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GEOTECHNICAL CHARACTERIZATION OF LOCAL MATERIALS USED IN ROAD CONSTRUCTION IN THE BRAZZAVILLE AREA, CONGO

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ABSTRACT

The survey of the road construction materials within the Brazzaville Area in the Congo was conducted on the geotechnical data of materials collected from different sites in order to establish a correlation with the norms of their use in Civil Engineering fields. These data include grading curves, consistency limits for the fine fraction, modified Proctor test results and CBR tests. Those data were subjected to classical statistic processing (characterization of every geotechnical parameter variability, study of correlations between parameters). The survey concludes that the material samples analyzed present so close physical properties that they cannot be clearly distinguished through statistical analysis. The overall analysis of the CBR index values varies depending on the materials used. As a consequences. These variations cause the deterioration of the pavement structure. The constituents that comply with the above defined physical properties can be used as materials of a pavement structural layer. The deterioration effects and the granular fragmentation from the *Inkisi* formations help appreciate the Micro-Deval coefficient and the Los Angeles coefficient, for the figures of both coefficients and result in high figures which mean better basic mechanical properties of the foundation and structural layers.

Keywords: materials, physical properties, mechanical properties, proctor tests, CBR tests.

1. INTRODUCTION

The Congo has seen considerable development of its road infrastructures during the few past years.

The roads whose life spans were supposed to be of at least fifteen years have been deteriorating very quickly after about two to three years' use. The degradations, superficial or structural, are due both to exogenous or endogenous causes

The Congo has an abundant supply of several materials, the differences in deposits, the quality and the sites of which have hardly been studied.

The present study sets itself the objective of researching and identifying the causes of the quick degradation due to the materials included in the development structures along the earth roads and urban or even suburban pavements.

The evaluation of local building materials which helps classify these materials in the spindle category complying with the standards of their use in the construction works. The present survey objectives focus on the recognition of the geotechnical properties of the materials collected from different sites and establish a correlation with the standards of their use in civil engineering fields.

The mechanical performance parameter most frequently correlated with the base or gravel foundation layer performances is the CBR (Californian Bearing Ratio) flotation index as the resistance to punching constitutes one of the basic properties of flexible pavements.

Researches were conducted to detect possible existence of other correlations between the performances of these pavements and simpler identification tests (grain size, plasticity, OPM dry density…) but they were not found convincing [1]. None of these tests viewed in isolation could account for the global performance of under traffic pavements satisfactorily. Their representative ness could be partially verified only through correlations, most of the time vague or scattered, by means of the CBR index itself.

The present survey presents the results of the different quarries in the Brazzaville area, located in the South-East of the Congo. The primary basic criteria for acceptance are the CBR index and the capability of borrow materials used in road sub-base layers in playing their role in a pavement structure.

2. PRESENTATION OF THE SURVEY ZONE

The Brazzaville area is located on the right-hand bank of the Congo River in the far South-Eastern end of the Congo. It has a tropical moist climate characterized by two seasons: a dry season from June to September and a rainy season from October to May. The rainfalls reach up to 1600 mm a year [2]

The area geology reveals the presence of the Stanley Pool series formations, from the Upper Jurassic to the Lower Cretaceous, made of clay and sandstone, of the BatékéPlateaux range, of Tertiary age, made up of polymorphic sandstone and recent formations of clays and sands [3&4]

The quarries studied are located in the Brazzaville area. Here they are: The Kintélé quarry, the Marien Ngouabi Military Academy quarry, the Kombé

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quarry, the KomboMoukondo quarry and the Mayanga quarry. These quarries vary depending on the bedrock and are made up of Batéké sands with very low clay and mineral elements contents and of Inkisi sandstone.

3. METHODOLOGY

3.1 Field study and geological exploration

Based on information provided by geological documents, an exploration of the geological out crops in the survey area and a minute analysis of the quarry faces were conducted on the field. On that occasion, a great number of samples was collected in order to study the physical and mechanical properties of quarry materials at depth of more than 50cm. These samples were collected by means of spades carried in plastic bag thus obtaining modified materials.

