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Karal Clay in the Far North Cameroon: Study on Behavioural Floor Structures

E. Ngale Haulin[1], F. Tchangnwa Nya[1,2,*] and B. Touogam Touolak[1]
[1] Department of Materiel Processing, Architecture and Habitat, Higher Institute of the Sahel
[2]Department of physics, Faculty of Sciences, University of Maroua.
**Corresponding author: nyafridolin@yahoo.fr*

Abstract:- The north is known for its scorching heat and swelling clay which in the presence of water, dramatical increase in water volume and by drying or even to crack [2] [5]. Many authors have addressed the problems posed by this type of ground vis-à-vis the construction and especially the buildings. What exact type of transport infrastructure can be built on these soils? It is to answer this question that we focus our research on Karal clay, the main constituent of soil in the region of Far Northern Cameroon. Over 21,489 km of roads in Cameroon in charge of the state, nearly 44.5% are in poor condition. The Far North Region of Cameroon is one with the longest straight road in poor condition. In about 2374 km of road, only 1% is in good condition, 20% in fair condition and 79 in poor condition [3] [8]. The damage seen on the N-1 Kousséri Maroua road in the region of the Far North is related to a combination of stresses: it supports the traffic, the weather, the layer thickness and the quality of materials that constitute it. All these stresses are associated in one way or another with the clay soil blowing up known for its instability to participate in the degradation of these roads [3] [6] [13]. The primary mission of this scientific work is to provide necessary information and capital on Karal clay, mineralogy, and its behaviour with respect to pavement structures in the Sahel. However, laboratory studies on Karal clay, allowed better assessment of its physical, chemical and mineralogical characteristics. Armed with these scientific findings it allow us to better understand the Karal clay and its behaviour on the ground in the Sahel region, we have developed strategies to increase the profitability of road investments on swelling clay soil. To achieve the expected results, we submitted samples of Karal clay testing of physical-chemical-mineralogical characterisation laboratory. It is in particular, the determination of the water content and organic matter, the complete particle size analysis, determination of Atterberg limits, Proctor changed, testing Californian Bearing Ratio of the oedometer test, the shear test straight to the box Casagrande, and finally the X-ray diffraction

Keywords:- Karal Clay - Swelling Clay Soil - Geotechnical and Mineralogy Clay - Sahelian Zone.

1. INTRODUCTION

The State of Cameroon has central goal of being an emerging country by 2035. To achieve this, we see that the program since 2013 in the Ministry of Public Works is essentially built around communication channels in general and more particularly road infrastructure, essential sector for the socio-cultural and economic development of a country. This is fully in line with this quote after the World Summit on the road which was held in Durban in 2003 "The road development through the development of the road" [1] [2] [3]. Around the Far North Cameroon is bordered to the North and east by the Republic of Chad, to the west by the Federal Republic of Nigeria, and to the south by the north Cameroon. The axis-Kousséri Maroua is the main communication channel and the shortest, linking Cameroon and Chad put off the air transport. This area is subject to climatic variability (recurrent droughts and indigence rainfall) and soil meet there is mostly clay commonly called 'Karal'. This soil is known for its instability (when the water content increases, its volume also increase and when the water content decreases its volume does the same) making it very vulnerable structures that support and causes premature deterioration of the pavement structures. This is one of the reasons why we are interested in specific Karal clay, a major constituent of the soil of the road Maroua-Kousséri [3] [5] [8]. This study also measures the impact due to the instability of swelling clay soil on pavement structures, in the case of the road Maroua-Kousséri.

II. LOCATION OF THE STUDY AREA

Created by Presidential Decree No. 83/392 of 22 August 1983 following the breakup of the former province of Northern three provinces (Adamawa, North, and Far North) and Presidential Decree 2008 amending appellation province in the region, the region in the Far North is one of the least equipped transport infrastructure areas and soil is not conducive to its isolation. Yet this is an area that has many diverse assets be it on the physical, social, cultural and economic need to return. Around the Far North extends over an area of 34,263 square kilometers, and has our six days (06) departments and 47 municipalities [2] [3].

Figure 1: Far North Cameroon map: Situation, lines of communication, administrative, Tourism, parks and reserves
Source: Road Master Plan of Cameroon: Executive summary. Yaoundé, Centre, Cameroon

III. SYSTEM CLAY SOIL AND WATER-SWELLING CLAY SOIL

1.1. THE WATER IN CLAY SOIL

Clay soil as any soil is a mixture of three components namely: solid, liquid and gas. We are interested in this subtitle to the liquid portion contained in this soil. Water exists in several forms in clay minerals. In order to understand the phenomenon of swelling clay, we present the different types of water that are directly or indirectly linked to this phenomenon [4] [10] [11] [12] [13]:

1.1.1. FREE WATER

By definition, free water in the soil is water that has the ability to move in the ground without any constraint. It is also found in clay. It is completely evaporated when the soil sample is placed in an oven at a constant temperature of 105°C.

1.1.2. CAPILLARY WATER

This water is retained in a meniscus shape in the vicinity of contact points between the particles by capillary forces in clay unsaturated, creating between the grains of the attractive forces. Thus, the capillary flow of water produced by a suction gradient across pores and results in generalised Darcy's law.

1.1.3. BOUND OR ADSORBED WATER

Clay soil are also characterised by the presence around each particle with a layer of water to the different properties of the free water (it has the properties of a fluid less viscous and finally move towards the properties of normal water border, water-free, water-adsorbed with equal to that of the open water final density): it is adsorbed or bound water.

1.2. CLAY-WATER INTERACTION

In clay, the seats of different reactions and interaction mechanisms that are established in the interfolliaire space (or in the vicinity of the outer surface of a particle) between particles and water are also witnessing the isomorphic substitution, some of the cations in octahedral structure between the sheets. These mechanisms work differently depending on whether or in the presence of one or clay, because of bonds between their atoms.

1.3. SWELLING CLAY

In swelling clay soil, changes in water content are the main causes that trigger the instability of these soils

1.3.1. CAUSES SWELLING

And swelling clay compaction are phenomena which occur once there is fluctuation in the presence of stress in water-swellable clay. The change in water content in a soil may have several origins. The main cause of the increase in water content is the change in groundwater level, which varies with seasonal fluctuations in natural groundwater regime. However, it is more variable due to the implementation of agricultural, hydro and construction work of development planning, implementing drainage, pipes, and other technical work that alter food groundwater, the flatness of the ground, the water permeability and the aeration zone [4] [5].

