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THE VALORIZATION OF BY-PRODUCTS OF THE BIDZAR QUARRY-CAMEROON

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ABSTRACT

To develop the by-products of the Bidzar quarry, particle size, chemical analysis and testing have been carried out in order to assess the potential for use in the manufacturing process cement plant Figuil. The results of this analysis showed that the lime content in the cut 5/50 mm is about 41.34% for a loss on ignition of 34.14%. The cut 0/5 mm and 3-5 mm fraction respectively contain about 24.82% and 26.78% lime for fire losses of about 25.97% and 23.82%. The cut 5/50 mm and 3-5 mm fraction could be used respectively for the manufacture of cement and thought, for incorporation into the marble clean and waste for at 1/5 of their tonnage.

KEYWORDS: by-product, Bidzar quarry, cement, lime

INTRODUCTION

The main fundamental materials used in the developing of our society are cement, concrete and other building materials but their manufacturing processes have significant environmental impacts. Cement is a mineral powder derived from the transformation of a mixture consisting essentially of limestone and marl clay. It is a hydraulic binder that is when combine with water they form a plastic paste and progressively become hardens even under water. Traditionally the cement industry uses 4/5th of limestone and 1/5th of clay to manufacture cement. The concrete is obtained by mixing water, cement, sand, gravel and pebbles [1].

The production cycle of cement has four main stages: extraction from the quarry and gravel grinding, raw preparation, baking, grinding and packaging [2]. The extraction and grinding of raw material require preparation operation, processing and planning within the quarry in order to get finished products (aggregates, mineral raw material ...) that meet certain specifications [3,4]. These operations however result in the elimination of a certain amount of material forming the wide range of by-products from the quarry. The cement manufacturing process allows the use of waste or by-products in two ways: either as a partial replacement of the basic constituents (limestone and clay) valorization of material or replacement of fossil fuels (petroleum coke, coal, heavy fuel ...) energy valorization.

The cement manufacturers have been using by-products from other industries such as blast furnace slag or fly ash to replace certain components of cement without changing its quality [5,6]. The marble quarry Bidzar in Cameroon is exploited by cement manufacturers subsidiary of the Lafarge Group, it provides among others one of the most important materials needed to manufacture artificial cement (CPJ 35 and CPJ40) marl rich in limestone. This extraction is done using explosives and mechanical shovels. With the aim to increase the production of limestone within the Bidzar marble quarry and conserve natural resources, this study was conducted to valorize the grinded by-product. In order to reduce the production cost of raw materials, some important test of these byproducts were performed in order to evaluate their usage in the cement manufacturing process of the CIMENCAM Figuil plant.

MATERIALS AND METHODS

Collection procedure

The materials were collected at the marble quarry grinding workshop at Bidzar (latitude 9 ° 53'56 " North, longitude 14 ° 7'70 " East and altitude 388.0 m), located 28 Km north of Figuil in the Mayo-Louti department (Northern Cameroon region), near the Garoua-Maroua highway [7.8]. The samples were collected on a conical bunch of different cuts shaped size particles constituting the byproducts after the phases of grinding and screening. For each cut particle size the laboratory tests focused necessarily on reducing amounts of materials which however made it possible to measure the characteristic parameters of the overall material in which the collection was made. To improve the representativeness of the sample used in the laboratory over the whole of each heap of material, the collection was conducted in two stages:

- Collection at the quarry, the quantity of materials will be significantly greater than that which will be used for the test;

- Collection at the Laboratory on the amount required for the test and a representation of the original sample.

So the minimum weight representative (MWR) was calculated according to the following formula:

$$\frac{10\rho f d^3}{S_{FSE}^2}$$

where 19 is a constant depending on the size of particle , ρ the material density (g /cm3), *f* the particle shape factor (0.5 for the raw materials of cement production), *d* of the diameter d_{95} (diameter corresponding to 95% in a cumulative way) of the particle size (cm) and S^2_{FSE} the basic variance of sampling.

