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Physical and Mechanical Characterization of a Swelling Clay: The Case of Dabanga Karal in the Far North Region of Cameroon

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***Abstract*— The purpose of this paper was to determine certain physical and mechanical characteristics of a swelling clay called Karal, at Dabanga in the Far North Region of Cameroon. Not limited to, the following tests were carried out natural moisture content, consistency characteristics (Atterberg limits), Modified Proctor, California Bearing Ratio tests (CBR) and linear swelling, weight density ... These tests were carried out on five samples reworked of Karal and results show that it is a swelling clay with a fairly high plasticity (of about 40%) of A7-6 class in the American classification Highway Research Board (HRB).**

Keywords*— *Karal; Dabanga; Geotechnical; Characteristics; Swelling Clay; Swelling;

I. INTRODUCTION

In Africa, the road network is essentially composed of dirt roads poorly maintained, which contributes to the problems of landlocked countries of this continent. According to the latest reports from the World Bank, Africa is particularly affected in its sub-Saharan part with only 12% of paved roads [Gumisai, 2002]. In Cameroon, the statistics of CTIN[1] of the Ministry of Public works (MINTP) reveals that in 2011, for a road network which stretched over about 77 589 km (including lanes and ways), only 5145 km of roads were bituminized (6.62 %). According this same report, the far North is not spared by this issue of isolation; Indeed, there are 586 km of roads paved out of a total of 12 533 km in this Region (4.68% only).

The Karal (classified as vertisols), is a clayey soil abundant in the northern part of Cameroon, specifically in the Far North, where it covers about 73% of soils in this region (Ekodek, 1976). To address the lack of laterite in this region, the Karal is frequently used both in the construction of paved roads in the development of earth roads. This very resistant clay dry season is quite swelling in the presence of water, making the dirt roads impassable during rainy seasons and paved roads subject to significant degradation, due to the phenomenon of shrinkage and swelling. This is a serious issue as far as the movement of people is concern.

[1] The 'Centre de Traitement de l'Information Numérique' (CTIN) uses data collected in the field by the various operational departments of the Ministry of Public Works and the results of research institutions such as SODECOTON.

This work is entitled "Physical and mechanical characterization of a swelling clay: The case of Dabanga Karal in the Far North Region of Cameroon". The objective of this paper concerns the geotechnical characterization of Dabanga Karal alone, in order to determine its physical and mechanical properties such as natural moisture content, consistency characteristics (Atterberg limits), Modified Proctor, California Bearing Ratio tests (CBR) and linear swelling, weight density ... This approach has the purpose to contribute in geotechnical road to deal with the poor performance of the roads in the northern part of Cameroon where the phenomenon of shrinkage and swelling of Karal is the origin of early destruction of roads, whether coated or uncoated.

II. THE KARAL OF CAMEROON

It is a clay of more or less dark gray color that soil scientists call tropical black clay. The bulk of the Cameroonian Karal is located in the far North, where Ekodek (1976) located it between the 14th and the 16th degree of longitude east and then the 10th and the 13th latitude north; He considers the area occupied by the Karal at about 25,000 km^2, nearly 73% of the soils of this region.

The Karal, consisting of a mixture of montmorillonite, kaolinite and illite and some other mineral, like which have the aptitude for the collection-swelling would be linked to the quantity of montmorillonite (30 %) and the importance of lower fraction in 2 μ_m that it contains (Livet, 1988).

When a sample of Karal is sieved, we find it consists essentially of fines which sometimes third is composed of montmorillonite. With a liquid limit of around 70%, the Karal has a plasticity index close to 40% which in the rainy season it is almost impossible to move; clay (the Karal) becomes subject to large deformations due to the action of traffic resulting in deep ruts that make movement almost impossible (Liautaud 1972).

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Fig. 1.1. Location of the site of sample of the Karal in Dabanga

Another feature of Karal is its plasticity is ability to withdrawal - swelling. Indeed, in the dry season, it shrinks and cracks of up to 1 m deep and open up to 4-8 cm wide are formed on the surface (Liautaud 1972). During the rains, the cracks are filled with water so that the clay absorbs and starts to swell.