3.2 Laboratory tests

The samples related to the geotechnical identification tests of natural materials borrowings for road construction were conducted in the laboratory in order to determine the physical properties (maximum size, Sieve non-passing percentage (% 80µm), sand equivalence, specific weight and sieve analysis: uniformity and bending coefficients; mechanical properties (apparent density and moisture content to the modified Proctor optimum) ; resistances (Micro-Deval Coefficient and Los Angeles Coefficient) and the consolidation and punching properties (CBR index etc…)

The specific weight is determined by means of an air pycnometer according to the EN 1097-7 standard [5]. The sieve analysis and the sand equivalent were conducted by means of sifting to assess the properties of the sands required in the manufacturing of concretes. The sand equivalence is computed by means of the formula:

$$SE = \frac{H_2}{H_1} x100$$

H_2: measure of the sand height in the set sand plus floc

H_1: measure of the sand height at the piston

The apparent density and the moisture content were determined by means of the Modified Proctor test conducted according to the NF-P94-093 standard [6]. The Micro-Deval and Los Angeles coefficients were determined by means of the Micro-Deval and Los Angeles tests (ASTMC 131.55; N.F. P18.573 standards) and computed by means of the formulas [5]

Coefficient Micro-Deval, $CMD = 100 \times \frac{m}{M}$

m: mass of the elements inferior to 1.6mm produced during the test

M: mass of the material tested

Coefficient Los Angeles $CLA = 100 \times \frac{p}{P}$

p: weight of the elements inferior to 1.6mm produced during the test

P: weight of the material tested

The CBR index was determined by means of the CBR test allowing the measurement of the resistance of a soil compacted at its natural water amount. Its formula:

$$ICBR_{25} = \frac{Force\ (en\ KN)2{,}5mm}{13{,}35KN} \times 100$$

$$ICBR_{50} = \frac{Force\ (en\ KN)5mm}{20KN} \times 100$$

$$ICBR = \max(ICBR_{25};\ ICBR_{50})$$

4. RESULTS AND DISCUSSIONS

The results achieved through laboratory tests show that the samples collected from the Brazzaville sites belong to the loose borrows type used mainly in the constitutive layers of pavements.

The results of physical parameters measured on Brazzaville materials are shown in Table-1. These results show the maximum sizes do not exceed 2mm in all the Brazzaville sand quarries, except when the aggregate obtained by crushing Inkisi sandstone (class 0/31.5, dmax,31.5mm) and sieve 20 (80 µm) non-passing fractions not to exceed 20% for all sands and Inkisi sandstones. That percentage has a major role: (i) if that percentage is zero or insufficient, the material is loose and very difficult to tighten up. (ii) if it is in excess, sludge formation appears on compaction. The sand equivalence values vary from a quarry to another. These results show out four types of sands. The clean sands (The Military Academy and Makabandilou sands), the low plastic sands corresponding to the low silt or clay contents (The Kombo sands), and the non-plastic sands having no clay contents (TheKintele, Mayanga sands and the Inkisi de Kombé sandstones).

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Table-1. Physical properties of the Brazzaville quarries.

Essais quarries	dmax	% 80µm	E.S	Weight p (g/cm^3)	Apparent Density (g/cm^3)	Granulometricanalysis Cu	Cc
Sand of Académie Militaire	1	5	98	2,72	1,57	3,11	1,02
Yellow Sandof Kintélé	2	15	32	2,61	1,67	3,14	1,27
Yellow Sand of Makabandilou	1	10	70	2,51	1,37	3,25	0,88
Yellow Sand of Kombo	1	7	18	2,80	1,60	6,00	1,27
Redsand ofKombo	2	13	16	2,88	1,54	8,33	2,08
Yellow Sand of Mayanga	1	20	26	2,40	1,43	3,50	1,40
Kombé **:** sandstone of Inkisi							
Granulat class 0/31,5	31,5	7	48	2,40	1,56	43,3	0,65
Sandstone 0/6	2	16	35	2,61	1,60	6,66	1,60

MS: Maximal size; %80µm: Pourcentage de refus au tamis; E.S: Equivalence of sand; Poids sp: Poids spécifique; Densité appa: Densité apparente; Cu: Coefficient d'uniformité; Cc: coefficient de courbure

The values of the specific weight and the apparent density are very low, do not vary much from a site to another whatever the type of the materials may be (sands or sandstones). These values help determine the soilcompactness.

The results on granulometric parameters display a spread-out grain-size, the uniformity coefficient exceeding 2 and the borrowings normally compact well. All the sands with the exception of the Makabandilou's and the type 0/31.5 aggregates of the Inkisi sandstones (grain size poorly graduated) show well graduated grain size because their bending coefficient ranges from 1 and 3.

4.1 Mechanical properties

The results of mechanical properties are shown in Figures 2 and 3 and Table-2.