This allowed to get about 0.3 kg and 300 kg respectively for the cuts between 0/5 mm and 5/50 mm. The collection of the dirty samples or large sterile (5/50 mm cut) was performed, using a manual shovel of height 210 mm and 6 barrels of 50 liters, and those fine particles (0/5 mm cuts) using a laboratory shovel and a 10-liter bucket. An overall sample was collected per day for each break and each sample was taken for the production of one day. To get a better representation of an overall sample from the initial portion, a basic collection on each heap of materials in every quarter was carried out, that is collection at the summit, collection at the mid-height and collection at the base, by collecting basic size, totally as indicated by figure 1 and figure 2.

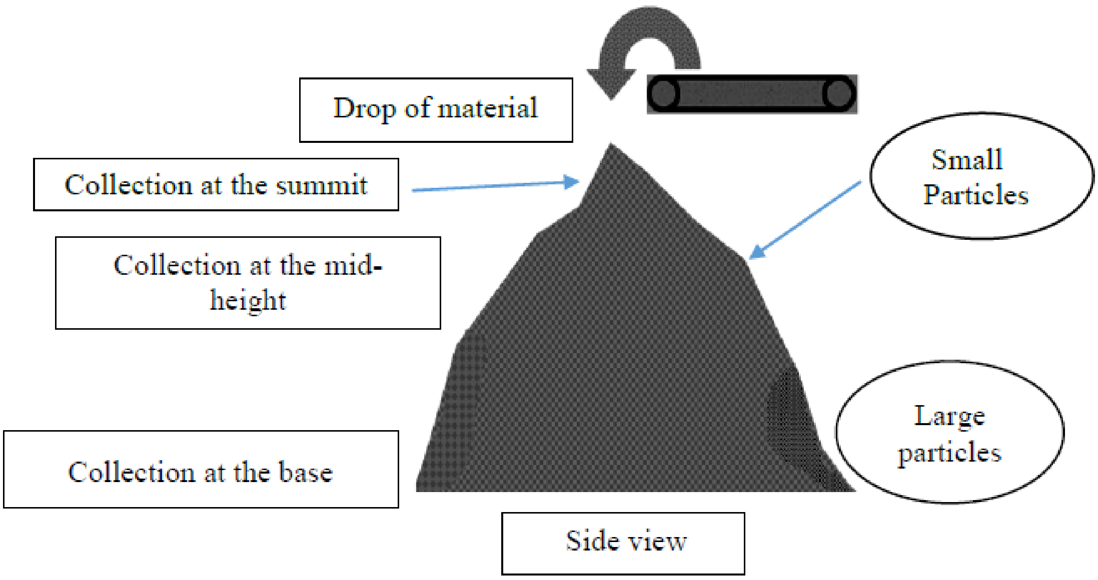

Fig 1. Collection procedure on a conical heap

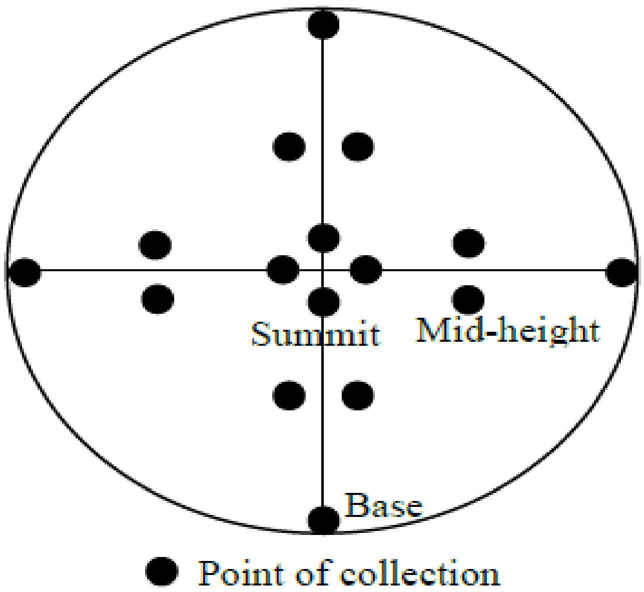

Fig 2. Stock tapered top view with 16 primary samples location collection

The basic elementary collection of 5/50 mm and 0/5 mm cuts were respectively 18.75 Kg and 0.5 Kg, for overall samples of 300 kg and 8 kg respectively.

Sample Preparation 5/50 mm and 0/5 mm

After sample collection the overall sample to the quartering was submitted to obtain representative amounts of each material then was screened, crushed and subjected to a second quartering to be grind to obtain the exact amount to be used as a test sample in the laboratory.