Fig. 1.2. Picture on the Dabanga Karal: opening of cracks greater than 10 cm

All these properties make Karal a material whose mechanical properties are often poor: in fact Liautaud (1972) and Livet (1988) show that the CBR of Karal soaked in 4 days rarely give a better result than 5%.

III. SOME RESULTS OF PREVIOUS WORK ON THE KARAL

Table 1.1 presents the results of previous work done on the Karal by various authors (Lyon Associates Inc. 1971 Liautaud 1972 Laroche 1973 Ekodek 1976 Livet 1988). These results relate to certain mechanical and physical characteristics of various types of Karal.

Table 1.1. Summary of some previous results on Cameroonian Karal

N°	Authors	Physical Characteristics								
		Identification			Atterberg limits (%)				Swelling	
		W (%)	γ	granulometry	LL	PL	PI	LS	free	potential
1	Lyon Associates Inc., 1971			coarse sand 5-8%; fine sand: 10 - 15 %; slits: 20 - 30 %; clays 60-75%					> 50%	28%
2	Liautaud G., 1972				59 - 85	29 - 45	30- 40	15		
3	Laroche C., 1973			%tage < 80µ: 94%; %tage < 5µ: 47%	67	29	38	15		
4	Ekodek G. E., 1976 – Maroua region	46	2,6		40,8	19,3	21,5		85	
	Ekodek G. E., 1976 – Kousseri region		2,5		58,2	26,6	31,6		95	
	Ekodek G. E., 1976 – Makari region		2,5		46,2	22,1	24,1		81	
5	Livet Marc, 1988			%tage < 80µ: 94%; %tage < 5µ: 47%	58 à 72	26 à 33	33 à 39	15		

N°	Authors	mechanical characteristics							
		Modified Proctor			CBR (%)		Shearing Test		
		$\gamma_{d\ opt}$ (g/cm^3)	W_{opt} (%)	n (%)	W_{opt} (%)	After 4 days of imbibition	ϕ_u	C_u (bar)	R_c(bar)
1	Lyon Associates Inc., 1971	1,66 à 1,91	13 à 20		CBR = 1,6 à 5,3 (No further details)				
2	Liautaud G., 1972	1,7	18,5						
3	Laroche C., 1973	1,61 à 1,86	14 à 22		31 à 34	2 à 4	5°	0,15	
4	Ekodek G. E., 1976 – Maroua region	1,92	13,2	26,15	38 à 44	7 à 13	42°	0,625	37,68
	Ekodek G. E., 1976 – Kousseri region	1,84	16,2	31,09	20 à 48	2 à 6	30°	2,675	22,82
5	Livet Marc, 1988	1,66	20		30	3			

IV. THE TESTS CONDUCTED IN LABORATORY

Laboratory tests carried out are shown in Table 1.2; there are compiled types of tests, the test materials, the required parameters and the standards defining the procedures of these tests.

Table 1.2. Program tests of characterization of Karal.

Type of tests		Parameters sought	Number of samples.	Number of tests/ sample	total tests	Norms
Tests on Dabanga Karal	Identification tests	Water content	5	**4**	20	NF P 94 – 050
		density of solid particles	5	**4**	20	NF P 94 – 054
	Particle size analysis	Soil grain diameter	5	**2**	10	NF P 94-056 & NF P 94-057
	clay content test	Activity of the clay fraction of soil	5	1	5	NF P 94-068
	Atterberg limits	Liquid Limit (LL) and Plastic Limit (WP); Plasticity Index (PI)	5	**5**	25	NF P 94-051
	Modified Proctor	Proctor Optimum	5	**5**	25	NF P 94-093
	CBR test	Indices CBR	5	3	15	NF P 94-078
	Oedometer tests	Consolidation pressure, oedometric module swelling and compression coefficients.	5	2	10	NF XP P 94-091
	triaxialn shear tests	Cohesion, internal friction angle	5	2	10	NF P 94-070

V. SUMMARY OF SOME RESULTS ALREADY OBTAINED

Several results are currently available from the current analysis. Table 1.3 presents the summary of some of them. The Table 1.4 shows a summary sheet of the results of physical and mechanical characterization of the G1 sample.

