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# Physical Characterization of Granite Alteration Products for Use in Civil Engineering

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## ABSTRACT

A study of the alteration products of granite was carried out. The observation on the site shows the presence of materials from five distinct horizons and materials consisting of these mixtures. Experimental studies reveal that the materials studied are essentially all-purpose sands. According to the sand equivalent values obtained, these materials are clean sand with a low percentage of fine particles, suitable for quality concrete. The specific density of materials from different horizons is quite large, ranging from 2.55t/m$^3$ to 2.74t/m$^3$. The fineness modulus and the expansion coefficient respectively have average values of 3.05 and 17.14%, showing that the studied materials are poor in fine elements. The absorption coefficients have an average value of 0.048%, indicating that these aggregates assure good durability of concrete in aggressive environments. The flattening coefficients have an average of 2.05%, indicating that these aggregates are suitable for making concrete. The optimum dry density, the optimum water content and the 95% CBR from OPM range respectively from 1.9 t/m3 to 2.07 t/m3, 5.2% to 12.2% and 35 to 100. With regard to these properties, the use of alterites thus studied as building materials in civil engineering requires special attention.

KEYWORDS: Physical characterization, products of alteration, granite, sand, civil engineering.

## INTRODUCTION

In Cameroon, the construction and public works sector is booming and of increasing concern. The majority of the population and companies produce works with the use of materials whose characteristics are poorly known, which leads very often to the ruin or the early deterioration of the structures. Increasingly concerned about the scarcity of aggregates of required quality, the State instructed the Mission of Promotion of Local Materials (MIPRAMALO) and the Ministry of Mines and Industry in their sovereign missions to develop catalogs of quality. The use of certain materials in buildings. This involves a vast campaign of geotechnical characterization of materials from different quarries used for construction in the country. It is to contribute to the success of this mission that this study was initiated. The present study uses the data obtained by experimentation of more than 100 samples of alterites collected in Takoucheu quarry (Baleng, Western Region of Cameroun). The experimentation was carried out in the Civil Engineering laboratory of IUT-FV of Bandjoun and the

National Laboratory of Civil Engineering of Cameroon. The obtained knowledge is necessary to regulate the conditions of use of these aggregates for construction.

# MATERIALS AND METHODS

## Location of study points and sampling

Figure 1 shows a map showing the study area covering approximately 39 hectares. The walls of the stratigraphic profile of this quarry show a mantle that rests on gabbro and presents five (05) horizons alteration of total average height 2.5 meters. From the geomorphological point of view, it is an area marked by the presence of altered granitic cuirasses, developed on the lateritic beds, following the alternation in hot and humid climate. Climatic conditions are typically "mountainous Cameroonian" Olivry (1986), [1] with an average annual rainfall of 1741*mm* and an average temperature of 20.2 ° C.

In order to have the most representative samples of the quarry, the chosen points were those located in different areas of the site and presenting all the apparent diversity in terms of shape, color, presence, size and voids on the basis of a macroscopic observation of different profiles of alterites. Sampling [2] for most of the points was facilitated by the use of embankments made by local operators. Other points were made on trenches created specifically for this investigation.