1.3.2. KINEMATICS OF SWELLING

Inspired by the literature review on the swelling clay soil, the kinetics of swelling clay is defined as a parameter that is a function of the deformation and time. Because of the very low permeability clay, the swelling rate is slow. The kinetics of swelling clay soil depends on the nature of clay, their water status and condition of loading [9] [10] [11].

IV. PHYSICAL, CHEMICAL AND MINERALOGICAL TESTS KARAL CLAY: RESULTS AND DISCUSSIONS

1.4. STRAIGHT SHEAR TEST (UU) IN THE BOX CASAGRANDE (NF P94-071-1)

Soil resistance is an absolutely necessary criterion that he should be read in the context of earthworks, embankments, foundations, retaining structures; this in order to solve the problems of soil stability. The determination of this resistance depends on several tests, including triaxial, the simple compression test and direct shear tests. We will use it to determine the short-term characteristics of our sample. It will also determine the total stresses.

1.4.1. SCOPE AND PURPOSE

The shear tests straight to the box, are carried out on all types of natural soil, reconstituted or artificial, the maximum grain size is 5 mm for trials in the box 60mm. The test provides strength parameters, straight shear materials tested, it is the cohesion C., bar and angle of internal friction φ, in degrees. These two parameters are used to calculate stability in soil mechanics.

1.4.2. PRINCIPLE OF THE TEST

The test is performed on a sample of disturbed soil or not placed in a shear box consisting of two independent half-boxes. The parting plane of the two half-boxes is a sliding plane corresponding to the plane of the shear specimen. It consists in applying to the upper face of the specimen a vertical load (N) maintained constant during the entire duration of the test. It is also to produce shear specimen in the horizontal plane according to the sliding of the two half-boxes one with respect to another, by imposing a relative movement at a constant speed of 2 mm / min. And finally, it is to measure the horizontal shear stress (τ) corresponding.

1.4.3. TEST RESULTS

Data from the shear test allowed us to represent the curves of shear unsaturated and saturated sample, from which we got straight Coulomb which allowed us to identify the specific characteristics of our sample in these two states. On unsaturated sample is obtained $\varphi u = 16.86$ ° and $Cu = 0.838$ bar. And saturated sample was obtained $\varphi u = 9.03$ ° and $Cu = 0.08$ bar.