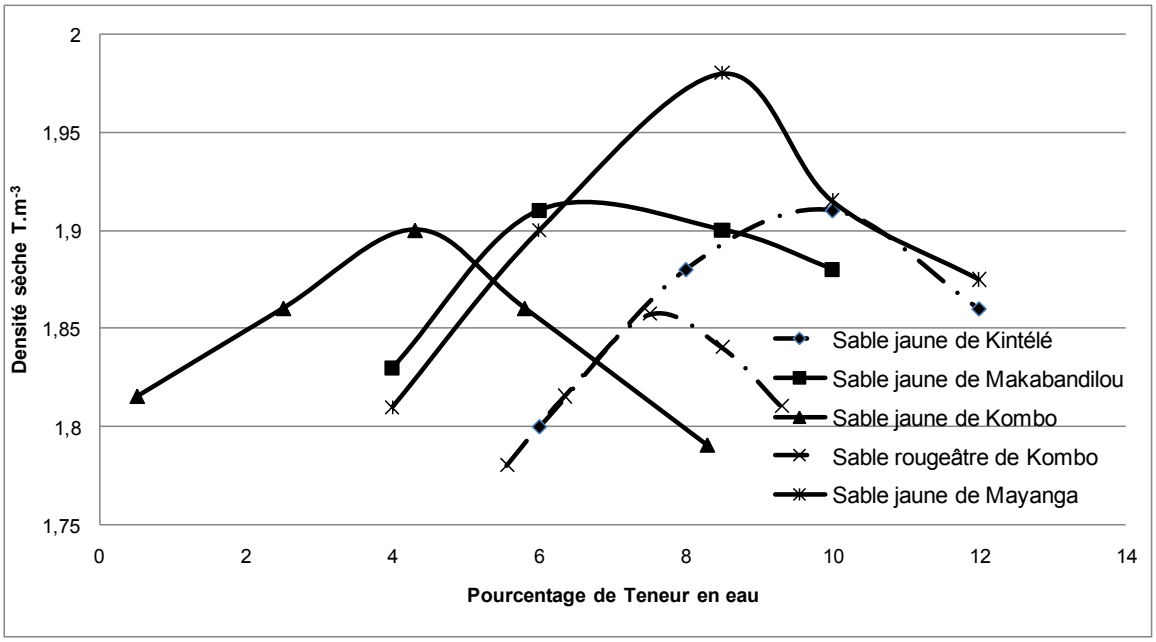

Figure-1. Proctor Curves of different Brazzaville sands.

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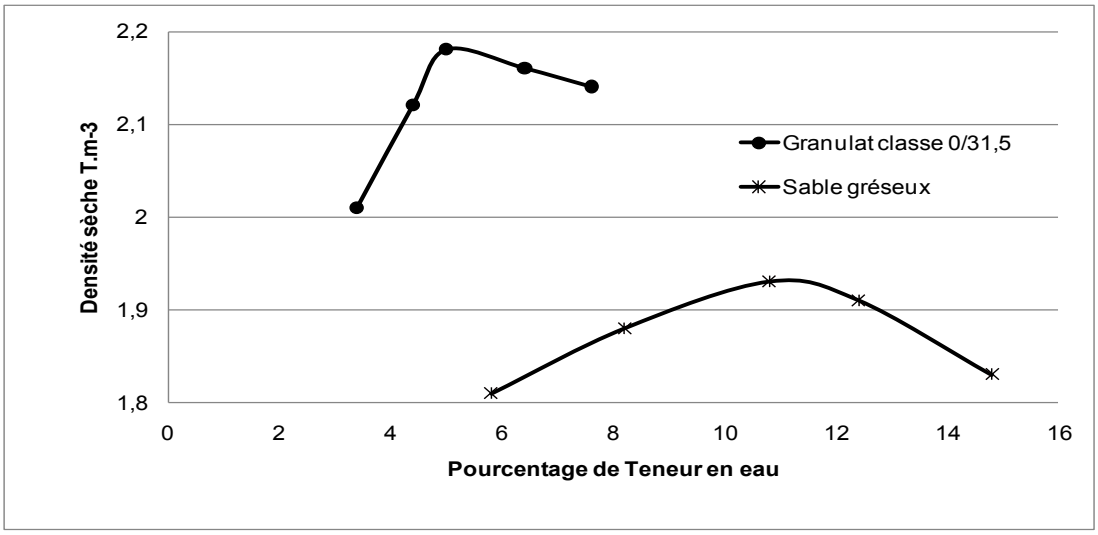

Figure-2. Proctor curves of the Brazzaville Inkisi sandstone.