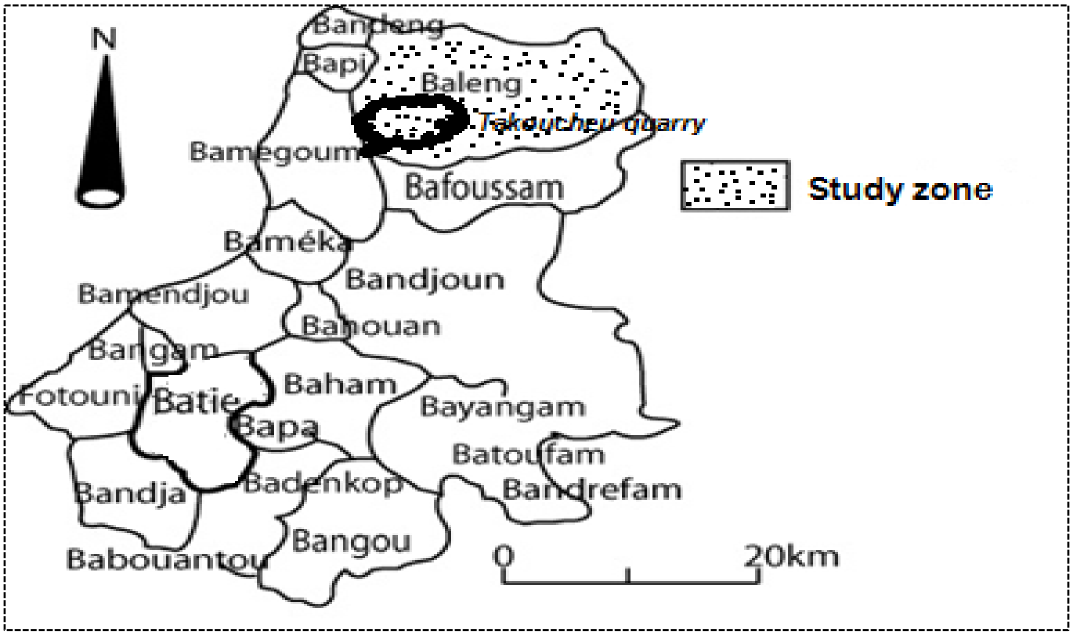


**Figure 1:** Location Map of Takoucheu-Baleng Quarry [1]

## Experimentation

Laboratory work consisted of standardized physical identification tests, according to the details and procedures of the French standards in force:

- The water content was determined by the method of successive weighings before and after drying the samples in an oven at 105 ° C for 24 hours, according to standard NF P 94-050 [3]. - The apparent density was determined using the weighing method, following the standard NFP 18-554 [4].

- The absolute density was determined using the pycnometers according to the prescriptions of standard NF EN 1097-7 [5].

- The particle size analysis was carried out by dry sieving according to standard NF EN 933-1 [6]. The flattening coefficient was determined according to standard NF EN 933-3 [7].

- The sand equivalent was determined on fractions smaller than 5mm, following the prescriptions of standard NF EN 933-8 [8]. The absorption coefficient was determined according to standard NF EN 1097-6 [9].

- The swarming of the samples was studied on the basis of the principle described by standard NF P 18-545 [10].

- The bearing capacity of the various samples was determined by Proctor modified test following the process defined by the NFP 94-093 [11]. The C.B.R (Californian Bearing Ratio) test was carried out, according to the prescriptions of standard NF P 94-078 [12].

# RESULTS AND ANALYSIS

## Water content and density parameters

The water content and material density of samples collected in August are presented in table 1.

**Table 1:** Water content and density parameters of materials for each horizon

| Horizons | Trade name | Depth of sampling (cm) | Water content: *w* (%) | Apparent mass volume $\rho$ (t/m$^3$) | Absolute density $\rho_s$ (t/m$^3$) |
|---|---|---|---|---|---|
| Horizon 1 | All type of sand | 0 – 65 | 2.9 | 1.71 | 2.65 |
| Horizon 2 | Clay sand | 65 – 97 | 14.4 | 1.4 | 2.53 |
| Horizon 3 | Whitish sand | 97 – 152 | 2.4 | 1.65 | 2.69 |
| Horizon 4 | Greyish coarse sand | 152 – 220 | 2.7 | 1.38 | 2.61 |
| Horizon 5 | Gray medium sand | 220 – 254 | 6.3 | 1.53 | 2.6 |
| Mixed Horizon | Mix Sand | 0- 65 and 97 - 254 (mixed of horizons, except horizon 2 ) | 4.94 | 1.63 | 2.75 |

According to table 1, clay sand has the highest water content (14.4%), which is explained by the high content in clay particles that retain a lot of water. This could explain why this horizon is generally excluded from commercial exploitation. On the other hand, the water content of the other horizons varies between 2.4% and 6.3%. These low values attest to the low content of fine particles, which makes it possible to predict that the swelling of these aggregates is negligible and therefore does not constitute a handicap for the production of concretes and the realization of pavement foundations. The density values of the materials from the different horizons are greater than or equal to 1.4 t / m$^3$, which confirms that the materials studied are indeed aggregates [13]. The values of the absolute density vary from 2.53 t / m$^3$ at 2.75 t / m$^3$, which means that the studied materials are common aggregates that can be used in road construction and in concrete [13].

## Sand equivalent and absorption coefficient

The values of the sand equivalent and the absorption coefficients of the aggregates studied are presented in Table 2.