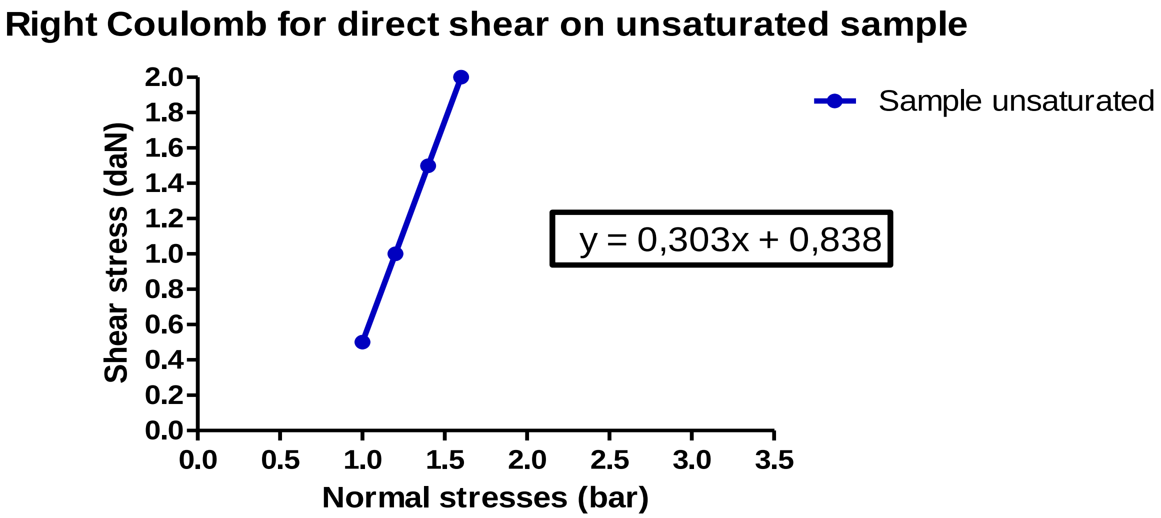

Figure 2: Right COULOMB for direct shear on unsaturated sample

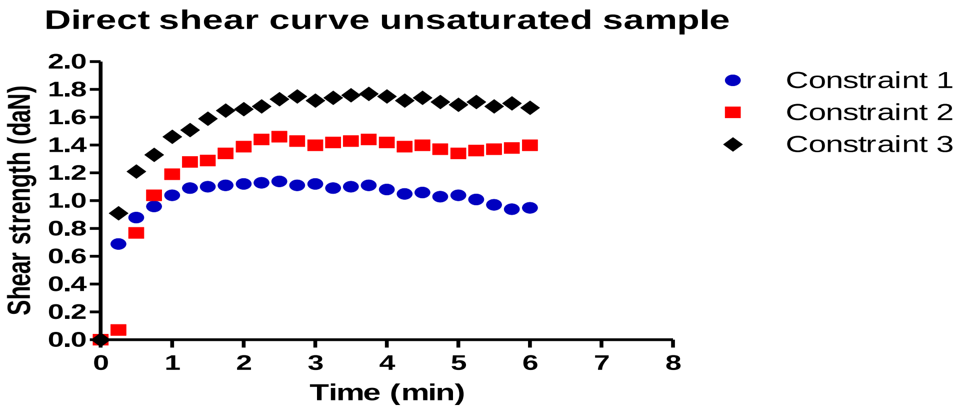

Figure 3: Curve on unsaturated direct shear sample

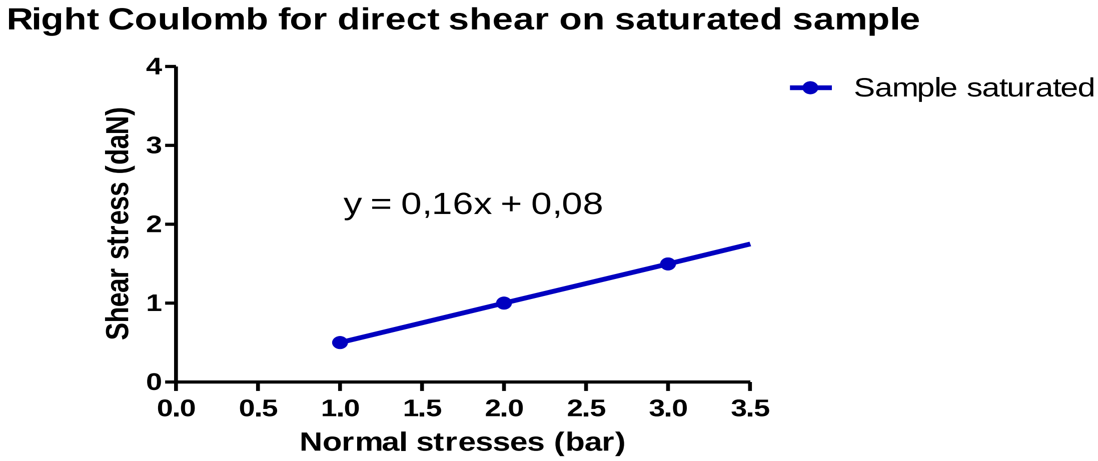

Figure 4: Right COULOMB for direct shear on saturated sample

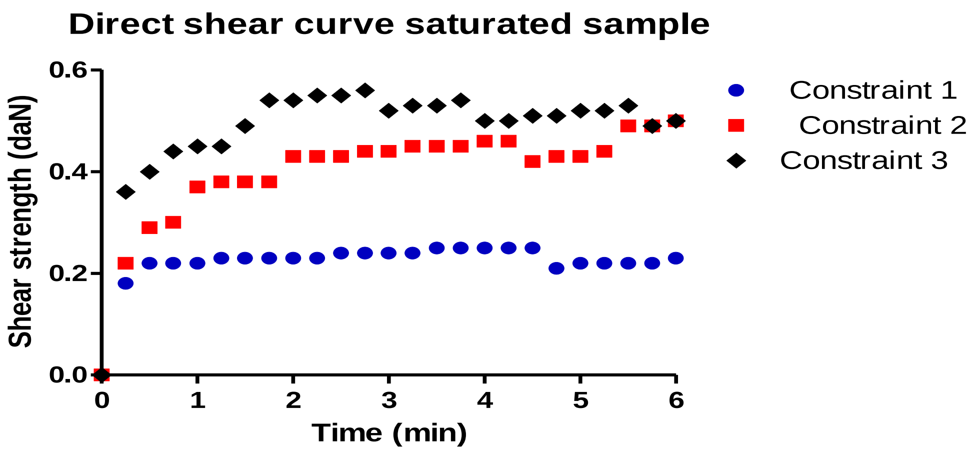

Figure 5: Curve direct shear sample saturated

It is found from these results that the soil moisture greatly influences its mechanical properties. The angle of internal friction in the unsaturated soil compacted to 95% of the PMS is 1.9 times greater than it's compacted to 95% of the PMS and unsaturated soil. Cohesion in an unsaturated soil compacted to 95% of the OPM is 10.5 times greater than in saturated soil compacted to 90% of OPM and saturated.

1.5. PROCTOR CHANGES (NF P 94 093)

1.5.1. AIM OF THE TEST

The lift of soil is the characteristic that determines its ability to withstand the loads applied to it. To achieve the maximum capacity to support these charges, Proctor identifies a particular optimum water content w, noted for Standard Proctor and w_{opm} for modified Proctor compaction which leads to a density ρd dry (or dry density) maximum. The maximum density corresponds to a state of maximum compactness and a maximum capacity of resistance.

1.5.2. PRINCIPLE OF THE METHOD

The American engineer Proctor has shown that for a given compaction energy, the water content had a great influence on the compactness obtained. The principle of the test is to moisten the soil water content to several and compacted in a conventional method and energy. For each value of water content in question, it is determined the dry density of the soil and the variation curve of the density as a function of the water content. In general, this curve called Proctor curve has a maximum value of the dry density, it is obtained for a particular value of the water content. These two values are called Standard Proctor compaction characteristics or Proctor test performed according to Modified. Since these works are oriented in the road sector, we realised only the modified Proctor.

1.5.3. RESULTS AND DISCUSSION

The results are translated into an x-axis representing the compaction water content and dry density ordered graph. The curve obtained is in the form of a bell, it is also pointed at the top. We can tell our soil compaction that is influenced by the water content: This is the inherent characteristic of clay soil. This curve passes through a maximum also called Optimum Proctor. At the optimum Proctor, is the optimum moisture content to achieve maximum compactness for a given soil and mode of compaction determined. The dry density is thus obtained: $\gamma d = 1.80$ kN / m^3 and the optimum water content is of about: $W_{OPM} = 15\%$.

