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Bidzar Marble Tailing Characterization and Potential for Civil Engineering Works Northern Cameroon

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Abstract: Stockpiling of tailings is a common phenomenon in most mines around the world, though these tailings can be exploited for better usage, little is been done as this is concern. The Bidzar-Bataol area is known for high marble concentration within the sub region and the setting up of cement factories will see an increase in marble tailings stockpile. This study focuses on the characterization of tailings collected from the crushing of marble in Bidzar, North Region of Cameroon. A total of four samples were prepared from a grab sample collected at the mining site. The Bidzar marble tailings were tested on their geo-mechanical properties and compared to that of aggregates used in civil engineering works and other similar study. The investigated properties with their methods in this study are: grain size analysis (NF EN 933-1), specific gravity (NF P 94-054), Los Angelos (NF EN 1097-2), Micro Deval (NF EN 1097-1) and Flakiness Index (NF EN 933-3). The results obtained shows that the tailings are poor but uniformly graded with a Coefficient of Uniformity (C_u) 2.42 and Coefficient of Curvature (C_c) 1.02. Also, aggregate of granular class 10/14 shows average Los Angelos value of 20.18 % and average Micro Deval 16.9 %, making them good for constructions. Similarly, with average specific gravity of 2.71 g/cm^3 and average Flakiness Index of 19.63 %, the tailings present good potentials for aggregate used in civil engineering. The tailings of granular class 10/14 mm present excellent results for specific gravity, and a satisfactory result were obtained on the Los Angelos and Micro Deval. It can therefore be concluded that Bidzar marble tailing can potentially serve as conventional aggregate and can be used in construction.

Keywords: Bidzar, Marble, Tailings, Geo-Mechanics, Civil Engineering, Aggregate

1. Introduction

Over the last decades, there has been rapid increase of civil engineering works in Cameroon. Most public and commercial quarry exploits the use of granite, basalts and gneiss as aggregate depending on the geological condition of the area. Whereas, construction works around the Figuil, Bidzar and Guider area uses marble waste (tailing) from the

Bidzar marble quarry. Also, the tailing is exploited by the local council in the opening and maintenance of secondary roads. So far, a large number of investigation has been made on the use of marble waste (aggregate and powder) in concrete production. Geseoglu [1] outline that marble has been used as an important building material, especially for decorative purposes for centuries and during processes like sawing, shaping, and polishing process, about 25% of the processed marble turns into dust or powder form, which was used in concreting making. Also, Belachia & Hebhoub [2] carry out an experimental approach to substituting natural aggregates by the recycled aggregates (marble tailings) and a satisfactory result of high concrete strengths were obtained by the 25% substitution rate and the maximum density was obtained for concretes of 50 % substitution rate. Also, marble waste may improve on properties of concrete such as the water absorption & permeability and resistance of chloride penetration and sulphate attack [3]. Gonfa [4] concluded that the use of marble waste aggregate up to 80% by weight is recommended for road base course layer, when it is found near to the construction site and in places where the materials are abundantly available. Meanwhile, Wouatong [5] carried out geological and physico-mechanical characteristic on the white marble of the Bidzar quarry. The physio-mechanical characterizations were carried out on white marble, which present features of a less resistant, satisfactory but limited rock.

The Bidzar-Bataol area is known for high marble concentration in the country, and this will attract many processing factories in the future. So far one of the major Portland cement produces stockpile about 54000 ton of marble tailings annually and just a few not up to 1 % is used by the local council and population for development. It may be relatively affordable to users as compared to other aggregate found within the region, but seems problematic as it has never been characterized for these purposes and maybe the reason for under exploitation. The government has recently awarded contract to a road construction company for the construction of the road between Carrefour Bidzar and Guider and other road maintenance work within the Mayo Louti Division, North region of Cameroon. Also, neighboring towns like Garoua and Maroua are fast developing and are in need of construction material. This study is creating the awareness of the use of Bidzar marble tailings in civil engineering works, although it may also be use as addictive for cement production and as fillers in paint production. The study concentrates on the geo-mechanical properties of the marble tailings and compare with that of aggregates used in civil engineering. In this context, the geo mechanical properties include: specific gravity, Los Angeles, Micro-Deval, and flakiness index were examined.