**Table 2:** Sand Equivalent and Absorption Coefficients of Different Aggregates

| Horizons | Trade name | Sand equivalent (ES) in % | Absorption Coefficients (Ab) (%) |
|---|---|---|---|
| Horizon 1 | All type of sand | 86.84 | 0.04 |
| Horizon 2 | Clay sand | 69 | 0.14 |
| Horizon 3 | Whitish sand | 92.77 | 0.02 |
| Horizon 4 | Greyish coarse sand | 92.66 | 0.01 |
| Horizon 5 | Gray medium sand | 89.98 | 0.03 |
| mixed Horizon *(commercial sample)* | Mixed Sand | 86.96 | 0.06 |

Table 2 shows the sand equivalent of horizon 2 is 69%, attesting that the material is slightly clayey but allows the realization of common concretes that may in condition that a Portland Cement is been used. The aggregates from the other layers and the mixture are very clean sands and contain very few fine particles (because ES> 85) [14]. Therefore, these materials are suitable for the manufacture of quality concrete. In addition, it follows that the different horizons and their mixture have an absorption coefficient (Ab) ≤ 5% [14] which is the specified upper value (Suv). This means that these different aggregates have poor pores and ensures good durability of concrete in aggressive environments.

## Sand growth and variation according to the water content

Variation in expansion versus water content was only studied for the sand sample commonly marketed. The results obtained are shown in figure 2.

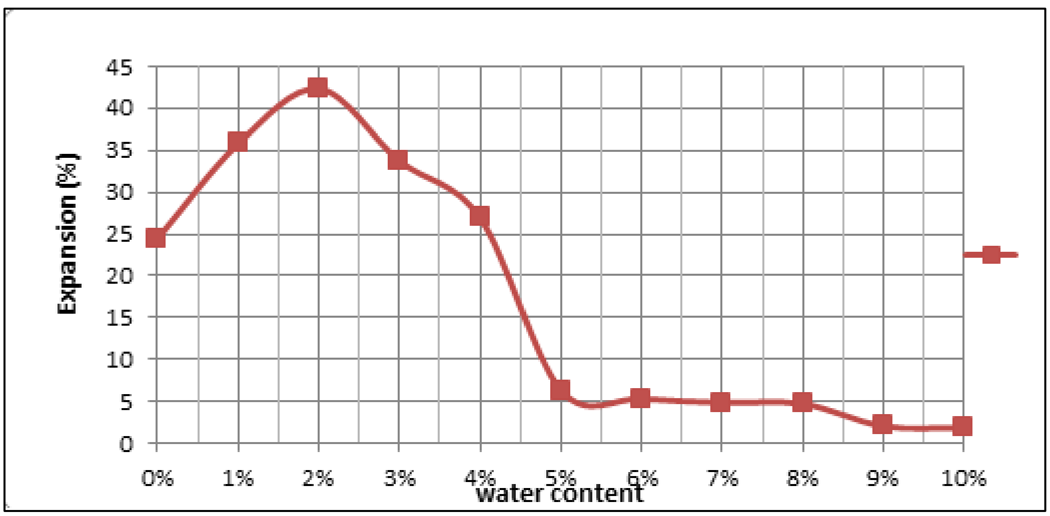


**Figure 2:** Expansion curve of the mixed of horizons

Figure 2 shows the volumetric expansion coefficient of sand can be estimated at 17.14%. This confirms that the sand studied is poor in fine elements (because 17.14% < 25% which is the specified upper value of the expansion coefficient of fine sand [14])

## Parameters at the Modified Proctor Optimum

Parameters at the Modified Proctor Optimum of Granules are presented in Table 3 and Figure 3.