Table-2. Brazzaville quarries' averagemechanicalproperties.

Carrières	Essai Proctor modifié. W%	Dry density (g/m^3)
Sand ofKintélé	8,9	1,84
Yellowsand of Makabandilou	8,1	1,92
Yellowsand of Kombo	5,3	1,86
Redsand of Kombo	6,7	1,87
Yellowsand of Mayanga	6,8	1,99
Kombé : **Sandstone of Inkisi**		
Granulat class 0/31,5	5,1	2,18
Sandstone	10,6	1,93

W% weight content percentage; gd: Dry density

All the curves of the sands studied with the exception of the Mayanga Proctor curve display a splayed shape that is a distinctive form of sands. It informs on the sensitivity of the water. (to the water) The flatter the curve obtained is the less sensitive it is to water. Only the Mayanga sands display a pointed shape which may be due to the presence of the clay content henceforth its sensitivity to water

The water contents are inferior to 10, (except for the sandstone) which confirm a good compaction and the dry density of the borrowings collected is almost the same everywhere.

4.2 Resistance properties

The resistance to wear test on the Inkisi sandstones shows that the sandstone has a 33% friability and the type 0/31.5, type 7% aggregate, The wear to impact test shows a 25% value for the 0/31.5 aggregate (Figure-4).

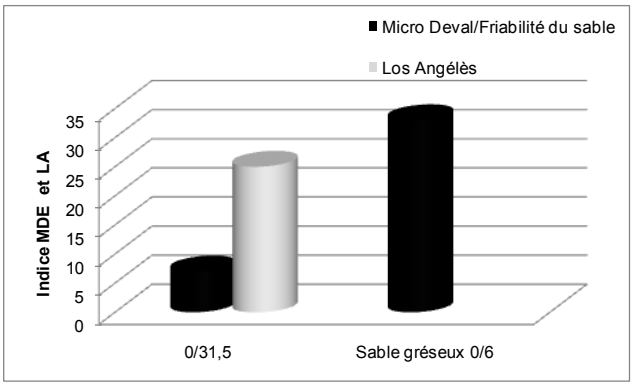

Figure-3. Micro Deval and Los Angeles coefficients.

4.3 Consolidation and punching properties (CBR index)

The Index CBR results obtained after 96hours'immersion of the sands and Inkisi sandstones from the Brazzaville quarries are shown in Figures 5 & 6 and Table-3.

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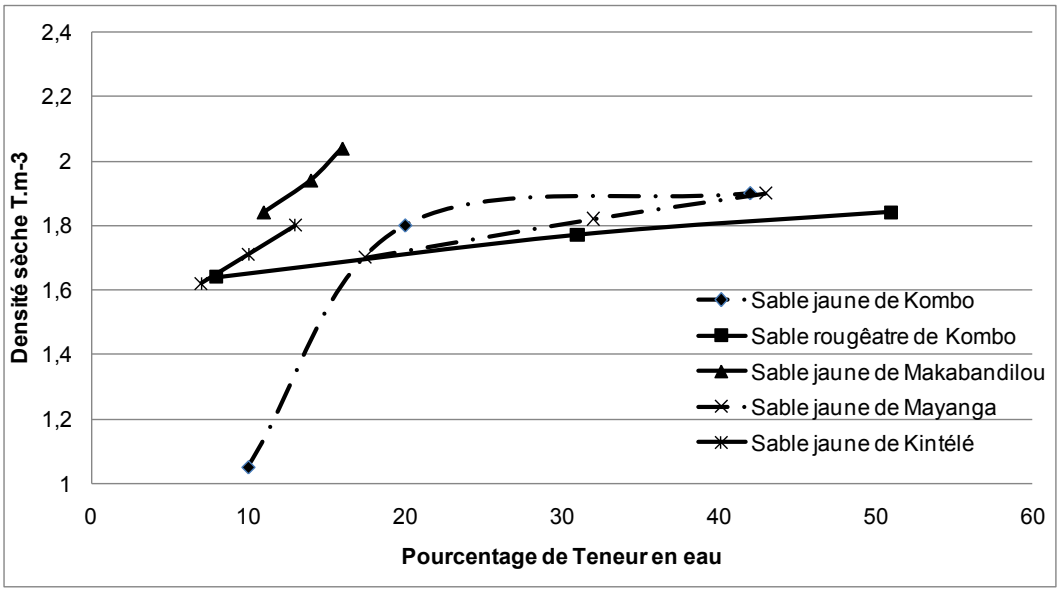

Figure-4. CBR Index curves of different Brazzaville sands.