2. Geological Setting

Bidzar is found in the Mayo Louti, North region of Cameroon. The area has a soudano-sahelian climate with two main seasons, dry (November to May) and rainy (ending May to October) season. This area is part of the North segment of the Pan-African range of Central Africa in Cameroon (Figure 1). The area is characterized with five main geological units: the neo-proterozoïc shale unit of volcanic and volcano-sedimentary origin [6-8], the neo-proterozoïc gneiss unit is in agreement with shale. The degree of metamorphism of the shales is one of the facies domain of the green shales to amphibolites while that of gneiss is characterized by high temperature amphibolites [8-11].

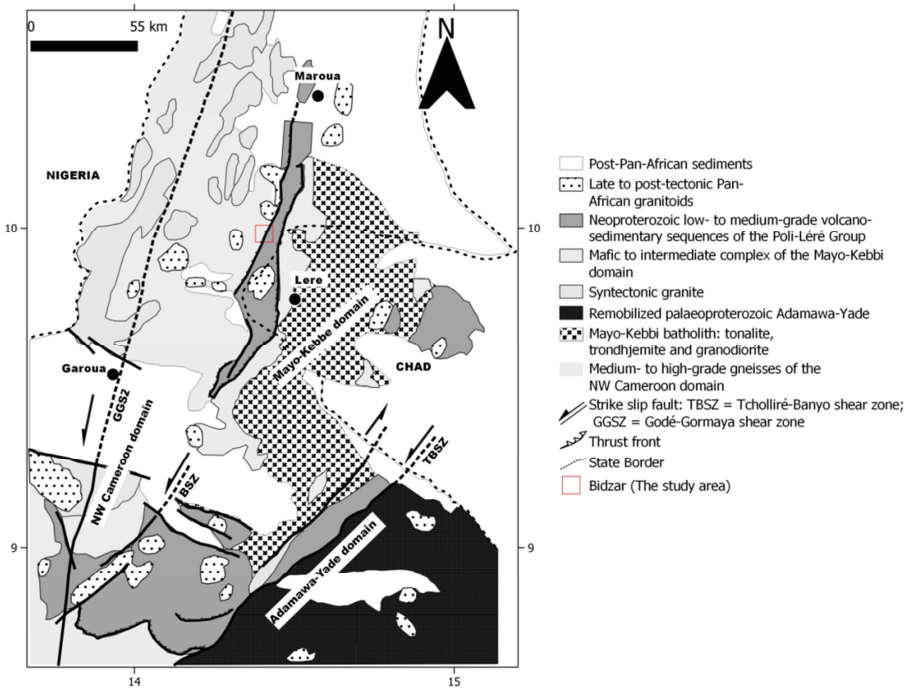

Figure 1. *Location of Bidzar in the lithostructural units on geologic maps of the North domain of the Pan-African Belt of Central Africa in Cameroon modified from [6, 7].*

3. Material and Methods

Grab samples of marble tailings (waste) aggregate were collected from the Bidzar marble quarry according to the procedure NF EN 932-2 norms. For each test, quartering, riffle splitter, and weighting are used for sampling processing. Four samples were collected for each of these tests.

3.1. Grain Size Analysis

The analysis was done with respect to NF EN 933-1 norm, which consist in arranging the vibrating sieves in decreasing order of diameter. The sieves used were 25 mm, 20 mm, 16 mm, 12.5 mm, 10 mm, 8 mm, 6.5 mm, 5 mm, 4 mm, 3.15 mm, and 2.5 mm. The mass of residue accumulated on each sieve expressed in percentage is determined as follows:

$$\% \text{ Residue} = \frac{R_i}{M_i} \times 100 \quad (1)$$

Where; R_i: Residue of a sieve (g) and M_i: Dried mass of origin (g).

