

# Petrographic and Geotechnical Characterization of Granites from the N’Goura Massif (Center-Sud/Tchad): Implication for their Used in Civil Engineering

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## Abstract

This work deals with the petrographic and geotechnical characterization of rocks from the N'goura massif with focus on their use in civil engineering. The study area is located in central southern Chad, about 205km to the north of N'Djamena. The N'goura massif is monzogranitic with two micas. The rocks outcrop as blocks, slabs and balls displaying fine, medium and coarse grained minerals. Monzogranite is composed of 34% quartz, 32% alkali feldspar, 26% plagioclase, 4% biotite, 2% muscovite and 1% chlorite on average. Geotechnical data show that the aggregates obtained from this rock have a Los Angeles coefficient ranging from 22.70 to 38.70% with an average of 30.70%, a Microdeval coefficient ranging from 4 to 13% with an average of 8.5% and a dynamic fragmentation coefficient ranging from 11.43 to 18.57% with an average of 15%. These results indicate that the studied materials are suitable to be used for construction and civil engineering works. The correlation between petrographic and geotechnical data reveals that the size (texture), grain structure and mineralogical composition (Qtz, Kfs and Bt+Ms+Chl+Ser) have an influence on the geotechnical behavior of these materials.

**Keywords:** Petrography, Geotechnics, Granite, construction and civil engineering works, N'Goura, Chad

## 1. Introduction

Made up of an association of minerals, rocks have numerous industrial applications. They are subdivided into five (5) categories: ores, industrial minerals, industrial materials, quarry materials, energy sources and water (Michel and Eric, 2008).

Due to the importance of their use throughout the world, after air and water, aggregates are the third most consumed substance by human being (Boufedah, 2011). According to Daho (2012), nearly 49 million tons of rock aggregates are produced daily to meet the global economy demands.

Chad, a country in sub-Saharan Africa, represents an important mineral patrimony known for its richness and diversity in terms of geological resources. The determination of these geological resources characteristics represents a scientific and economic interest that needs to be valued. In addition, the country is committed to be an emerging country by 2030 and this commitment includes the realization of major projects such as stadiums, roads and bridges construction and many other infrastructures of various kinds and types. This requires large amounts of construction materials, especially aggregates. However, the country continues to encounter many problems, among which, the massive production of good quality aggregate due to lack of petrographic and geotechnical studies of this material's source rocks. This lack leads to the use of recycled aggregates which often have very critical geotechnical characteristics on the resistance of the materials, and consequently constitute a great danger for infrastructures durability.

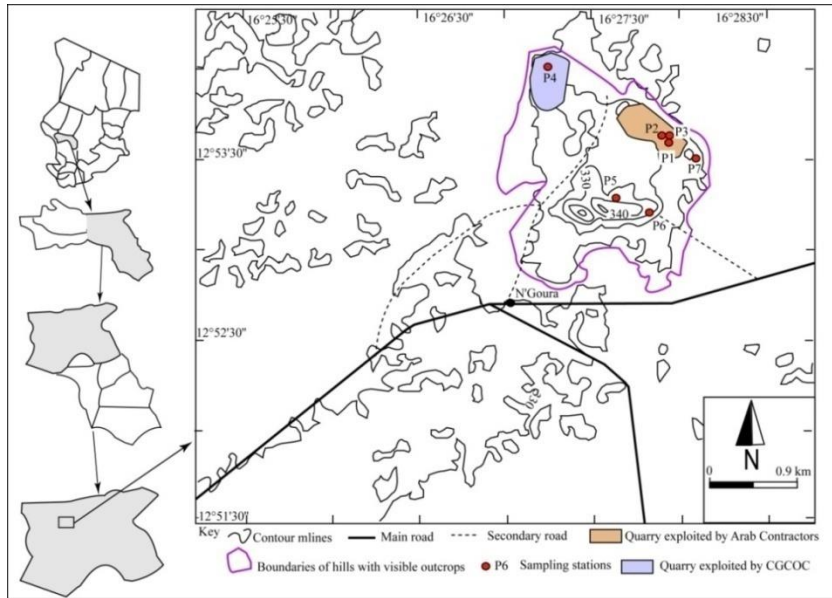


Figure 1. Map of the study area showing the sampling stations and the hill areas with visible outcrops

The town of N’Goura, which constitutes the study area, has a large number of geological formations that need to be valued as building materials after determining their petrographic and geotechnical characteristics (Fig. 1). The present study is focused on petrographic and geotechnical characterization of the aggregates from the N’Goura massif in order to determine their potential use in civil engineering.

