29
	$\bar{X}$	0.24	1.5	0.30	0.75	0.20	0.6
	X_{min}	0.09	0.40	0.14	0.48	0.10	0.45
No. of values		40	29	14	13	8	8

X_{max}—maximum value; $\bar{X}$—mean value; X_{min}—minimum value.
$[S/R] = [SiO_2]:([Al_2O_3] + [Fe_2O_3])$
$[S/A] = [SiO_2]:[Al_2O_3]$
$[F/A] = [Fe_2O_3]:[Al_2O_3]$

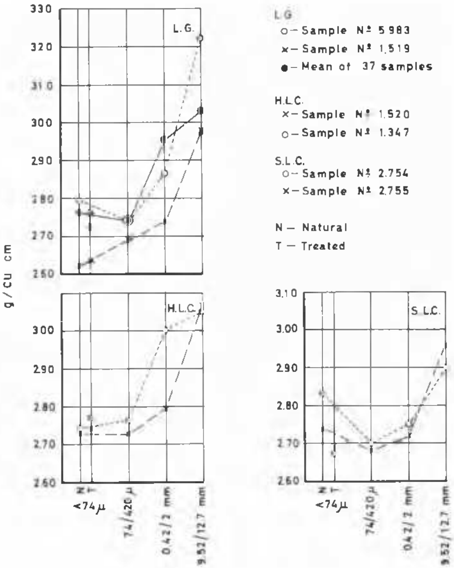

FIG. 2. Specific gravity of solid material reduced to powder.

compared. The results distribute along a straight line at 45° which corresponds to identity of values. The deviation from that line seems to be exclusively due to dispersion of tests, and is not significant.

Regarding the compaction action in the compaction and CBR tests and also on the job, it is known that the particle size composition alters in the direction of an increase of the fines (L.N.E.C., 1959; Baker, 1958; Evans, 1958). If the sample is previously treated the results no longer suffer so much from that influence (see the relations of M_G before the test to M_G after the test in Tables IV and V). The difference in behaviour is accentuated as the hardness of the material decreases. It should be noted that compaction also has an aggregation effect which is deduced from the tendency of the granulometric moduli to decrease after the test when the lateritic material is harder. The values of $(M_{Gb}/M_{Ga}) > 1$ have an aggregation signification.

The AASHO M-147-57 standard specification refers in 2(b) to a percent of wear, by the Los Angeles test, not more than 50. Lateritic materials submitted to the Los Angeles test show, as a rule, a percentage above 50 per cent and sometimes even higher than 70 per cent (L.N.E.C., 1959). Portuguese engineering laboratories have accepted 65 per cent as the maximum value (L.N.E.C., 1959) because it was found that, generally lateritic materials with this value give good results in roads.

The Los Angeles* test carried out with material just as it

*In this case it is about the AASHO T 96 test, therefore with ball load together with the sample.

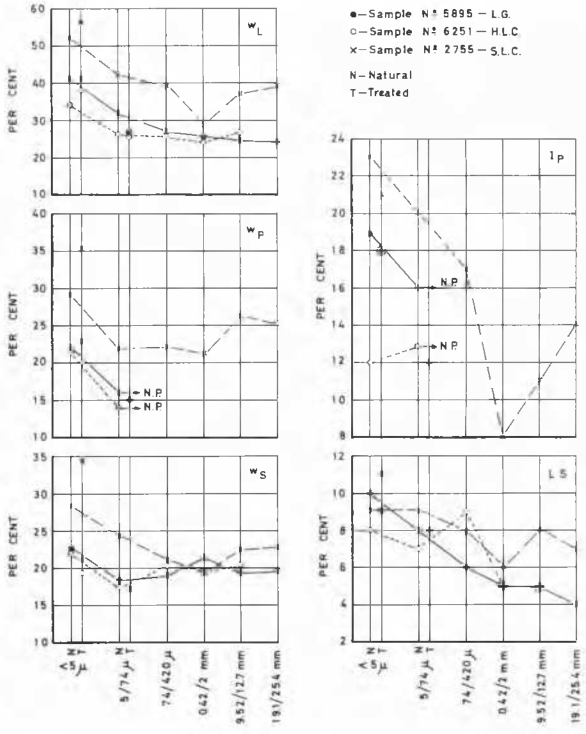

FIG. 3. Physical properties of the material reduced to powder.

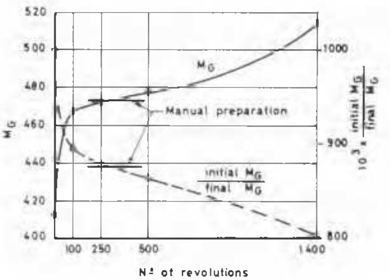

FIG. 4. Influence of the number of revolutions on the grain size (Los Angeles abrasion machine).