3.2. Specific Gravity

The specific weight or gravity test was carried out according to the (NF P 94-054) norm with the aim to determine the real density of a material. The mass of solid particles is obtained by weighing, and the volume is measured with a pycnometer. The real density P_S of solid particles is defined by:

$$P_S = P_w \frac{(m_2 - m_1)}{(m_4 + m_2 - m_1 - m_3)} \quad (2)$$

Where, P_w is the density of water (1000kg / m^3), m_1 is the mass of the empty pycnometer, m_2 the mass of the pycnometer and aggregates, m_3 the mass of the pycnometer, aggregates and water and m_4 the mass of the full pycnometer water in grams.

3.3. Micro Deval

This test was prepared using the NF EN 1097-1 standard with the aim of measuring the wear resistance of aggregate samples. This standard is applied for aggregates from natural or artificial origin, used in the domain of housing and civil engineering. The test consists of determining the Micro Deval coefficient, which is the percentage of original sample reduced to less than 1.6 mm per rotation in a cylinder.

The coefficient of Micro Deval (M_{DE}) is by definition the ratio of:

$$M_{DS} = \frac{M - M_r}{5} = \frac{M_r}{5} \quad (3)$$

Where; M is specimen of mass (500 g) corresponding to the 10 – 14 mm aggregate class and M_r the mass in gram of the reject from a 1.6 mm sieve.

3.4. Los Angeles

The said test was prepared using the NF EN 1097-2 standard with aim to measure the impact fragmentation resistance of the elements of a sample of aggregates. This standard is applied for aggregates from natural or artificial origin, used in the domain of housing and civil engineering. The test consists of measuring the quantity of element less than 1.6 mm produced after impact of the material with standard balls in the Los Angeles machine.

The coefficient of Los Angeles (L_A) is by definition the ratio of:

$$L_A = \frac{100 \times m}{5000} \quad (4)$$

Where; m is the mass in gram passing through sieve 1.6 mm and 5000 g the mass of specimen corresponding to the 10 – 14 mm aggregate class.

3.5. Flakiness Index

It was prepared using the NF EN 933-3 standard, which has as objective to determine the Flakiness Index of aggregate samples with dimension found 4 and 31.1 mm. The said standard is applied for granular from natural or artificial origin, use in the domain of housing and civil engineering.

The global Flakiness Index A of a sample is equal to the weighted sum of the Flakiness Index of the different aggregate classes d/D composing the sample

$$A = \frac{\sum M_e}{M} \times 100 \quad (5)$$

Where, M_g is Mass of each granular class d/D, in gram; M is the sum of M_g and M_e the Mass of element in each granular class d/D passing through corresponding grid.

Figure 2. *Marble tailings from the quarry (a) before, (b) after grab sample collection.*

Figure 3. *Marble Tailings used as aggregate for construction by local population.*

4. Results and Discussion

Physical and mechanical property of Bidzar marble tailing aggregate (MTA) shows results of specific gravity, Los Angelos, Micro Deval and Flakiness Index. (Table 1).

Table 1. *Geo-mechanical properties of the Bidzar marble tailings.*

Parameters	Standard	Granular class (mm)	Sample				
			MTA1	MTA2	MTA3	MTA4	Average
Specific gravity (kN/m)	NF P 94-054	5/25	2.7	2.73	2.7	2.71	2.71
Los Angelos LA (%)	NF EN 1097-2	10/14	20.5	20	20.4	19.8	20.18
Micro Deval MDE (%)	NF EN 1097-1	10/14	17	16.5	16.8	17.3	16.9
Flakiness Index FI (%)	NF EN 933-3	5/25	19.8	20.2	19.5	19	19.63

To interpret our mechanical results we use the standard of guide for evaluating the quality and durability of material, presented in table 2 as seen in [12, 5].

Table 2. *Guide for evaluating the quality and durability of material.*

Criteria	Standard	Excellent	Satisfactory	Limited	Mediocre
Specific Gravity g/cm^3	EN 13383-2	>2.7	2.5 - 2.7	2.3 - 2.5	<2.3
Micro Deval %	EN 1097-1	<10	10 - 20	20 - 30	>30
Los Angelos %	EN 1097-2	<15	15 - 25	25 - 35	>35

4.1. Particle Size Distribution

Based on NF EN 933-1 Bidzar marble tailings aggregate depict a coarse aggregate with greater than 50% retained on 13.25 mm sieve far above the 4.75 mm requested by USCS. The aggregate is poorly graded with coefficient of Uniformity C_u lesser than 4 and uniformly graded with Coefficient of Uniformity C_c approximate to 1. With respect to the USCS classification according ASTM D 2487, the tailings are pure and uniformly graded gravel. Particle Size Distribution of Bidzar marble tailings aggregate is shown in Figure 4. This result differs with that of Gonfa [4], but similar with result obtained in [13-15] (Table 3).