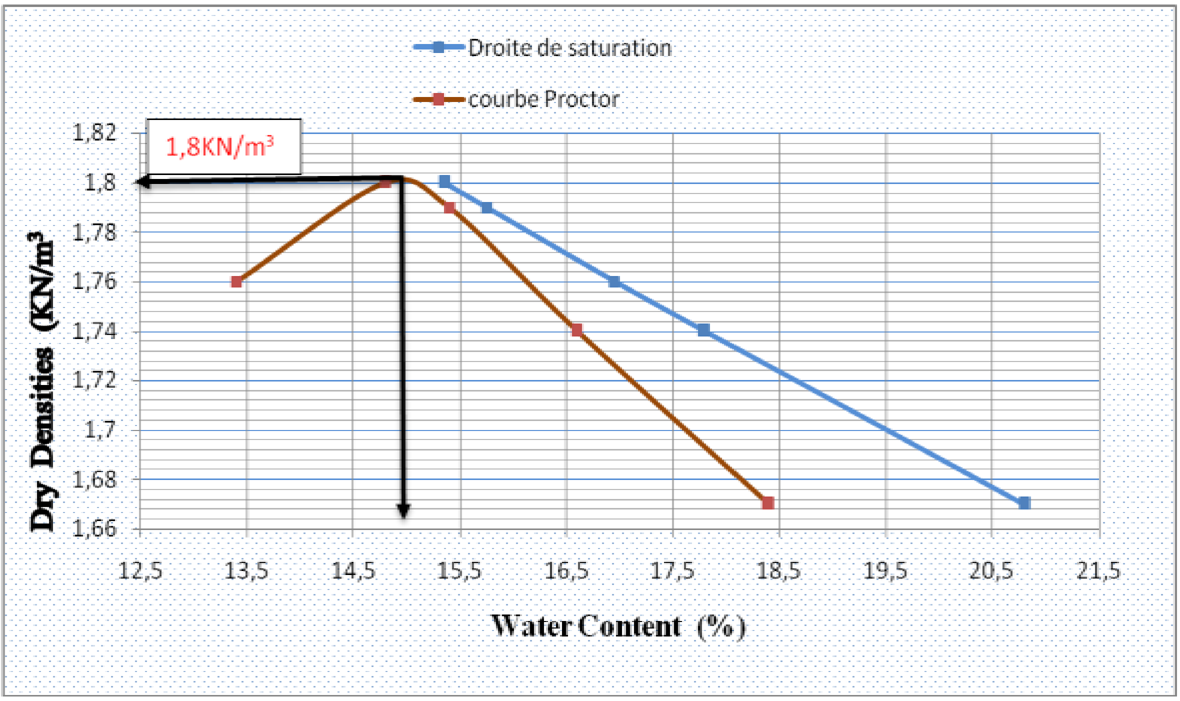

Figure 6: Proctor curve of Karal clay

1.6. CALIFORNIA BEARING RATIO (NP F 94078)

1.6.1. DEFINITION AND PURPOSE OF THE TEST

The CBR test is used to measure the lift of compacted material. It involves comparing the puncture resistance of a material to be tested to that of a reference material California (severe natural). This material is such that a depression of 2.5 mm is observed for a force of 13.2 kN; and a depression of 5 mm for a force of 20 KN. CBR tests to determine: the CBR index after immersion, the CBR immediate index and immediate bearing index of a sample of soil or material to size of the pavement structures. This value is the CBR to 95% of the OPM.

1.6.2. PRINCIPLE OF THE TEST

The general principle of the test is to measure the forces to be applied to a cylindrical punch to make it penetrate to a constant speed in the axis of a specimen to rate of 1.27 mm / min into tubes of the compacted soil energy Proctor (normal or modified) in the CBR mold. Continuously measuring the force applied as a function of the penetration of the punch usually up to 10mm. During this test, a load is placed on the surface of the specimen in order to simulate the load that the structure of the floor exercises.

1.6.3. TEST RESULT AND DISCUSSIONS

The test data have allowed us to draw the CBR curve from which we determined by projecting the x-axis, the meeting point between the curve and the line y = dry density of 95% of the OPM (corresponding to energy compaction to 25 shots) that the CBR value is equal to 7.2. In addition we got a swelling nearly 1.76% on the mold packed with an energy of 25 shots (95% OPM) after 4 days of immersion. Yet the most often recommended in the CCTP (Special Technical Papers Clauses) threshold is 1%. Therefore adequate soil treatment to reduce the swelling rate is required, see paramount.

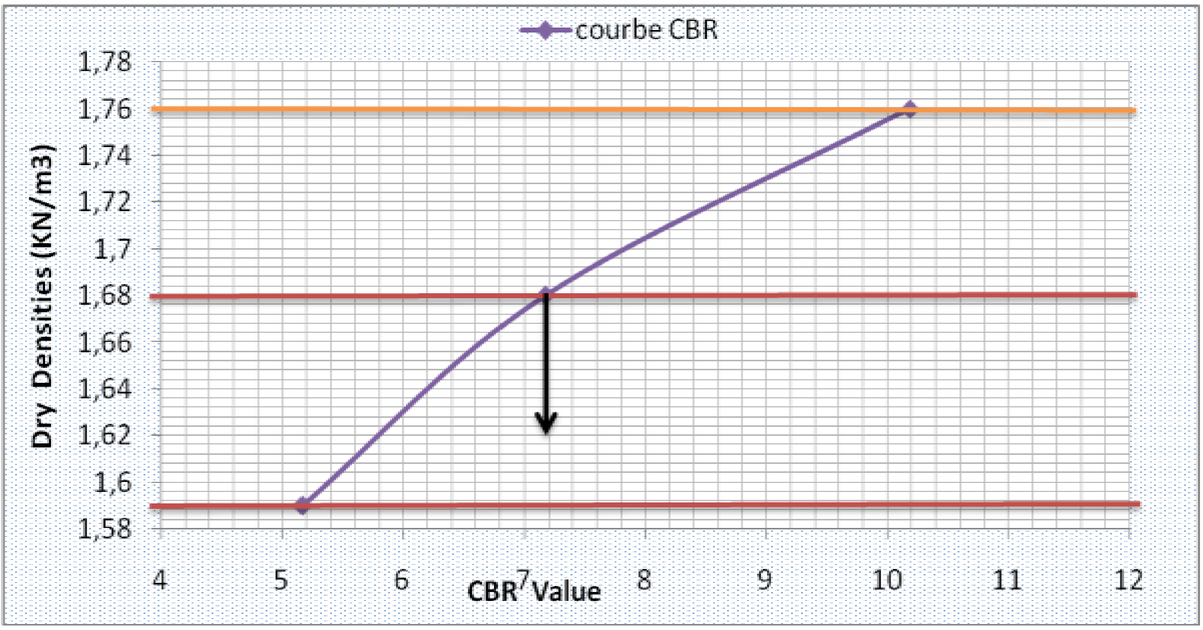

Figure 7: CBR curve Karal clay

1.7. FULL SIZE ANALYSIS (NF P 94-056 AND NF P 94-057)

1.7.1. PARTICLE SIZE ANALYSIS BY SIEVING

This is a set of operations leading to the separation by size of the components of a sample, using a square mesh sieve to obtain a representation of the distribution of the mass of dry particles in a state according to their size. The test consists in separating the agglomerated grains of a known mass of material in the water by stirring, to split the soil once dried through a series of sieves, and the cumulative oversize successively weigh on each screen. The mass accumulated on each sieve refusal is based on the total dry weight of the sample under analysis.