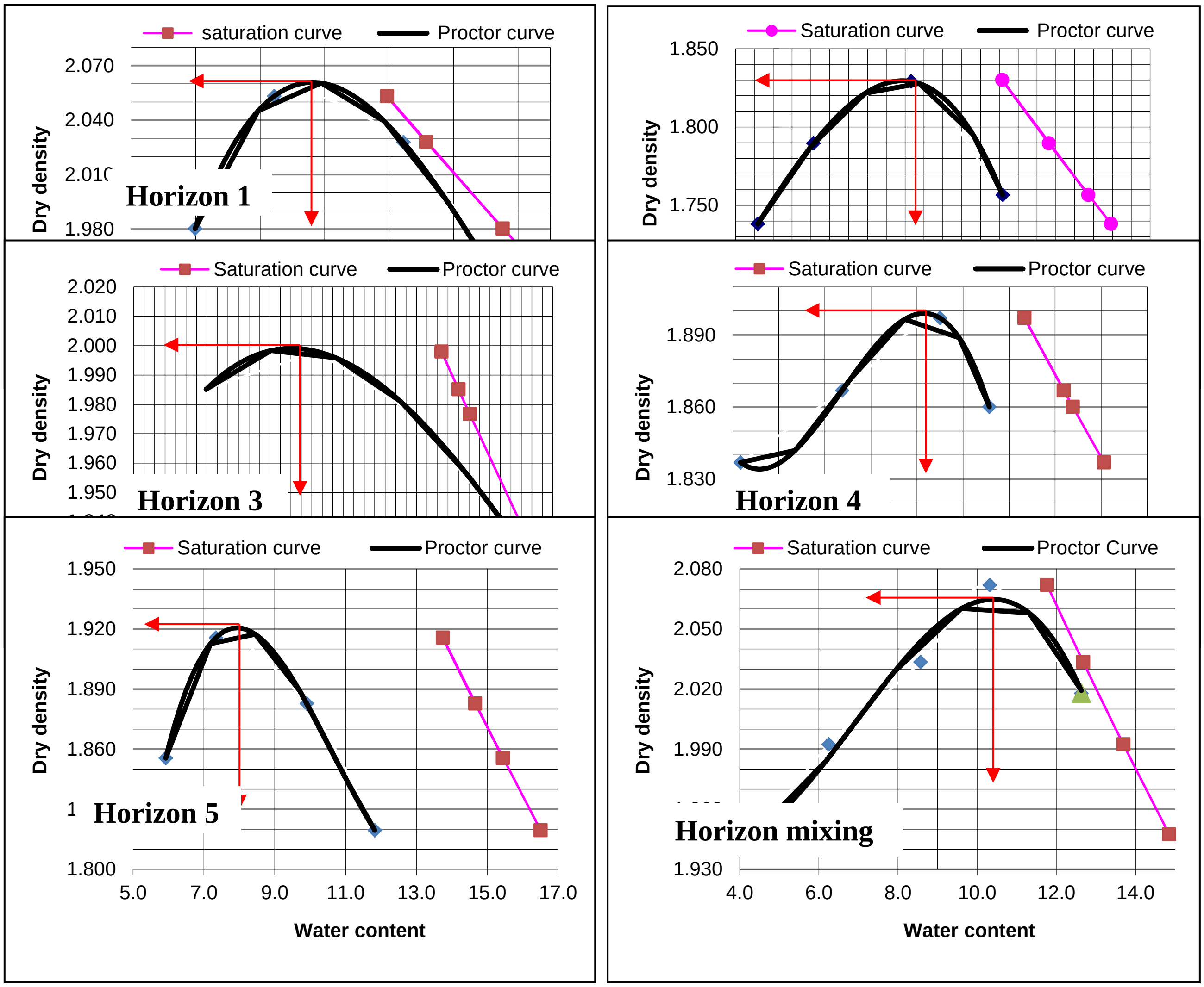


**Figure 3:** Modified Proctor and saturation curve of materials

**Table 3:** Parameters at the Modified Optimum Proctor

| Horizons | Trade name | Optimal dry density $\rho^{OPM}$ (t/m$^3$) | Optimal water content $w_{OPM}$ (%) |
|---|---|---|---|
| Horizon 1 | All type of sand | 2.06 | 9.8 |
| Horizon 2 | Clay sand | 1.83 | 12.5 |
| Horizon 3 | Whitish sand | 2.01 | 10.2 |
| Horizon 4 | Greyish coarse sand | 1.91 | 12.2 |
| Horizon 5 | Gray medium sand | 1.92 | 8 |
| Horizon mixed *(commercial sample))* | Mixed Sand | 2.07 | 10.5 |

Figure 3 and table 3 show the Optimum dry density at Modified Proctor Optimum (OPM) of different aggregates (except for clay sand which needs amelioration) range from 1.91 to 2.07 t/m$^3$. Since their OPM water contents also vary from 8% to 12.5%, which shows that these materials can be recommended for the preparation of base layers and foundations of pavements [11] ( $1{,}9t/m^3 \le \rho^{OPM} \le 2{,}1t/m^3$ $\rho^{OPM}$ , and $7\% \le w_{OPM} \le 13\%$).