Table 3. *Bidzar marble aggregate classification compared with other study.*

Aggregate Type	Coefficient of Uniformity C_u	coefficient of Curvature C_c	Ref.
Marble tailings Aggregate (MTA)	2.42	1.02	This Study
Fine Marble aggregate (FMA)	3.96	1.09	[13]
Coarse Marble aggregate (CMW)	2.8	1.411	
Marble waste Aggregate (MWA)	68.33	3.13	[4]
Convectional Aggregate (CA)	23.64	1.98	
Gravel	3.16	1.74	[14]
Granite	1.44	0.7	
Coarse gravel	2.4	1	[15]
Granite	2.8	1.16	

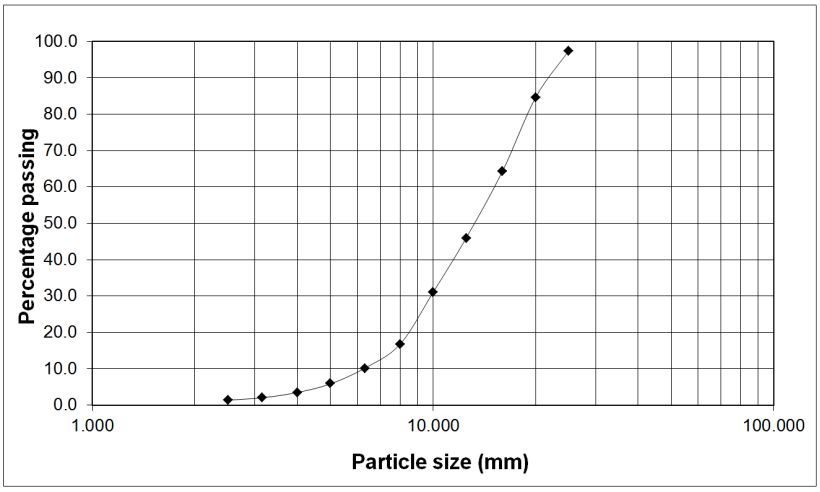

Figure 4. *Particle size distribution of Bidzar marble tailings.*

Benjeddou & Mashaan [12] based on particle size distribution resulted that marble aggregates are preferred for the different road layers construction. With strong correlation between both results, Bidzar marble tailing aggregate is a potential conventional aggregate for road construction and concrete production. The correlation was done with the coarse marble waste (CMW) in [12] and the Bidzar marble tailing aggregate MTA.

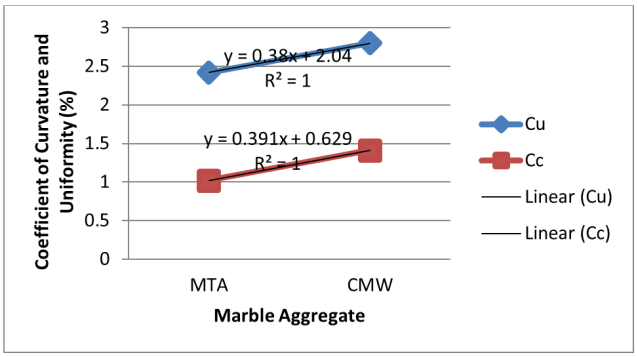

Figure 5. *Comparison between MTA and CMW by Benjeddou & Mashaan [13].*

4.2. Specific Gravity

The results of the physical properties of marble aggregates, presented in Table 1, show that the average specific gravity of Bidzar marble tailing aggregate is 2.71 g/cm^3. The specific gravity according to NF P 94-054 of aggregates normally used in construction ranges from about 2.5 to 3.0 g/cm^3 with an average value of about 2.68 g/cm^3. Similar results were obtained with coarse marble aggregate in [4, 13, 16]. Also, Aboubakar [12] with four samples from the Beka-Gotto rock matrix of granular sizes 10/14 had specific gravity ranging from 2.62 to 2.77 g/cm^3, and Gonfa [4] from the conventional aggregate recorded a value of 2.83 g/cm^3. Since specific gravity of aggregates is considered as an indication of strength and the Bidzar marble tailings does not only fall within the range but have same value with other rock types well known for their use in civil engineering. Therefore the Bidzar marble tailings aggregate are of higher strength and thus good for construction.