From a geological point of view, Chad is located in a vast mobile domain known as the Pan-African mobile zone of Central Africa (Bessoles et Trompes, 1980), formed essentially during the orogeny which took place towards the end of the Precambrian (700-520Ma). Precambrian formations are distributed between the Tibesti massif in the North, the Ouadda ĩn the East, the Yad é or Mbaibokoum in the South, the Mayo Kebbi in the South-West and the Gu ĩrain the Center (Bessoles and Trompes, 1980). In the study area, there are rock outcrops to north of the Mo ĩo-Bokoro road which meet that of N’Djamena-Ab éch é They form several isolated outcrops and two small elongated hills separated from each other by a few hundred meters which dominate the plains (Fig. 1), where granites outcrop (Fig. 2).

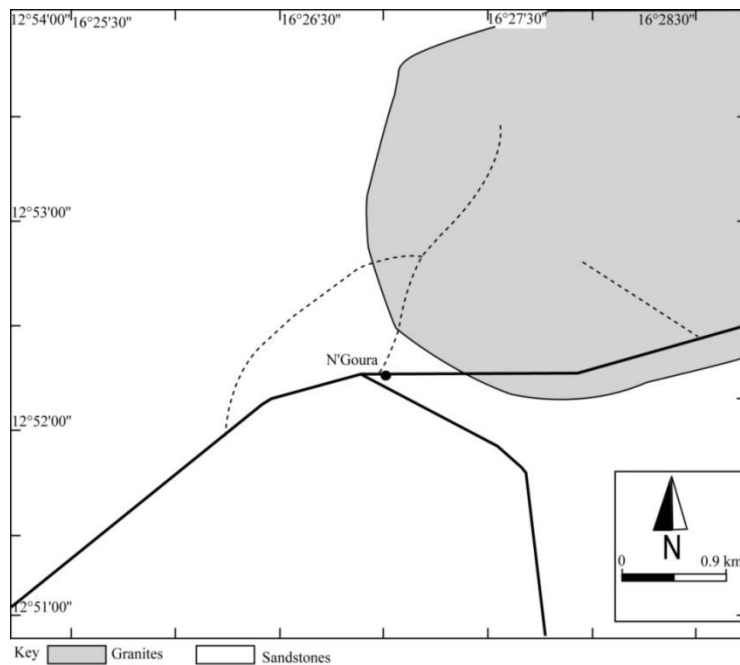


Figure2. Geological map of the N’Goura area

## 2. Methods

During field investigations, five (05) stations were visited and described within the granitic massif, two of which are located in quarries actually exploited. Seven (07) samples representative of the different petrographic types encountered in the massif were collected from these stations. These collected samples were used for thin sections realization and geotechnical analyses.

### 2.1 Laboratory Works

The laboratory works consisted of the fabrication and description of the thin sections of rocks on the one hand and the crushing of the rock samples into aggregates to the 10/14mm class on the other hand. The preparation and description of the thin sections were carried out respectively at the Laboratory of Internal Geodynamic of the University of Yaoundé I and the Laboratory of Environmental Geology at the University of Dschang (Cameroon).

The geotechnical analyses were carried out in accordance with the standards used at the "Laboratoire du bâtiment et des Travaux Publics (LBTP)" of N'Djaména (Chad). The apparent density was determined according to the prescriptions of standard NFP98-250-1 (1992) and the specific density was carried out according to NFP18-554 standard (1991). In addition, the mechanical parameters, in particular the Los Angeles (LA), Humid Microdeval (MDE) and Dynamic Fragmentation (F D) coefficients were respectively determined according to the pre-registrations of standards NFP18-573 (1990), NFP18-572 (1990) and NFP18-574 (1990).