## The CBR after 4 days of immersion

The 95% CBR indices of the OPM after 4 days of immersion of aggregates studied are presented on Figure 4 and summarized in Table 4.

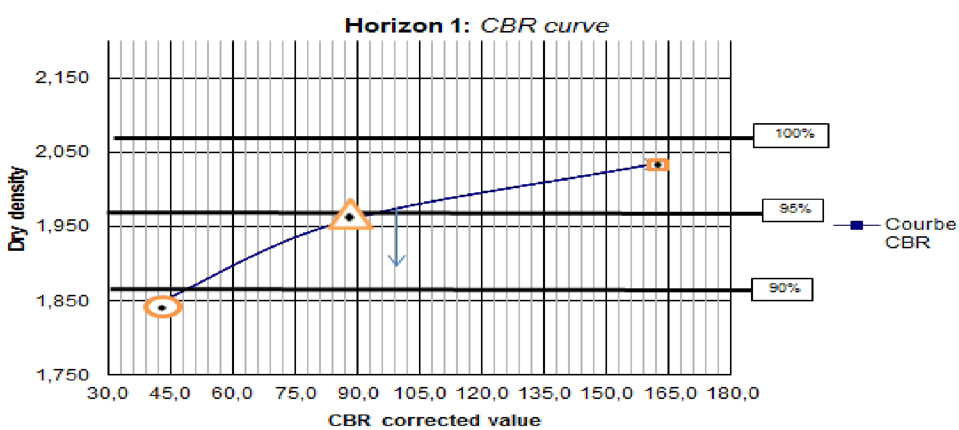


**Figure 4:** CBR curves of different materials – *Continues on the next page*

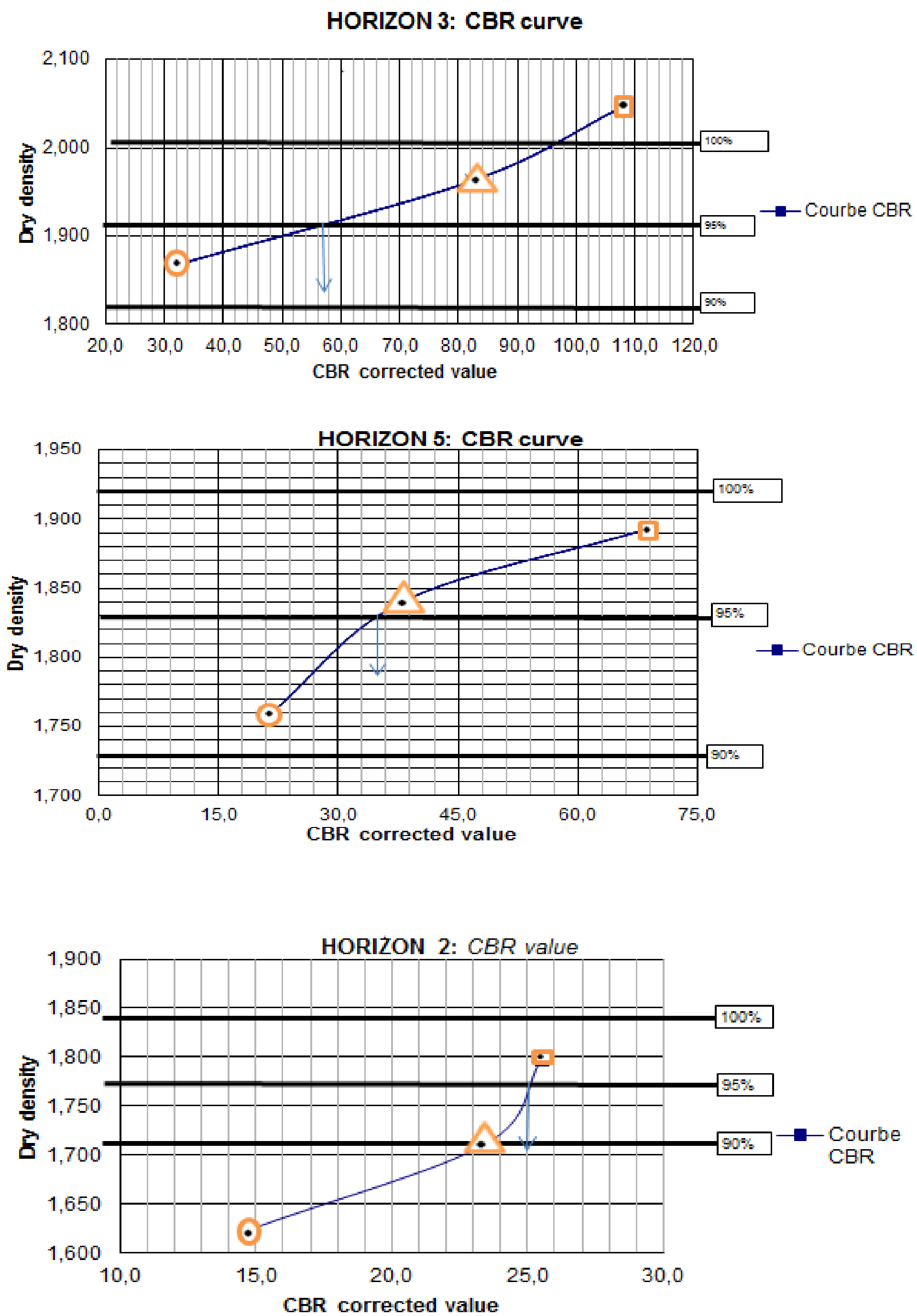