Table 1.3. summary of some results already obtained (Samples G1, G2, G3, G4 and G5)

N°	Designation	SYMBOL	G1	G2	G3	G4	G5	AVERAGE
1	Natural Water Content (%)	W nat	18	13		13	11	13,75
2	Liquidity Limit (%)	LL	64,1	66,2	62,5	57,6	64,1	**62,90**
3	Plasticity Limit (%)	PL	26,1	21,3	22	21,1	26,1	**23,32**
4	Plasticity Index (%)	PI	38	44,9	40,5	36,5	38	**39,58**
5	Linear Swelling (%)	G	2,13	3,07	4,17	3,15	3,31	**3,17**
6	Soil Dry Density (kN/m^3)	γd	16,6	17	17	17,6	16,6	**16,96**
7	CBR after 4 days of immersion	CBR	6,6	4,5	5	6	6,5	**5,72**
8	Saturation water content (%)	Wsat	22,4	17,6	23,5	18,4	22,4	**20,86**
9	Greatest density (kN/m^3)	γd opt	17,4	17,8	17,6	18,6	17,4	**17,76**
10	Optimum water Content (%)	Wopt	17,6	15	19	14,6	17,6	**16,76**
11	Tamisat to 80µ (%)		65,38	90,99	82,42	91,69	91,70	**84,44**
12	consolidation pressure (bar)	σ_0	**0,515**	**0,575**	**0,550**	**0,350**	**0,600**	**0,518**
13	compression coefficient	Cc	**0,170**	**0,134**	**0,160**	0,129	0,133	**0,145**
14	swelling coefficient (free)	Cg	**0,015**	**0,013**	**0,017**	0,014	0,012	**0,014**
15	Cohesion (bar)	c	0,220	0,460	0,390	0,320	0,520	**0,382**
16	internal friction angle (°)	φ	20,00	**13,22**	9,00	23,00	19,00	**16,844**
17	Tamisat the 2µ (%)		49,92	68,19	58,99	58,90	70,01	**61,203**
18	Activity of karal	A	0,761	0,658	0,687	0,620	0,543	**0,654**
19	Index empty	e_0	0,648	0,615	0,675	0,59	0,657	**0,637**

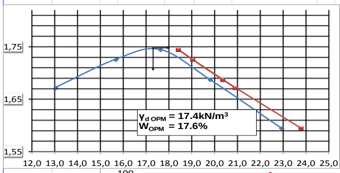
Table 1.4. summary sheet of the results of physical and mechanical characterization, the example of G1 sample

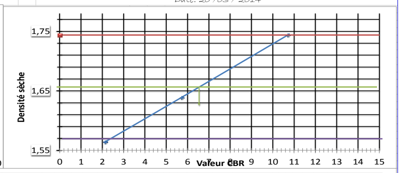
LABORATOIRE NATIONAL DE GENIE CIVIL
BP 349 - LABOGENIE - YAOUNDE
Tél. et Fax 22 30 30 06

Dossier: Travaux de Recherche - LIMALEBA - Etude d'amélioration du karal de Dabanga
Provenance: Dabanga - Echantillon G 1 | Nature: Karal grisâtre