### 2.2 Results Processing and Analysis

The processing and analysis of the data enable to highlight the correlations between the petrographic and geotechnical results in order to determine influence of mineral composition of rocks on the geotechnical properties of aggregates. In addition, results analyses were done in other to validate or invalidate the use of the studied aggregates for infrastructures construction.

## 3. Results and Discussion

### 3.1 Petrography

The petrographic studies of rocks from the N'Goura Massif were carried out on seven (07) samples (Fig. 1) and were based on the macroscopic samples and thin sections description. In the field, these granites crop out as slabs, blocks and bowl on slopes and at the top of hills. The slabs outcrop extends over few meters; while the blocks and the bowls are distributed in the way to form a chaotic landscape (Fig. 3a, 3b). Samples display light gray to dark gray or pink color (Fig. 4), with millimetre to centimetre grain sizes. They are composed of quartz, alkali feldspar, biotite, muscovite and displaying fine to medium grained to coarse texture, massive structure with a slight weathering patina.

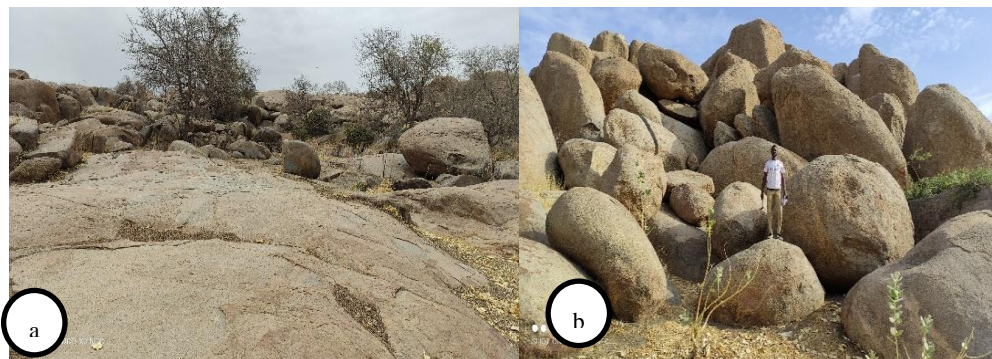


Figure 3. Outcrops of granites. a) flagstone b) Bowland blocs

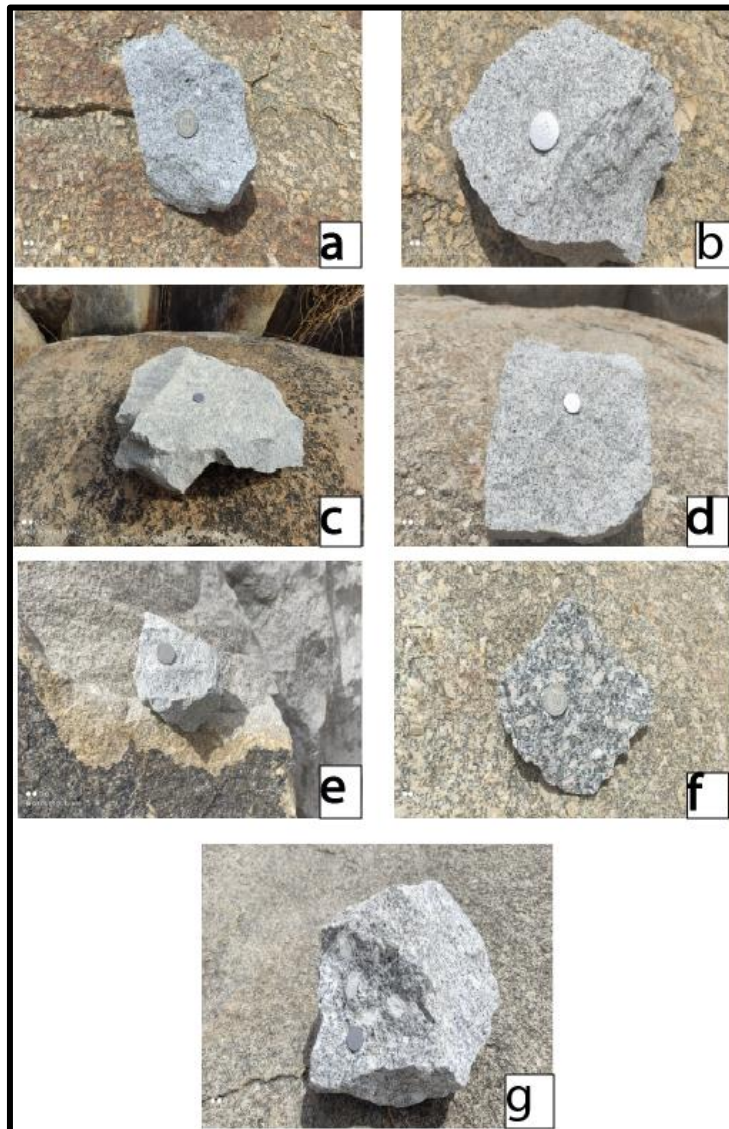


Figure 4. Outcrops and hand samples of the different types of granite

Fine grained Granite: (a, b and c); medium grained granite: (d and e) and coarse grained: (f and g). Diameters of coins: 100F:  $\Theta = 2.5\text{cm}$ ; Pi à ce 50F:  $\Theta = 2,2\text{cm}$

Microscopic observations show that, megacrysts granite display porphyritic texture, composed of quartz, alkaline feldspar, plagioclase, biotite and muscovite. Accessory phases are opaque minerals while chlorite and sericite constitute the secondary phase.