**Figure 4:** CBR curves of different materials – *Continues on the next page*

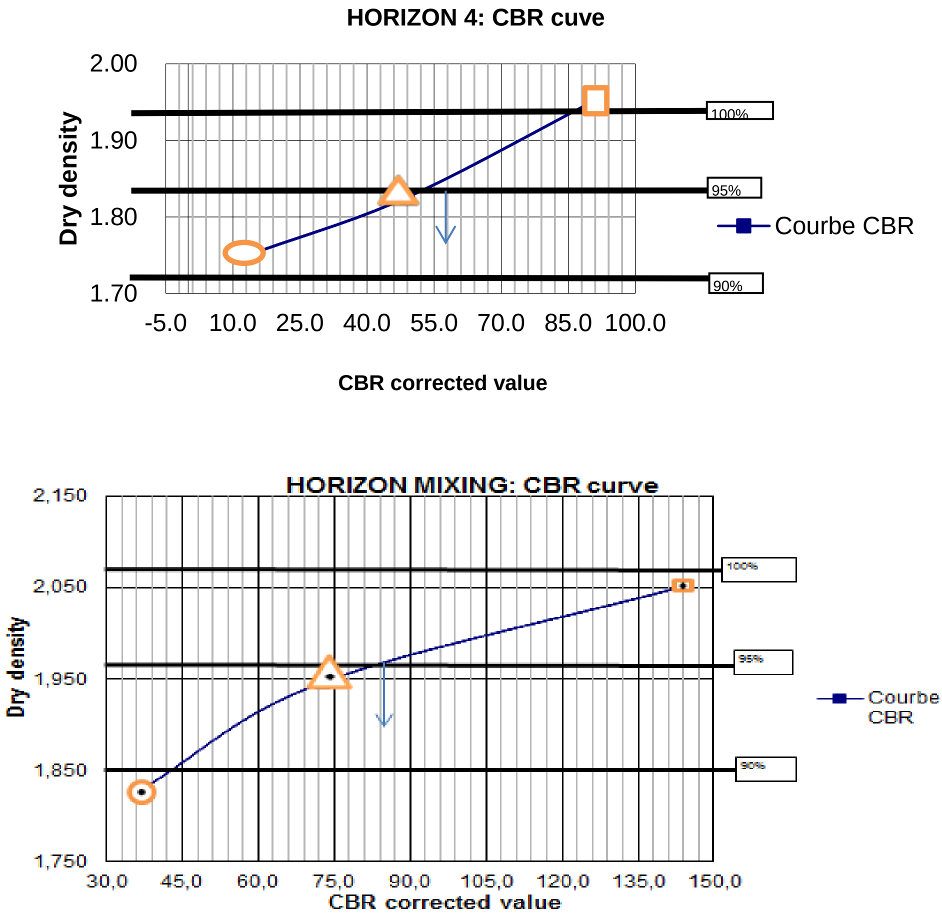


**Figure 4:** CBR curves of different materials

The summary of 95% CBR values of OPM and swelling of studied aggregates are presented in Table 4.