PRESENTATION OF RESULTS AND DISCUSSION

The test particle size analysis has enabled us to get past the screening grading curve representative for a given dimension D, the abscissa the opening screens, and ordered the lower percentage of grains passers dimensions. These results show that the studied soil was 97.4% passing through a sieve of 80 µm (97.4% fine). It is therefore deduced that our studied soil is in the range of clays. These are indeed the 97.4% previously obtained allow us to continue with densitometry analysis.

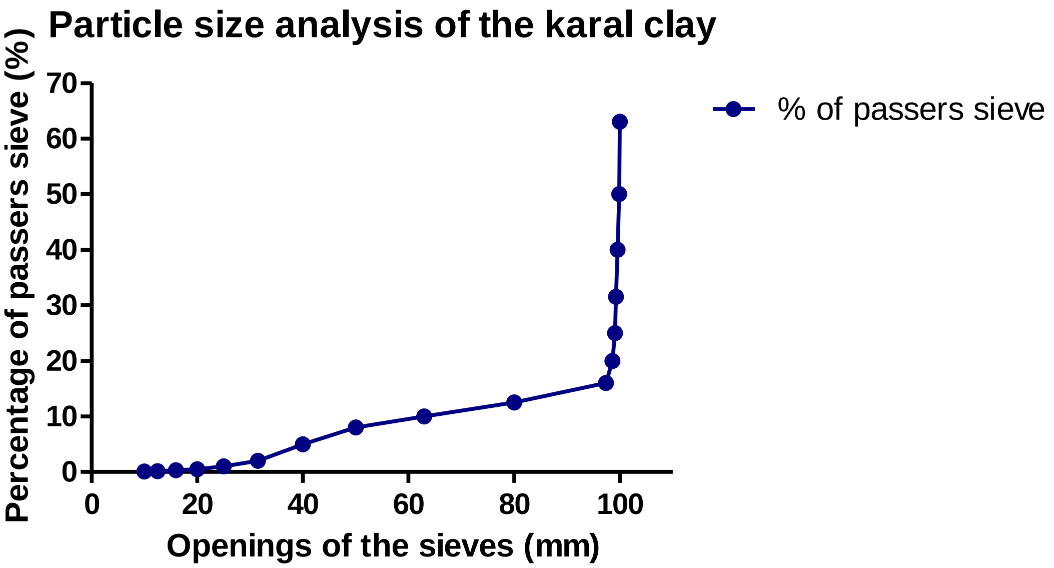

Figure 8: granulometric curve Karal clay

1.7.2. PARTICLE SIZE ANALYSIS BY SEDIMENTATION

Particle size analysis of a soil by the sedimentation is a method to determine the weight distribution of the particle size of a ground object to end. This test applies to particles passing through a sieve with a square mesh of 80 microns. However, particles of a size below 1 micron cannot be distinguished by this assay. The test uses the fact that in a liquid medium at rest, the settling velocity of fine grained depends on their dimensions. Stokes law given in the case of spherical grains of same density, the relationship between the diameter and the speed of sedimentation. By convention, this law is applied to the elements of a soil to determine equivalent particle diameters.

1.7.2.1. TEST RESULTS AND DISCUSSIONS

Table 1: results of particle size analysis by sedimentation

date 21/05/2014	heur 8h30	Time 0"	Température t°	Reading Hydrometer R	Correction M	Read corrigée R+M	Depth reading Hr	Diameter of Hydrometer (µm)	% of grains < d
		15"	25	26	0,64	26,64	3,66	100	97,4
		30"	25	25,8	0,64	26,44	3,66	70	96,7
		1’	25	25	0,64	25,64	3,66	50	93,7
		2’	25	23,7	0,64	24,34	3,66	36	89,0
		5’	25	21,6	0,64	22,14	3,66	23	81,3
	8h40	10’	25	21	0,64	21,64	3,66	16	79,1
		20’	25	19,3	0,64	19,94	3,66	11	72,9
		40’	25	18,5	0,64	19,14	3,66	8	70,0
		80’	25	17,2	0,64	17,84	3,66	5,5	65,2
	10h30	2h	25	16,6	0,64	17,24	3,66	4,6	63,0
	12h30	4h	25	15,8	0,64	16,44	3,66	1,6	60,1
22/05/2014		24	25	13,9	0,64	14,54	3,66	1,35	53,2

At the time of washing the material for particle size analysis, of less than 80 microns separate soil particles are suspended in water containing defloculating (Solution of Hexametaphosphate Sodium 5%). The particles settle at different speeds according to their sizes. By means of a densitometer, as and as time passes the changing density of the solution is measured and the immersion depth of the device. The weight distribution is calculated from these data.

1.8. LIMITS OF ATTERBERG

1.8.1. SCOPE AND PURPOSE

The behaviour of much soil varies with the amount of free water existing in the voids (pores), along with the amount of absorbed water which coats the particles. The limits are ATTERBERG geotechnical elements to identify and characterise its ground state through its consistency index. Both limits are set on the ATTERBERG fraction of less than 400 microns grains. The liquid limit is geotechnical parameters for identifying and characterising a soil nature. To achieve this we used the standard French NF_P 94-051.

1.8.2. SAMPLE PREPARATION

The test is performed on the portion of soil passing 400µm mesh sieve. This fraction is prepared by sieving the soil dipped for 24 h wet. And passing the wash water is collected in a tray. Settling is allowed to operate for at least 12 hours, and then the clear water is siphoned. The residue is then dried by baking at 60°C maximum. However, if after drying the soil is in a paste form, it may still be appropriate for the test according to the level of the state.