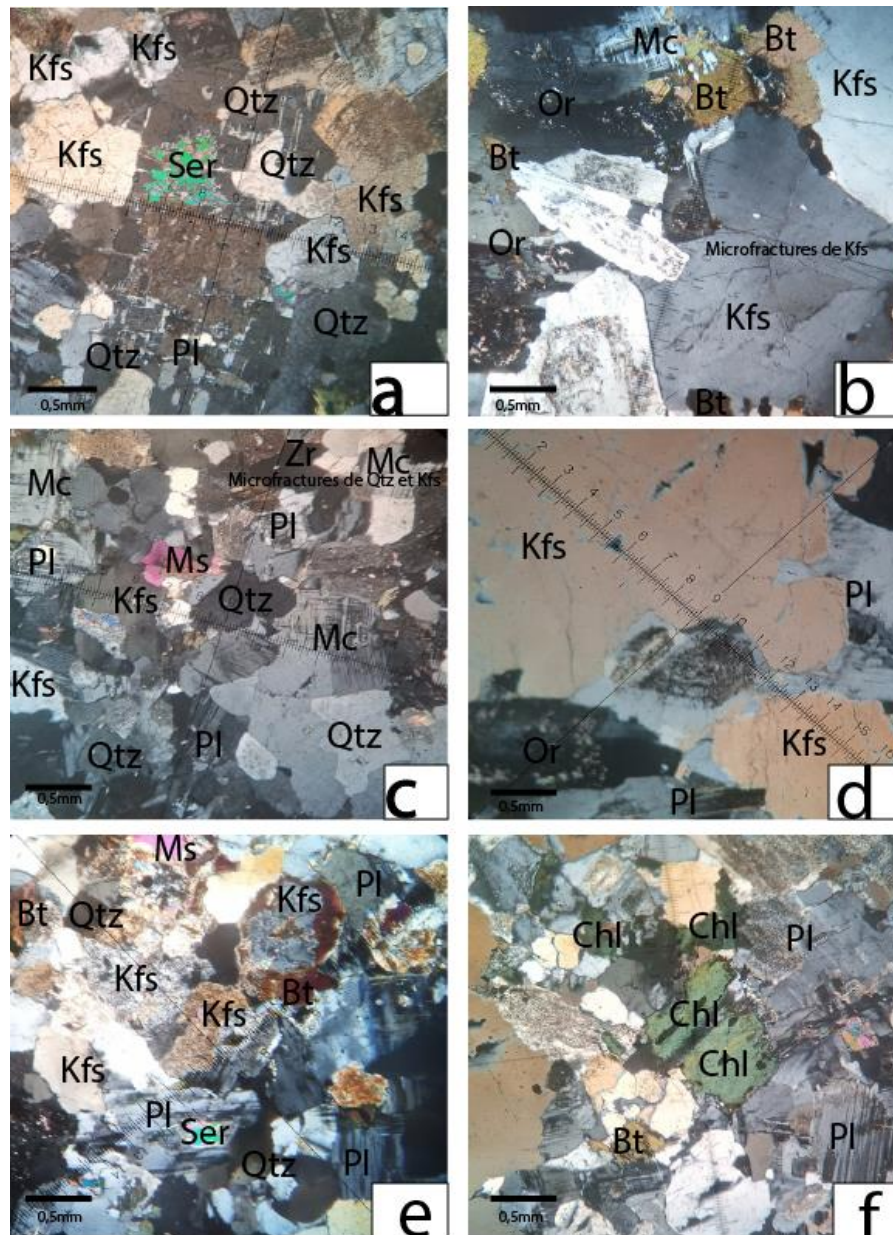


Figure 5. Microphotograph of megacrysts granite

Rocks observed in the study area outcrop as slabs, blocks and balls on hill sides and at the top of hills. The slab outcrop extends over a few meters of extension, on the other hand the blocks and the balls are arranged one on top of the other, forming a chaotic landscape (Fig. 3a, 3b). Hand sample is light gray to dark gray or pink with grain sizes varying from millimetre to centimetre (Fig. 4). They are composed of quartz, alkali feldspars, biotite, muscovite and display coarse, medium and fine grains texture and also show numerous microfractures (Fig. 5).

The estimation of mineral proportions was done using the tracing or statistical method on thin sections (Tab. 1) and the name of rock was obtained by plotting in the Tridraw software, the percentage of cardinal minerals without taking into account the essential minerals (Tab. 2). This knowledge enables to classify samples in the respective domain to which they belong in the Streckeisen diagram (Fig. 6).

Table 1. Mineral pourcentages per sample