**Table 4:** CBR Indices and swelling after 4 days immersion

| Horizon | Trade name | CBR Indics at 95% | *Swelling* |
|---|---|---|---|
| Horizon 1 | All type of sand | 100 | 0.05% |
| Horizon 2 | Clay sand | 25 | 0.20% |
| Horizon 3 | Whitish sand | 57 | 0.03% |
| Horizon 4 | Greyish coarse sand | 58 | 0.02% |
| Horizon 5 | Gray medium sand | 35 | 0.06% |
| Horizon mixed *(commercial sample)* | Mixed Sand | 83 | 0.08% |

According to table 4, for 95% OPM the CBR values of horizon 1 and mixed horizon are greater than 80. Therefore, these materials can be used for base layer in road construction [15]. As for the materials from horizons 2, 3, 4, 5 with a CBR index of less than 80, they will have to be improved before their use in the production of the base layer of high-traffic pavements. Materials from horizons 3 and 4 that have a CBR index close to 60, can thus be accepted as base layer materials for T1 traffic [15].

In addition, it appears that the values of swellings are less than 2%, which is the specific upper value [15] for the materials to be used as seat for pavement. This confirms the values of the absorption coefficient obtained above and indicates that these aggregates are conducive to road construction.

## Geometric characteristics of the different horizons

### *Grain size distribution*

The grain size distribution of the materials studied is presented on figure 5. It follows that the particle size curves obtained are almost offset from each other, which shows the differentiation of these materials although from the same petrological profile. However, the shape of the curves is essentially the same, showing that the materials are generally from the same source rock. The exploitation of these granulometric curves makes it possible to obtain the data in table 4 below.

**Table 4:** Granulometric parameters

| Parameters | Horizon 1 | Horizon 2 | Horizon 3 | Horizon 4 | Horizon 5 | Horizons Brewing |
|---|---|---|---|---|---|---|
| Finesse module :$M_f$ | 4.1 | 1.25 | 3.66 | 3.31 | 2.8 | 3.2 |
| Coefficient of curvature Cz | 0.77 | - | 0.76 | 0.28 | 0.15 | 0.89 |
| Coefficient of uniformityCu | 24.02 | - | 12.6 | 43.94 | 64.45 | 11.36 |
| Maximum size of Dmax grains (mm) | 50 | 16 | 40 | 25 | 16 | 25 |
| Content in Fine (%) | 4.55 | 39.9 | 2.85 | 3.56 | 5.86 | 4.58 |
| Sand content (%) | 40.71 | 54.2 | 60.95 | 76.22 | 81.54 | 71.76 |
| Grains content (%) | 32.17 | 5.9 | 23.26 | 19.1 | 11.08 | 22.51 |
| Stones content (%) | 22.57 | 0 | 12.94 | 1.12 | 0 | 0.67 |