1.8.3. TEST RESULT AND DISCUSSIONS

Following this test, we found the liquid limit W_L = 34.5. The plastic limit is itself W_P = 16.1. Finally, the withdrawal limit in the water content beyond which dried soil volume decreases almost, is expressed by the following formula: $\mathbf{W_S = 5{,}4 + 0{,}27\ W_L - W_P = -\ 1{,}385}$.
We also plasticity index IP = WL – W_P = 18,4 > 17. Conclusion, we are in the presence of a clay consistency index $I_C = \frac{W_L - W}{I_P}$ = 1, 60 > 1. Clay question also a semi-solid consistency. And liquidity index $I_L = \frac{W - W_P}{I_P}$ = -0,60 < 0 leads us to believe that we are in the presence of a plastic clay. The organic matter content is 6.20% of MO = 6,20% ϵ [3 ; 10]. There is therefore a weak organic soil.
From Table soil classification end GTR NF 11300 torque (W_L; I_C) = (34,5 ; 1,6), our sample belongs to the class of clay and marl or highly plastic silt (A3 , ts). Soils in this class are very consistent in content and low average soil water. These soils are sticky or slippery when wet, making it difficult to implement on-site (and manipulation in the laboratory). In addition, the permeability of the Karal clay is reduced, making their content variations very slow water. However, an increase of the water content of these clay is fairly large, even necessary to substantially change their consistency.

Table 2: SUMMARY OF RESULTS OF ATTERBERG LIMITS

Number of strokes	15	20	25	30	35
Number of tare	1	2	3	4	5
Total wet weight	24,139	23,587	23,266	22,574	21,87
Total dry weight	21,825	21,443	21,264	20,675	20,198
Weight tare	15,259	15,303	15,465	15,115	15,246
Weight water	2,314	2,144	2,002	1,899	1,672
Weight of dry material	6,566	6,14	5,799	5,560	4,952
Water content	35,2	34,9	34,5	34,2	33,8

Number of tare	A	B
Total wet weight	21,719	21,774
Total dry weight	20,916	20,928
Weight tare	15,917	15,671
Weight water	0,803	0,846
Weight of dry material	4,999	5,257
Water content (%)	16,06	16,09
Average	**16,1**	

WL	**34,5**
WP	**16,1**

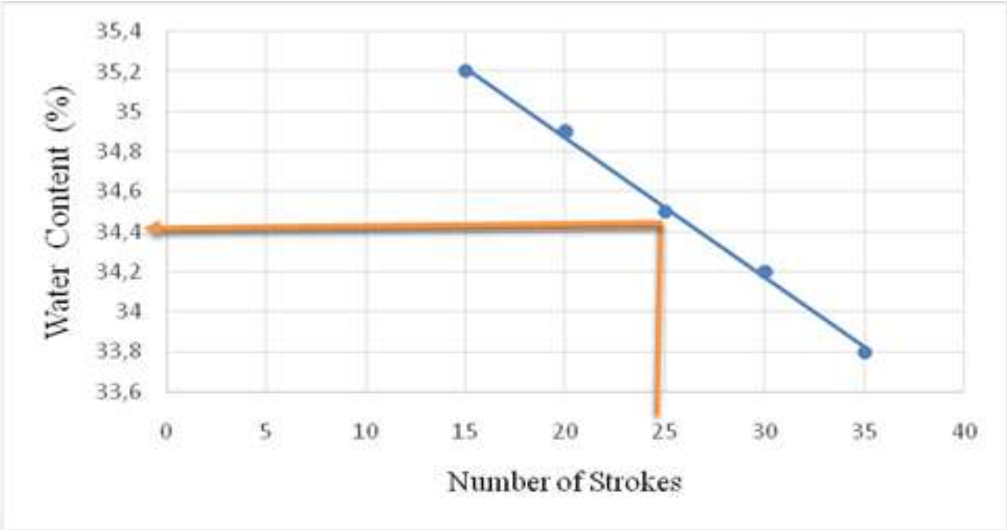

Figure 9: Variation curve of Atterberg limits of karal clay

1.9. OEDOMETER TEST

1.9.1. AIM OF THE TEST

Determining the void ratio of this test is intended, the coefficient of consolidation, the compression index, the rate of settlement of consolidation pressure, the coefficient of kinematic swelling and swelling clay.

1.9.2. PRINCIPLE

The principle is to place the sample intact and undisturbed soil in a cylinder C of section S. This cylinder is filled with interstitial water. Thus the sample is loaded with a normal stress σ applied using a piston sealingly slidable in the cylinder. The measuring cylinder is placed in the cell and the frame oedometric allows applying to the piston of the vertical loads of 5-2500 kPa. A comparator is used to measure compaction due to the stress over time (15 s, 30 s, 1 min, 2 min, 4 min, 8 min, 2 h, 4 h, and 24 h). The test is carried out in 3 phases including loading, unloading, and finally reloading. The results are in turn represented as empty eo index versus log σ variation.

1.9.3. RESULTS AND DISCUSSION OF THE OEDOMETER TEST

The results of oedometer tests on unsaturated and saturated samples allow us to determine the characteristics of soil resistance to compression. These results also provide information on soil permeability, while allowing comparing the characteristics of the latter and not the saturated states.

Table 3: Worksheet test compressibility and permeability of unsaturated sample

Survey :	**OPM Sample n°OPM à 95% saturated**				**Depth (m)**		**1**	
Nature :	**Karal**							
Wet weight (g)	**136,8**	**Dry weight**	**124.3**	**Tare (g)**			**58,92**	
Initial water content :			**Final water content (%)**				**19,23**	
Section unit (cm^2) :	**20**		**Specific weight γs (kN/m^3) :**				**27**	
hp (mm) = Ps/(γs x S)	**12,11**		**Initial height H0 (mm) :**				**20**	
eo : Initial gap index			**C_c : Compression coefficient**				**0,156**	
σ0 : Consolidation pressure : (bar)			**C_g : Swell factor**				**0,010**	
C_V: Consolidation coefficient (cm^2/s)			**E_{oed}: Oedometer modulus**					
PRESSURE	**M**	**H = H0 - M**	**e = (H - Hp)/Hp**	**Scores**		**Eoed**	**C_V (cm^2/s)**	**K (cm/s)**
0	**0**	**20**	**0,652**					
0,05	**0,0110**	**19,989**	**0,651**	**e_0 =**	**0,64**	**91,16**	**1,13*10^{-3}**	**4,96E-**
0,25	**0,1756**	**19,824**	**0,637**	**σ0**	**0,60**	**24,30**	**4,14*10^{-}**	**3,74E-04**
0,50	**0,4012**	**19,599**	**0,619**	**Cc =**	**0,15**	**22,16**	**1,97*10^{-3}**	**3,14E-04**
1,00	**0,9653**	**19,035**	**0,572**	**C_g =**	**0,01**	**17,73**	**8,65*10^{-}**	**2,77E-04**
0,25	**0,8708**	**19,129**	**0,580**			**158,73**	**4,93*10^{-}**	**2,96E-04**