Granitetype	Sample	Mineral						
		Qtz(%)	Kfs(%)	Pl(%)	Bt(%)	Ms(%)	Chl(%)	Ser(%)
Finegrained	1	35	32	27	4	1	1	0
	2	42	32	22	2	1	0.5	0.5
	7	32	32	31	4	1	0	0
	Average	36	32	27	3	1	1	0
Mediumgrained	3	37	30	27	3	2	1	0
	5	33	36	22	3	2	2	2
	Average	35	33	25	3	2	1	1
Coarsegrained	6	30	30	31	5	1	2	1
	4	30	34	25	6	2	2	1
	Average	30	32	28	5.5	1.5	2	1

Table 2. Percentage of cardinal minerals

Sample	Qtz(%)	Kfs(%)	Pl(%)	Total
AD1	37	34	29	100
AD2	44	33	23	100
AD3	40	32	28	100
AD4	33	39	28	100
AD5	37	40	23	100
AD6	33	33	34	100
AD7	34	34	32	100

Petrographic data show that the studied massif is granitic and occupies the monzogranite sub-domain according to the Streckeisen classification (Streckeisen, 1976). These results are close to those of Kusnir (1995), according to which the Chari Baguirmi granites are monzogranites with porphyritic texture emplaced as a late-tectonic intrusions.

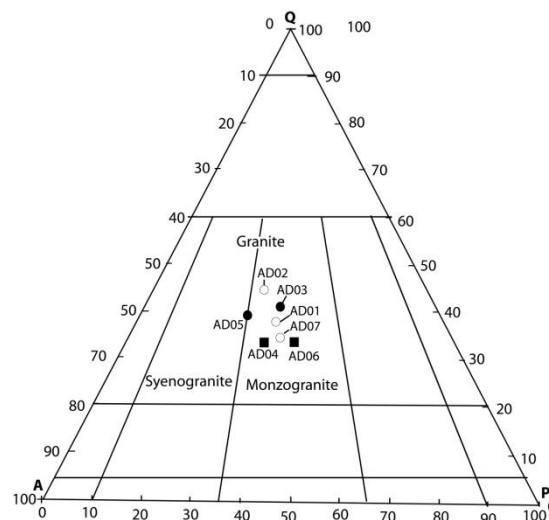


Figure 6. Streckeisen (QAP) diagram (1976)

Empty circle, filled circle and filled square correspond respectively to fine, medium and coarse grained granite.