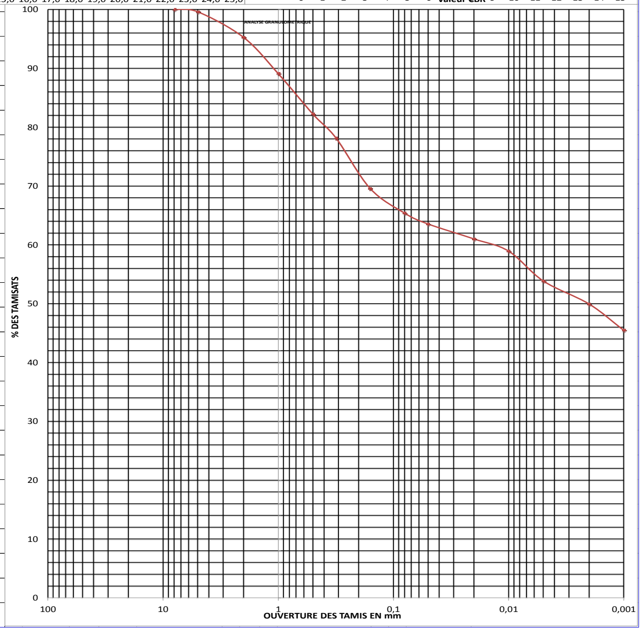
ESSAIS D'IDENTIFICATION								Classification	
W_L	64,1	γ_S (KN/m^3)	25,7	γ_d (KN/m^3)		CBR	Wsat (après 4jrs im.)	H.R.B.	G.T.R.
W_P	26,1	M.O.		55cps	17,4	11	21,6	A - 7 - 6(20)	A 3
I_P	38,0	Gonflement	2,13	25cps	16,6	6	22,4	CBR à 95% OPM après 4jours d'immersion	
I_C	1,2	Wnat. (%)	18,0	10cps	15,7	2	23,5	6,5	

Date: 20 /03 / 2014





Tamis en mm	% Tamisats
80	
63	
50	
40	
31,5	
25	
20	
16	
12,5	
10	
8	100,0
5	99,6
2	95,3
1	89,1
0,5	82,2
0,315	78,1
0,160	69,6
0,080	**65,4**
0,05	63,5
0,02	61,0
0,01	58,9
0,005	53,8
0,002	49,9
0,001	45,4



LABO GENIE

Provenance :	Travaux de Recherche LIMALEBA			**Prof:**	1,5m
Sondage :	G1 OPM 95%	**Nature :**	KARAL DE DABANGA		Date: 03 / 04 / 2014

Réalisation :

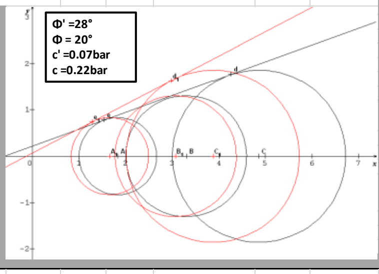
Contraintes à la rupture			
σ3 (bar)	**1**	**2**	**3**
σ1-σ3 (bar)	*1,669*	*2,596*	*3,725*
U (bar)	*0,176*	*0,227*	*0,995*
σ'1=σ1-U (bar)	*2,493*	*4,369*	*5,730*
σ'3=σ1-U (bar)	*0,824*	*1,773*	*2,00477*

Paramètre des cercles en contraintes totales

	Cercle n°1	Cercle n°2	Cercle n°3
Centre	*1,83*	*3,30*	*4,86*
Rayon	*0,83*	*1,30*	*1,86*

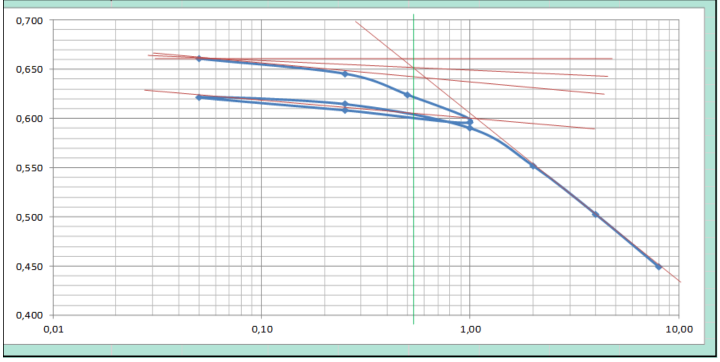
Paramètre des cercles en contraintes effectives

	Cercle n°1	Cercle n°2	Cercle n°3
Centre	*1,66*	*3,07*	*3,87*
Rayon	*0,83*	*1,30*	*1,86*