0,05	**0,7425**	**19,257**	**0,591**			**31,17**		**3,23E-04**
0,25	**0,7891**	**19,211**	**0,587**			**85,87**		**2,87E-04**
1,00	**1,0320**	**18,968**	**0,567**			**61,76**		**2,63E-04**
2,00	**1,1019**	**18,898**	**0,561**			**285,92**		**2,37E-04**
4,00	**1,7414**	**18,259**	**0,508**			**62,55**		**2,18E-04**
8,00	**2,2390**	**17,761**	**0,467**			**160,76**		**2,03E-04**

Table 4: Worksheet test compressibility and permeability of saturated sample

Survey :	**OPM Sample n°OPM à 95% saturated**					**Depth (m)**		**1**
Nature :	**Karal**							
Wet weight	**141,03**	**Dry weight**	**127,61**	**Tare (g)**			**58,76**	
Initial water content :			**Final water content (%)**				**19,49**	
Section unit (cm^2) :		**20**	**Specific weight γs (kN/m^3) :**				**27**	
hp (mm) = Ps/(γs x S)		**12,75**	**Initial height H0 (mm) :**				**20**	
eo : Initial gap index			**C_c : Compression coefficient**					
σ0 : Consolidation pressure : (bar)			**C_g : Swell factor**					
CV: Consolidation coefficient (cm^2/s)			**Eoed: Oedometer modulus**					
PRESSURE (Kg/cm^2)	**M**	**H = H0 - M**	**e = (H - Hp)/Hp**	**Scores**		**Eoed**	**CV (cm^2/s)**	**K (cm/s)**
0	**0**	**20**	**0,569**					
0,05	**0,4303**	**19,570**	**0,535**	**e0 =**	**0,495**	**2,32**	**$2,19*10^{-4}$**	**2,46E-**
0,25	**0,7075**	**19,293**	**0,513**	**σ0(bar)**	**0,775**	**14,43**	**$2,18*10^{-3}$**	**9,40E-**
0,50	**0,9547**	**19,045**	**0,494**	**Cc =**	**0,144**	**20,22**	**$4,30*10^{-3}$**	**8,80E-**
1,00	**1,3269**	**18,673**	**0,465**	**C_g =**	**0,030**	**26,87**	**$9,12*10^{-4}$**	**7,54E-**
0,25	**1,1775**	**18,822**	**0,476**			**100,4**	**$4,86*10^{-3}$**	**9,73E-**
0,05	**0,7459**	**19,254**	**0,510**			**9,27**	**$2,45*10^{-3}$**	**1,12E-**
0,25	**0,8484**	**19,152**	**0,502**			**39,04**	**$2,43*10^{-4}$**	**9,16E-**
1,00	**1,2340**	**18,766**	**0,472**			**38,90**	**$3,86*10^{-3}$**	**7,25E-**
2,00	**1,6869**	**18,313**	**0,436**			**44,16**	**$3,81*10^{-3}$**	**5,87E-**
4,00	**2,2559**	**17,744**	**0,392**			**70,30**	**$4,03*10^{-3}$**	**4,88E-**
8,00	**2,7890**	**17,211**	**0,350**			**150,0**	**$3,64*10^{-3}$**	**4,30E-**

Using these tests, we realise that for a specimen compacted to 95% of OPM, and the water content of the OPM (unsaturated), a swelling coefficient Cg = 0.01 is obtained. Also note that the coefficient of inflation is three times higher when the soil is saturated. Is a coefficient of swelling of Cg = 0, 03.

1.9.3.1. Kinematics of swelling

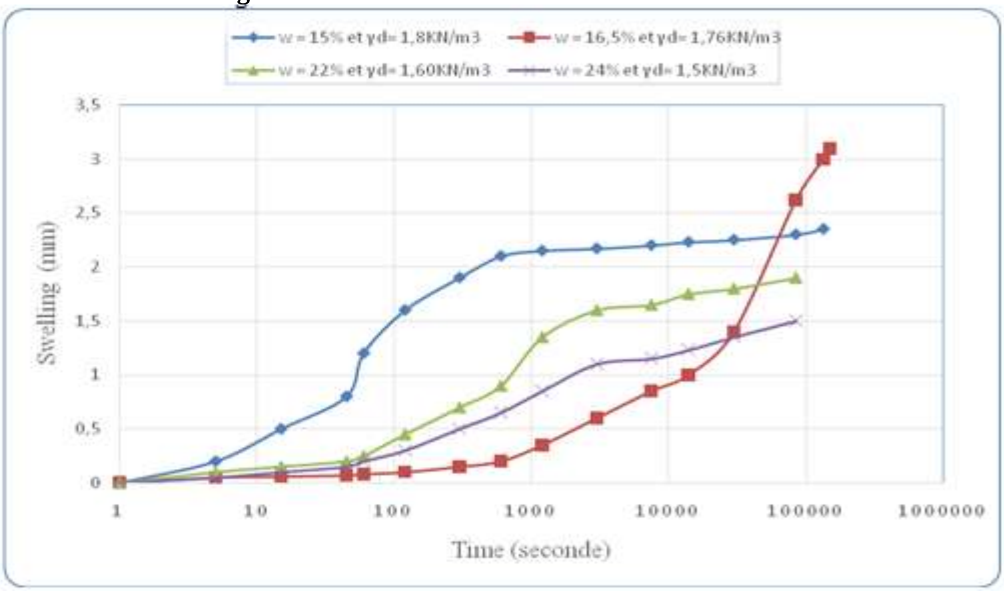

Figure 10: KINEMATIC SWELLING KARAL CLAY

We see three clear phases of swelling. First, we have a first phase of swelling that can characterise primary blowing. In this phase, the clay is slightly permeable and unsaturated, resulting in a low swelling. In the second phase called secondary, there is a change in concavity of the curve of swelling, water seeped into the clay after a relatively long time, which has accelerated the swelling. In the third phase may be called tertiary, there is a saturation of the clay and the gradual stabilisation of swelling.

1.10. X-RAY DIFFRACTION

1.10.1. SCOPE

The X-ray diffraction analysis is an analysis method that applies specifically to the crystalline material such as metals, ceramics, minerals, to mention only these, but that is not used on materials amorphous.