### 3.2 Geotechnical Data

The geotechnical data focuses on the physical and mechanical parameters. Physical characteristics are assessed by bulk density and absolute density while mechanical parameters are assessed by Los Angeles, wet Microdeval and Dynamic Fragmentation coefficients. The interpretation of these physico-mechanical parameters permit to evaluate the quality of the constructive properties of materials. The results according to each type of granite are

shown in Table 3.

Table 3. Geotechnical data

Granitetype	Sample	GeotechnicalParameters					Appreciations
		p (g/cm <sup>3</sup> )	Ps (g/cm <sup>3</sup> )	CLA (%)	CMDE (%)	CFD (%)	CLA and CMDE
Finegrained	AD1	1.44	2.56	25.70	5.00	11.43	-Very good quality material
	AD2	1.50	2.57	22.70	4.00	14.28	(25<CLA<30)
	AD7	1.41	2.38	32.50	6.00	15.71	-Excellent quality material
	Average	1.45	2.50	26.97	5.00	13.81	(CMDE<10%)
Mediumgrained	AD3	1.38	2.52	30.30	5.00	14.28	-Good quality material
	AD5	1.43	2.56	31.70	11.00	17.14	(30<CLA<35)
	Average	1.41	2.54	31.00	8.00	15.71	-Excellent quality material (CMDE<10%)
Coarsegrained	AD6	1.40	2.63	29.30	6.00	18.57	-Admissible quality material
	AD4	1.44	2.60	38.70	13.00	18.57	(35<CLA<45)
	Average	1.42	2.62	34.00	9.50	18.57	-Excellent quality material (CMDE<10%)
Generalaverage		1.44	2.51	30.70	8.50	15	Usable aggregates

Table 3 shows that the fine, medium and coarse-grained granites have the mean values of 1.45, 1.41, and 1.42g/cm<sup>3</sup> respectively; for bulk density of 2.50; 2.54 and 2.62g/cm<sup>3</sup> specific density, 26.97; 31.00 and 34.00% for Los Angeles coefficient, 5.00; 8.00 and 9.50 for wet Microdeval coefficient and 13.81; 15.71 and 18.57% for coefficient of dynamic fragmentation.

As far as physical parameters are concerned, the apparent density varies in the interval 1.4< $\rho$ <2 (except for the sample 3 where  $\rho = 1.38\text{g/cm}^3$ ) and meet the recommended specifications of the Technical Guide for the Construction of Tropical Countries. The aggregates from samples 3 and 7 respectively show low values ( $\rho = 1.38\text{g/cm}^3$  and  $1.41\text{g/cm}^3$ ) due to their angular shape. These results are close to those found by Manseur and Ziani (2014) on classes 3/8; 8/15 and 15/25 of natural aggregates where they respectively find 1.42; 1.40 and  $1.42\text{g/cm}^3$ . On the other hand, the results obtained do not agree with those of Vouffo et al. (2020) where the apparent density is  $1.62\text{g/cm}^3$ . This difference is explained by the fact that the studied aggregates do not have the same rock types.

The absolute densities  $\rho_s$  vary from 2.38 to 2.63 g/cm<sup>3</sup> and characterizes common granite aggregates according to the classification of Schumann (1989) which sets values from 2.3 to  $2.8\text{g/cm}^3$ . The results obtained do not agree with those found by Al-hadj (2014) which vary from 2.62 to  $2.64\text{g/cm}^3$  and those found by Houga et Soltana (2014) which are from 2.61 to  $2.68\text{g/cm}^3$ . These differences are explained by the mineralogical nature, size and shape of the aggregates as well as the degree of fracturing and weathering undergone by the rocks.