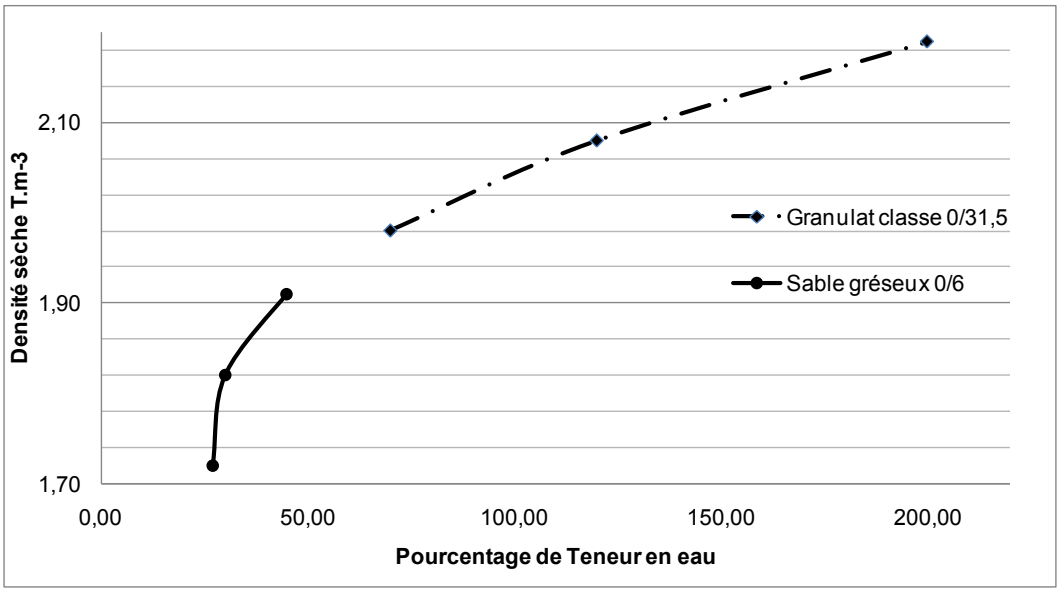

Figure-5. CBR Curves index of Brazzaville Inkisi sandstone.

Table-3. Average consolidation and punching properties of the Brazzaville quarries.

Quarriers	**CBR**	**Dry density** (T/m^3)
Sand of Kintélé	15,3	1,77
Yellowsand of Makabandilou	19,2	1,70
Yellowsand of Kombo	23,8	1,77
Redsand ofKombo	28,4	1,69
Yellowsand of Mayanga	21,0	1,88
Sandstone of Inkisi,Kombé		
Granulat classe 0/31,5	117,1	2,075
Sand gréseux	44,0	1,84

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The CBR index values of the sands used as borrows range depending on the quarries between 15 and 19. Henceforth these sands can be used only as subgrades and not as foundation layers because their indexes are inferior to 30. Whereas, the CBR index for the type 0/31.5 aggregates, for the Inkisi sandstones is very high (117.1). This explains a good distribution of the grains in this material and a very low optimal moisture content with a maximum dry density of 2.075 T.m3. Sandstones have a CBR index of 44, which can be interpreted in terms of the grain distribution, what is more, made of fine elements, with a maximum dry density of 1.84 T.m3, and can be used as a foundation layer.

5. CONCLUSIONS

The results achieved with the physical properties of the samples collected from different sites do not vary significantly on the whole. The overall analysis of the CBR index values varies depending on the material used. These variations result in the deterioration of the pavement structure. The samples which comply with the physical properties can be used as a pavement subgrade. The results of the Inkisi aggregate formations wear and crushing helped assess the Micro-deval coefficient and the Los Angeles coefficient, both coefficients produce high level values corresponding to the best mechanical properties of the base layers, the foundation layers and the subgrades. For a durable use of the Batéké formations quarries whose alteration results in the white sands of the Military Academy, Makabandilou and Kintélé, it is necessary to broaden the study of the materials so as to determine their position in the pavement construction. To end with studies will have to be conducted on the different materials as regard their use as pavement layers so as to gain thorough knowledge on the untimely degradations found in the pavements of the city of Brazzaville and its surroundings.

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