4.3. Los Angelos

According to the results shown in table 1 the average Los Angelos value of Bidzar marble tailing is 20.18 %, similar to 22 % in Benjeddou & Mashaan [13]. Interpretation based on the guide for evaluating the quality and durability of the materials shows that Bidzar marble tailings aggregate is satisfactory to be used as conventional aggregate (Table 2). Los Angelos value of the Bidzar marble tailings aggregate falls within range of limestone according to [17]. Also, the tailings is classified as high quality for concrete, A-type for asphalt concrete, high performance for surface dressing and subbase course based on [18]. Meanwhile, the mechanical fragmentation strength differs with that recorded by Wouatong [5] with the 10/14 mm granular class. This may be due to the fact that during crushing not only the white marble are crushed but rather mixed with the other marble types found in the area.

4.4. Micro Deval (MDE)

As presented on table 1, the Micro Deval (MDE) coefficient of Bidzar marble tailings aggregate has an average value of 16.9 %. This value shows that the tested marble aggregate has good abrasion resistance. The MDE indicate that the tailing is resistant to abrasion actions and will withstand the high stresses induced due to heavy traffic wheel loads and the charge of building. Thus with this value, Bidzar marble tailings aggregate has an acceptable abrasion resistance to be suitable for as aggregate in construction. Similar results were recorded in [12, 13].

4.5. Flakiness Index (FI)

It depict from table 1 that the average Flakiness Index (FI) of Bidzar marble tailings aggregate is 19.63 %. According to result from [4], which shows respectively FI of 26.48% and 14.44 with marble tailings waste aggregate and conventional aggregate, were suitable for use as a base coarse material because it is within the ERA standard specification limit. The BS standard recommends a maximum value of 30 % for FI; this means Bidzar marble tailings aggregate is suitable to be use as aggregate in construction work.

The aim of this research was to create the awareness on the potential and possible use of the Bidzar marble tailings as aggregate in construction work. The result shows good prospect and this means since 80% of the tailings are left annually after been used by company, a profitable forecast can be drawn. Result by statista 2022 [19] say mining company makes a profit of 15 % of the total income. Paradoxically, the only work needed for the tailings will be sieving and stock piling into different granular classes so the profit margin may quadruple. Notwithstanding, with granular class 10/14 the aggregate produce from the Bidzar marble tailings offers an acceptable results as convectional aggregate for civil engineering works. Nevertheless, for a potential and sustainable exploitation the mixing of Bidzar marble tailings with standard granite aggregate in the area may also boost the results.

Table 4. *Forecast of commercializing the tailings as aggregate.*

Annual production (ton)	80 % of tailings (ton)	Unit Cost of aggregate (FCFA)	Total (FCFA)	15% Profit (after [19]) (FCFA)
54000	43200	8000	345,600,000	51,840,000

5. Conclusions

The main objective of this study was to create the awareness by investigating the suitability of aggregates obtained from marble tailings to be use as conventional aggregates for construction work. It resulted that if classified in granular classes the tailings will potentially serve as conventional aggregate. So rather than stock piling this valuable tailings a mechanism should be set up for it use in the construction industries. It is timing for such a mechanism to be set up as the marble potential in the area will favor many other companies and this tailing may become an alarming problem. Tailings from mines and quarries may be

considered waste, but the Government through her research centers needs to characterize them for a better understanding of their usage. Mapping of these tailings may in civil engineering reduce cost per kilometer of road and or valorized to extract other valuable minerals. In the case of this study, detailed environmental work needs to be done to estimate the danger level and also a complete geotechnical study on the different granular classes, with a possible combination of standard granite aggregate.

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