	LABORATOIRE NATIONAL DE GENIE CIVIL							
	BP 349 YAOUNDE Tél. et Fax. 22 30 41 65							
	CALCUL D'ESSAIS DE COMPRESSIBILITE							
	ET DE PERMEABILITE							
Provenance :	Travaux de Recherche LIMALEBA ENSTP					Date :	05/04/2014	
Sondage :	OPM à 95%		Echantillon n°G1 Bis		Profondeur : m			
Nature :	100% de Karal+0% de sable							
Poids humide (g) :	139,13	Poids Sec (g) :	123,5	Tare (g)		58,79		
Teneur en eau initiale :			Teneur en eau finale (%)			24,15		
Section Appareil (cm²) :		20	Poids spécifique γs (kN/m³) :			27		
hp (mm) = Ps/(γs x S)		11,98	Hauteur initiale H0 (mm) :			20		
eo : Indice des vides initiale			C_c : Coefficient de Compression					
σ0 : Pression de consolidation : (bar)			C_g : Coefficient de Gonflement					
C_V: Coefficient de consolidation (cm^2/s)			Eoed: Module oedométrique					

PRESSION (Kg/cm²)	M	H = H0 - M	e = (H - Hp)/Hp	Résultats		E_{oed}	C_V (cm^2/s)	K (cm/s)
0	0	20	0,669					
0,05	0,0986	19,901	0,661	e_0 =	0,648	10,15	$3.93*10^{-3}$	6,63E-04
0,25	0,2819	19,718	0,645	σ0(bar) =	0,515	21,82	$1.64*10^{-3}$	5,93E-04
0,50	0,5383	19,462	0,624	Cc =	0,170	19,51	$9.58*10^{-4}$	4,81E-04
1,00	0,8738	19,126	0,596	C_g =	0,015	29,80	$1.08*10^{-3}$	4,19E-04
0,25	0,7268	19,273	0,608			102,04	$2.01*10^{-3}$	5,93E-04
0,05	0,5676	19,432	0,622			25,12	$8.76*10^{-4}$	6,45E-04
0,25	0,6519	19,348	0,615			47,46	$2.28*10^{-3}$	5,10E-04
1,00	0,9455	19,055	0,590			51,10	$6.65*10^{-4}$	4,22E-04
2,00	1,4032	18,597	0,552			43,70	$1.06*10^{-2}$	3,65E-04
4,00	1,9945	18,006	0,503			67,65	$5.15*10^{-4}$	2,98E-04
8,00	2,6320	17,368	0,449			125,48	$2.88*10^{-4}$	2,71E-04



VI. DISCUSSION OF RESULTS

According to the classification American soils of the Highway Research Board (HRB) based on the particle size analysis and Atterberg limits, Dabanga Karal is classified in the A7-6 group, which corresponds to clayey soils. Indeed, it has a percentage of passing through a sieve of 80µ 84.44% (> 36%), a liquid limit of 62.90% (> 41%) and a plasticity index of 39.58% (> LL-30).

Furthermore, with a 62.90% of liquid limit and a plasticity index of 39.58%, the Dabanga Karal is classified, on the Casagrande plasticity abacus, from the group of the minerals clays of high plasticity.

The results of the study show that the mechanical properties of Dabanga Karal are rather weak; in fact it has a CBR of 5.72% (with a linear swelling of 3.17%), optimum dry density of 17.76 kN / m3 (with optimum water content of 16.76%).

The consolidation pressure of Karal is 0.518 bars with a coefficient of compression of 0.145, whilst its cohesion is in the order of 0.382 with an internal friction angle of about 16.844°.

All these results show in adequacy that the Karal of Dabanga, to be used in road building, requires an improvement of its geotechnical characteristics.

VII. CONCLUSION

In this paper, the issue was to determine the physical and mechanical characteristics of Dabanga Karal, in the region of the Far North of Cameroon. Laboratory tests were the basis of this characterization; the results thereof show that Karal of Dabanga is a swelling clay which to be used as fill material in the construction of roads in this area, should be treated or enhanced.

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