1.10.2. AIM OF THE TEST

Basic analysis well known in the characterisation of crystalline materials, the X-ray diffraction method allows the identification of micro mineral phases and / or poly-crystalline.

1.10.3. PRINCIPLE OF X-RAY DIFFRACTION

The process returns to send x-ray emanating from a metal anode, and which are initially collected by a collimator in a divergence slit with a view to transmitting a sub-parallel beam. This beam is directed to the material to be characterised by an angle θ and is diffracted when the elements of Bragg's law are observed.

1.10.4. EXPRESSION OF RESULTS AND DISCUSSIONS

Analysis by X-ray diffractometry is used to identify the constituent Karal clay minerals. This license test does not quantify the minerals in a sample, but rather information about the different minerals present in the sample Karal clay. Table 5 provides an overview of the different minerals found in Karal clay.

Table 5: Some major minerals in the Karal clay sample

SS-VVV-PPPP	Compound Name	Formula	Cristallisation systeme
01-085-0457 (I)	Quartz, low, syn	SiO_2	Hexagonal
00-058-2038 (N)	Montmorillonite, calcian	$(Ca, Na)_{0.3}Al_2(Si, Al)_4O_{10}(OH)_{2\cdot x}H_2O$	Monoclinic
01-078-2110 (*)	Kaolinite	$Al_4(OH)_8(Si_4O_{10})$	Triclinic
01-072-6233 (I)	Iron Oxide	Fe_2O_3	Orthorhombic

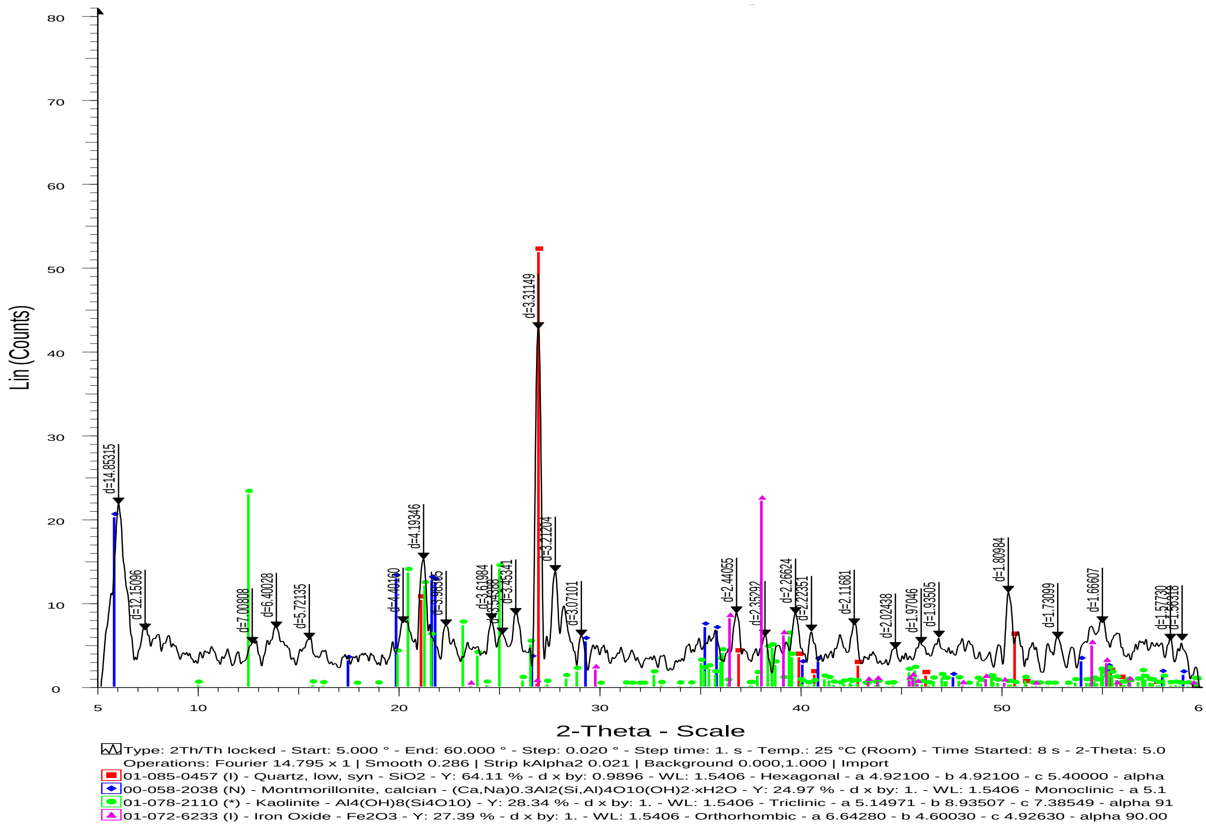

Figure 10: SPECTRUM OF KARAL X-RAY DIFFRACTION STUDY

At the end of this test, we are able to identify minerals potentially present in our sample. These include quartz, kaolinite, calcium montmorillonite, and finally the iron oxide.

IV. CONCLUSIONS AND PROSPECTS

The Far North Region occupies a strategic position because of its geographical location between Cameroon and countries such as Chad and Nigeria. National Highway N° 1, specifically the Maroua road - Kousséri is the main highway that connects the region with the countries mentioned above. Above all, this is the road that allows you to open up the entire region. Unfortunately, this road is now home to a multitude of damage probably related to the instability of Karal on which it rests.

The main purpose of such a scientific work was to determine the direct or indirect impact due to the instability of swelling clay soil, degradation present on a pavement structure based on swelling clay soil: the case of Maroua Kousséri road. Following geotechnical tests at the conclusion of which we determined some soil characteristics such as limits ATTERBERG (W_L = 34.5; W_P = 16.1) which is used to classify the soil and CBR (7, 2); index for determining the strength class and combined with the class of traffic, we were able to determine the thicknesses of the various layers of the pavement structure and materials that constitute them. This study helps us to understand the degradation modes pavement on swelling clay soil, so it is now more convenient knowing these degradation modes taken into account in the design of pavement structures on expansive clay soil in the Sahel. And also to better understand the contours of the Karal clay on road works in the Northern part of Cameroon.

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