Mechanical parameters include: the whole Los Angeles coefficient which varies between 22.70 and 38.70%, with an arithmetic mean of 30.70%, the Microdeval coefficient which is comprised between 4 and 13%, with an arithmetic mean of 8.5% and the coefficient of Dynamic Fragmentation which varies between 11.43 and 18.57%, with an arithmetic mean of 15%.

The Los Angeles coefficient (22.70 to 38.70%) of the studied materials is similar to those obtained by Schumann (1989) on the Ouaddai granite where the Los Angeles coefficient varies between 28 and 31%. This comparison indicates that the studied rocks are granites with slightly different mineralogical composition. On the other hand, they are much lower than those obtained by Bekon (2012) on migmatitic gneisses from the Okola area, Central Cameroon, whose values vary between 41 and 43%. This difference is explained by the fact that the materials studied do not have the same petrographic type, nor the same structure and texture. As for the results of the wet Microdeval test, the studied materials all have a Microdeval coefficient of less than 15%. This value is characteristic of good quality materials. The results from samples 2, 1, 3, 6, and 7 (4%; 5%; 5%; 6%; 6% respectively) of the study area are inconsistent with those found by Ketcha (2016) on the geotechnical characterization of granites of the Maka quarry whose values are between 5.98 % to 9.89% according to the classes 6.3/10-10/14 and those obtained by Kenfack (2017) on the comparison between the gneiss of Bangangt é and that of Akak and Esse in Cameroon.

The values obtained from the mechanical parameters; the Los Angeles coefficient and the wet Microdeval coefficient in particular, enable to know the quality of the aggregates and its field of use (Tab. 4 and 5).

Table 4. Mechanical characteristics used for base layer (CEBTP, 1984)

Traffic	LA	MDE
T1-T3 admitting an axle of 8 at 10 tons	≤45	≤15
T4-T5 and all traffics admitting an axle of 13 tons	≤30	≤12

In general, on the basis of the characteristics established by the ‘Centre Experimentation du Bâtiment et des travaux Publiques’ CEBTP (1984), table 5 shows that fine-grained granite can be used for T4-T5 traffic and all traffic admitting an axle of 13 tons. On the other hand, medium and coarse-grained granites can only be used for T1-T3 traffic and all traffic admitting an axle of 8 to 10 tons. On the basis of mechanical parameters all the granites of N’Goura can be used for base layer. From the above it can be notice that the rock texture (grain size) influences the physic-mechanical characteristic.

### 3.3 Influence of Grain Size, Composition and Structure of Rocks on the Mechanical Behavior of Aggregates

The grain size, composition and structure of rocks are the most important factors influencing the mechanical strength of rock materials (Tab 6).

Table 5. Evaluation of aggregate quality

Macroscopic characteristic		Los Angeles		Microdeval		Appreciations
Sample	Granite type	Value	Intervals	Value	Intervals	CLA and CMDE
AD01	Fine grained granite	25.7	≤30	5	≤12	T4-T5 and all traffics
AD02	Fine grained granite	22.7	≤30	4	≤12	allowing an axle with 13 tons
AD03	Medium grained granite	30.3	≤45	5	≤12	T1-T3 allowing axle from 8 to 10 tons
AD04	Medium grained granite	38.7	≤45	13	≤15	
AD05	Medium grained granite	31.7	≤45	11	≤12	
AD06	Coarse grained granite	29.3	≤30	6	≤12	T4-T5 and all traffics allowing an axle with 13 tons
AD07	Coarse grained granite	32.5	≤45	6	≤12	T1-T3 all traffics allowing and axle from 8 to 10 tons
	Fine grained granite	26.97	≤30	5.00	≤12	T4-T5 and all traffics allowing an axle with 13 tons
	Medium grained granite	31.00	≤45	8.00	≤12	T1-T3 all traffics allowing an axle from 8 to 10 tons
	Coarse grained granite	34.00	≤45	9.50	≤12	T1-T3 all traffics allowing an axle from 8 to 10 tons