For each overall sample of 5/50 mm cut, the contents of the barrel (300 Kg) was emptied on a well cleaned place and then divided into two identical parts with the help of a shovel in order to preserve one of them. This method of quartering was done twice and the reduced preserve sample was about 75 Kg. Subsequently each reduced sample to sifting was submitted through sieves made of a metal mesh defining square holes of dimension 30 mm and 20 mm respectively. At the end of each screening, three size particle fractions (30-50 mm, 20-30 mm and 5-20 mm) was obtained and then were weighed, crushed and subjected to a quartering to be finely grinded to the grinder ROCKLABBS and sieved using a 200 um mesh sieve. The different unsieve particles were submitted to sieving after a second grinding before mixing them with the undersize particles. Both particles were eventually delivered to the laboratory for analysis.

For a 0/5 mm cuts, each global sample (8 kg) to quartering using a sampler (quarter) was subjected to obtain 500 g of sample reduced needed for testing. Each reduce sample was sieved using a PROLABO sieve with circular holes of diameter 3 mm to obtain size fractions between 3-5 mm and 0-3 mm. Fraction of 3-5 mm was weighed and then finely grind in an electrical grinder ROCKLABS for 3 minutes. The resulting powder was then sieved through a 200 µm mesh sieve and the unsieve particles were finally crushed and then added to the resulting tamisat and all of them were kept for laboratory analysis.

Laboratory work

In the laboratory, the previously prepared sample was submitted in to three analyzes:

- The percentage loss on ignition (LOI) was determined after igniting materials in a muffle furnace at 1150°C. For this, a mass was weighed of P_0 (2.0000 g) for each sample material in a cylindrical refractory crucible platinum alloy/gold previously weighed height and at least a diameter of 2 cm. The crucibles were then worn for 15 minutes in a muffle furnace previously heated to 1150°C, then cooled for about 15 minutes in a desiccator with a porcelain background. After releasing the crucibles of the dryer we weighed the final weight P_1 (crucible + calcined powder) and the loss of the percentage of material mass upon ignition during the experiment was calculated using the formula = PAF $(P_0-P_1)\times100/2$.

- The percentage of lime was determined by complexometric assay EDTA (ethylene diamine tetra acetic acid) in alkaline medium. For each sample, 2.0000 g of material were weighted and introduced in an Erlenmeyer flask of 250 mL and later on added 25 mL of distilled water and 5 ml of concentrated hydrochloric acid. After haven heated the boiled solution for 3 minutes, the volume was extended to 100 mL with distilled water and then added 15 mL of triethanolamine 1/3, 40 mL of 2 N normality of sodium hydroxide and a spatula of reagent Patton and Reeder, in order to introduce magnet and perform a burette way down. The end point is reached when the solution turns from purple to light blue. The assess of calcium was changed to an assess of calcium oxide and the percentage of lime was calculated using the formula % CaO = $T_1 \times V_1$, where V_1 is the volume of EDTA elapsed burette and T_1 the assess of EDTA.

- The chemical composition of the materials was determined by X-ray fluorescence spectrometry. For this latter analysis, the previous materials were dissolved by homogenizing at 1150°C these materials with lithium tetraborate to obtain a homogeneous glass solution from which beads were obtained. For this 7.2000 g flux (lithium tetraborate) were accurately weighed and mixed thoroughly with 0.8000 g of material in a beaker, and then the mixture was transferred of the latter in a crucible made of alloy platinum/gold, in order to bring the mixture at temperature of 1150°C in the muffle furnace for 15 minutes. 5 minutes before the outlet of the furnace crucible, red platinum plate (45 mm diameter) were pre-heated on a Meeker spout 190 mm high, curved valve supplied with butane gas. The flame diameter was 25 mm. Using a forceps, the crucible was then removed from the oven and its contents immediately poured into the cup while maintaining it above the flame. 30 minutes after this operation, the gas inlet has been closed and the cooling of the cup has ended in the open air. Pearl obtained with a diameter of 35 mm and a thickness of 3 to 4 mm was finally labeled with its identifier before being analyzed by X-ray fluorescence spectrum.