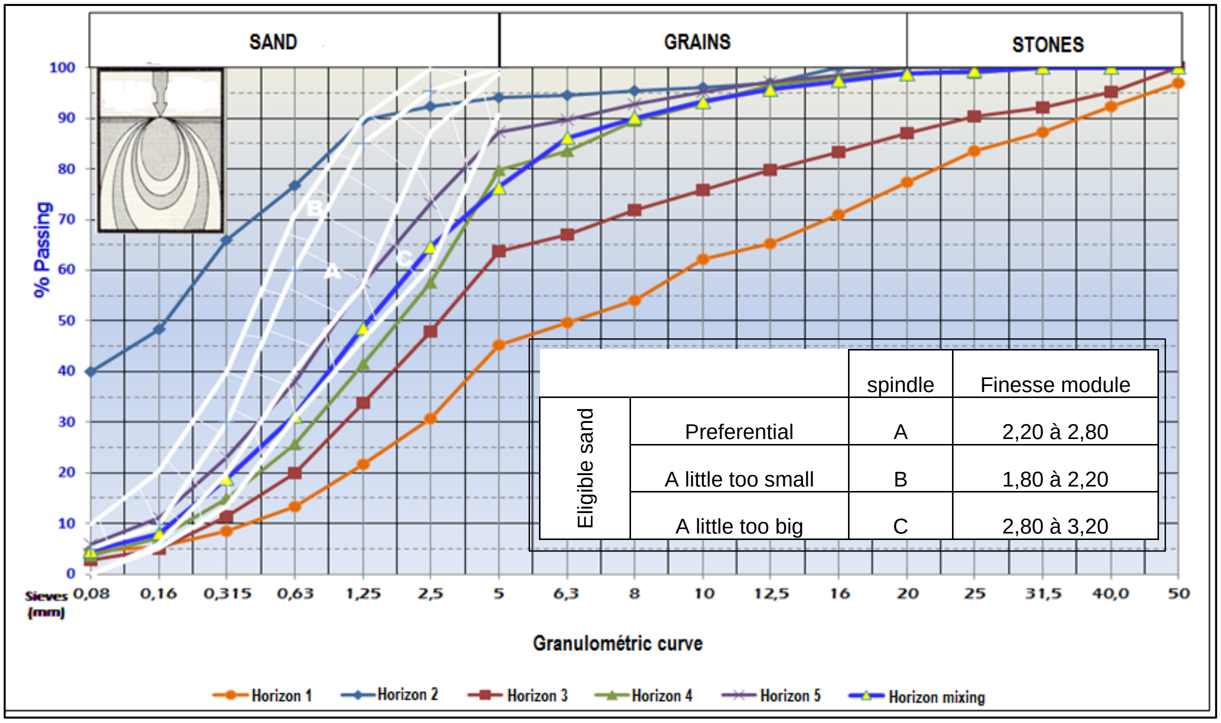


**Figure 4:** Granulometric curves of the different materials and preferential zones

Table 4 shows that for the different materials (except horizon 2), the Coefficient of Curvature (Cz) is less than 1 and the Coefficient of Uniformity (Cu) is greater than 2, indicating that the particle size of these materials is spread out and poorly graduated [16]. In addition, as Cu ≥ 10, these materials can be used as pavement sub-base materials [16], as well as for making high-strength concretes with less workability.

According to the values of the fineness modulus, the grayish mean sand and the mixed sand are included in the spindle A and C respectively [16]. The grain size distribution curves of materials from the horizons 1, 2, 3 and 4 do not belong to the granulometric spindle of good sand for concrete . The values of fineness modulus equal to 1.2 for second horizon and more than 3.2 for the others. It shows that the materials form horizon 2 are very fine materials from horizon 1, 3 and 4 are of high dimensions. Therefore, granulometric correction is necessary.

It is important to note that according to finesse modulus, the sands studied can be corrected to be suitable for all uses in construction works. Moreover, if the materials coming from the different horizons are screened, one would obtain in great and excellent quantity, all the fractions of aggregates (0/5, 5/15, 15/25, 0 / 31.5, 0/40 ...) found to be used in civil engineering works.

*Coefficient of flattening*

The values of the flattening coefficients of aggregates studied are presented in Table 5.

**Table 5:** Flattening coefficients of different horizons

| Horizon | Trade name | *Flattening coefficients* 'A' |
|---|---|---|
| Horizon 1 | All type of sand | 4.20% |
| Horizon 2 | Clay sand | 0% |
| Horizon 3 | Whitish sand | 2% |
| Horizon 4 | Greyish coarse sand | 2.40% |
| Horizon 5 | Gray medium sand | 0% |
| mixed horizon *(commercial sample))* | Mixed Sand | 3.70% |

The datas in table 6 shows the total absence of flat elements in horizons 2 and 3. Although present in the other horizons, these elements have a very low coefficient (much lower than 20% which is the specified upper value [16]). Thus, these materials are therefore aggregates popular for the manufacture of quality concrete.

According to the LPC classification of aggregates [17], the table below is established in the present work to guide the use of there materials studied:

**Table 6:** Classification and areas of use of sands

| Horizon | Trade name | Different domains in which materials can be used |
|---|---|---|
| Horizon 1 | All type of sand | Foundation layer |
| Horizon 2 | Clay sand | Base layer and mortar joint |
| Horizon 3 | Whitish sand | Concerete and mortar ; road construction |
| Horizon 4 | Greyish coarse sand | Concerete and mortar |
| Horizon 5 | Gray medium sand | Concerete and mortar |
| Mixed horizon *(commercial sample))* | Mixed Sand | Concerete and mortar ; base layer for roads |

## CONCLUSION

The present study made it possible to determine the peculiarities and the parameters of the sands derived from the alteration of a granite. For most of them, materials studied are essentially clean sand with a low percentage of fine clay. They are ideally suitable for the formulation of quality concretes and for the realization of the basecoats of pavements. With all the above, a careful study of the mechanical characteristics of these aggregates is necessary to do propositions for their use in concretes manufacturing.

In addition, the large fraction of gravel that results can be implemented in asphalt concrete for the realization of pavement wearing courses.

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