Table 6. Summary of the mechanical results according to the proportions of minerals by type of granite

Granite type	Samples	Mineral composition							Mechanical Parameters		
		Qtz (%)	Kfs (%)	Pl (%)	Bt (%)	Ms (%)	Chl (%)	Ser (%)	CLA (%)	CMDE (%)	CFD (%)
Fine grained	1	35	32	27	4	1	1	0	25.70	5.00	11.43
	2	42	32	22	2	1	0.5	0.5	22.70	4.00	14.28
	7	32	32	31	4	1	0	0	32.50	6.00	15.71
	Average	36	32	27	3	1	1	0	26.97	5.00	13.81
Medium grained	3	37	30	27	3	2	1	0	30.30	5.00	14.28
	5	33	36	22	3	2	2	2	31.70	11.00	17.14
	Average	35	33	25	3	2	1	1	31.00	8.00	15.71
Coarse grained	6	30	30	31	5	1	2	1	29.30	6.00	18.57
	4	30	34	25	6	2	2	1	38.70	13.00	18.57
	Average	30	32	28	5.5	1.5	2	1	34.00	9.50	18.57



Table 6 shows that the values of these mechanical parameters increase with the size of the grains of the granites. From this table it can be seen that the fine-grained granite has a low Los Angeles coefficient (except for sample 7) and wet Microdeval, followed by medium-grained granite and finally coarse-grained granite. It should be noted that the larger the grain size, the lower its mechanical strength. From the above, it can be easily concluded that, grain size influences the mechanical properties of the aggregates.

The composition and structure of rocks are intrinsic factors which are also the important starting point in the process of selecting and evaluating materials frequently used in the construction industry. Minerals do not have the same characteristics depending on their hardness and resistance. For example, aggregates that are rich in quartz have higher resistance than those rich in cleavable minerals, ferromagnesian, alumina, weathering minerals and fractured minerals (Tab 6). The influence of quartz is observed by the behaviour of the rock content. It is demonstrated by an increase in fine-grained granites (36%), on the other hand, a decrease is noted in coarse grains (30%). The same is true for the resistance of these materials to impact.

Conversely, mechanical resistance decreases when the proportions of ferromagnesian (Bt), aluminous (Ms), weathering minerals (Chl+Ser) increase. For example, the mineralogical association Bt+Ms+Chl+Ser represents an average content of 5% in fine-grained granites. This proportion gradually changes to 10% in coarse-grained granites. These analyses show that the mechanical strength decreases when the proportions of ferromagnesian, aluminous and weathering minerals are high. This is explained by their low hardness.

The mineralogical nature of the components, their shapes, their volumes, their arrangements, the presence of microfractures and their weathering states have been geological factors that have influenced the mechanical properties of monzogranite. The various mechanical tests enable to classify these minerals by degree of resistance and to select them in their specific field of use.

#### 4. Conclusion

The main objective of this work was to contribute to the petrographic and geotechnical characterization of the N'goura granites with a view to their use in civil engineering. Petrographic analyses revealed that the massif is made up of fine, medium to coarse grained granite composed of primary minerals Qtz+Kfs+Pl+Bt+MS+Zr and the secondary phase is represented by the chlorite and serpentine. The geotechnical analysis gave the values of the physical and mechanical parameters varying from one textural class to another, but they generally fall in the intervals values accepted for hard rocks to be used for civil engineering construction. Fine-, medium- and coarse grained granites have mean values, respectively, 1.45-1.41, and 1.42 in bulk density; 2.50-2.54 and 2.62 specific density; 26.97-31.00 and 34.00% in Los Angeles coefficient; 5.00-8.00 and 9.50% in wet Microdeval coefficient and 13.81-15.71 and 18.57% in dynamic fragmentation coefficient. The above results are of scientific interest for the valorisation of materials in the context of basic infrastructures. However, the variability in mechanical strength as a function of grain size and mineralogical composition explains in particular their influence on geotechnical properties. To this end, these factors could be clues serving as a decision guide for the choice of the right materials already knowing the petrographic nature of the rock.

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