TABLE II. FREQUENCIES OF M_G

Values of M_G	Frequencies					
	LG		HLC		SLC	
	Nat.*	Treat.†	Nat.*	Treat.†	Nat.*	Treat.†
240 to 280			2			
280 to 360	8		3	1	2	
360 to 440	12	8	8	4	5	1
440 to 520	44	19	14	8	2	
520 to 600	9	38	1	11	1	4
600 to 680	2	7		3		3
680 to 760		3		1		2
No. of values	75	75	28	28	10	10
AVERAGE	464.8	536.8	436.4	517.8	412.7	600.0

*Nat.—natural material.
†Treat.—material treated (200 turnings).

comes from the pit separation of fine material adherent to those concretions.

A total of 113 laterite samples have been prepared and the obtained hardness indices are shown in Table III. Although they have varied between 0.54 and 0.98, the median values are high and approximately equal for the lateritic gravels and for the hard concretions, and much lower for the soft concretions. The requirement $I_{HC} \geqslant 0.80$ eliminates all soft concretions tested, and also some hard concretions which are rather vesicular and easy to fragment. In Angola only laterites with an $I_{HC} \geqslant 0.80$ are used for roads and as far as we know this standard has proved satisfactory.

In conclusion it is verified that:

1. The treated material does not alter the results of the chemical and physical tests carried out on fine fractions of the lateritic materials.

2. The treated material shows a more stable grading during the mechanical tests.

3. The I_{HC} value seems very useful for separating the soft materials from the hard ones.

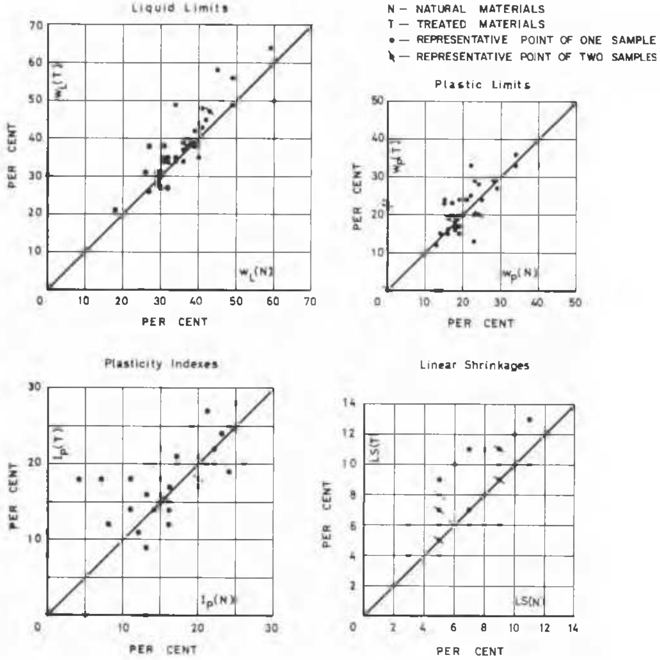

FIG. 5. Physical properties.

TABLE III. HARDNESS INDEX OF CONCRETIONS (I_{HC})

I_{HC}	Frequencies		
	LG	HLC	SLC
0.54 to 0.60	1	1	1
0.60 to 0.64		1	2
0.64 to 0.68	1	1	2
0.68 to 0.72		1	1
0.72 to 0.76	4	1	1
0.76 to 0.80	3	3	3
0.80 to 0.84	10	3	
0.84 to 0.88	21	6	
0.88 to 0.92	26	3	
0.92 to 0.96	7	6	
0.96 to 1	2	2	
VALUES	75	28	10
AVERAGE	0.85	0.84	0.96

TABLE IV. EFFECT OF COMPACTION ON PARTICLE SIZE COMPACTION TESTS

Sample no.	I_{HC}	Compaction	Sample preparation	M_{Gb}/M_{Ga}
6.250 LG	0.92	Standard	Natural	1.02
			Treated	0.15
		Modified	Natural	1.01
			Treated	1.04
6.251 LG	0.84	Standard	Natural	0.92
			Treated	0.99
		Modified	Natural	0.90
			Treated	0.98

TABLE V. EFFECT OF COMPACTION ON GRAIN SIZE CBR TESTS

Sample no.	I_{HC}	Sample preparation	M_{Gb}/M_{Ga} per no. of blows			
			12	24	56	56-H
6.250 LG	0.92	Natural	1.03	1.02	1.01	1.00
		Treated	1.08	1.07	1.05	1.06
6.251 LG	0.84	Natural	0.98	0.94	0.92	0.91
		Treated	1.04	10.1	0.99	0.99

12, 24 and 56 blows by layer with the common rammer.
56-H-blows by layer with the heavy rammer.

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