RESULTS AND DISCUSSION

Particle size analysis

Particle size analysis by sieving the 5/50 mm and 0/5 mm cut samples showed that the 5/50 mm cut included about 46.76 % of 30-50 mm fraction, 27.40 % 20-30 mm fraction and 25.84% of 5-20 mm fraction. The 0/5 mm cut consists of about 60.12% of 3-5 mm fraction and 39.88% of 0-3 mm fraction. These results illustrated in Figures 3 and 4 show that for the two cuts (5/50 mm and 0/5 mm), the weight percentages of the size fractions increase. It also follows that the products from the Bidzar quarry upon primary crushing consist essentially of size particles greater than 20 mm.

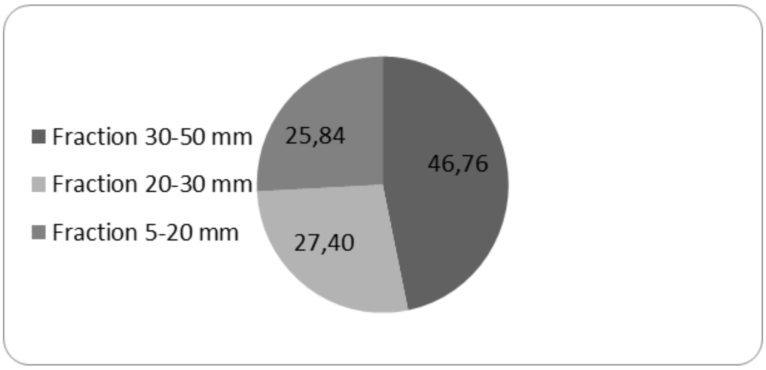

Fig 3. Weight percentage composition of the 5/50 mm cut

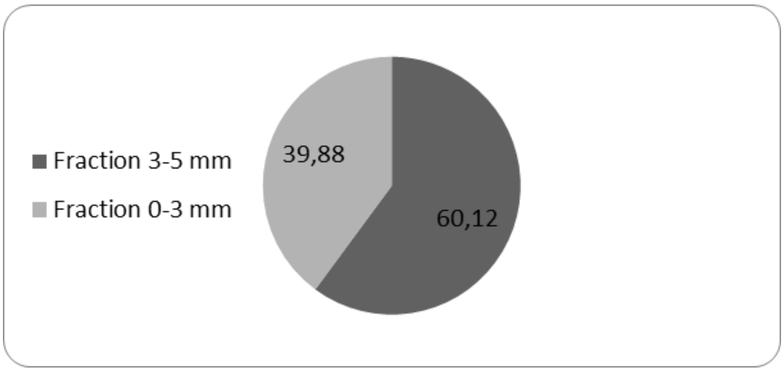

Fig 4. Weight percentage composition of the 5 0/5 mm cut

Chemical composition and loss on ignition

5/50 mm cut

The percentages of lime determined by complexometry and those of the ignition loss of the 5/50 mm cut and its different size fractions are reported on Table 1.
This table also shows the chemical composition of these materials as determined by X-ray fluorescence spectrometry. Each value is the mean of 13 consistent trials.

Table 1. Chemical composition of marble and nasty rock

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	TiO_2	P_2O_5	Mn_2O_3	PAF	Total
5/50 Cut	13.17	4.09	3.30	41.34	2.29	0.38	0.36	0.20	0.56	0.13	0.05	31.14	100.00
30-50 Fraction	10.25	3.22	2.60	43.94	2.46	0.35	0.31	0.13	0.43	0.13	0,04	36.13	99.99
20-30 Fraction	14.21	4.20	3.56	40.62	2.03	0.37	0.37	0.24	0.58	0.13	0.05	33.65	100.00
5-20 Fraction	18.35	5.29	4.27	37.41	1.85	0.39	0.38	0.27	0.75	0.14	0.06	30.84	100.00
Marble	2.61	1.07	0.54	52.15	1.58	0.31	0.12	0.06	0.08	0.09	0.02	41.38	99.99

The percentage of ignition loss increases with the lime content which was predictable because during calcination (decarbonization loss on ignition), calcium carbonates ($CaCO_3$) present in the materials decompose according to the equation:

$CaCO_3$ (s) → CaO (s) + CO_2 (g)

The loss on ignition is high, because of the presence of calcite, indicating an important presence of an organic material within the materials. It therefore increases with the calcium carbonate content within the materials.

The 5/50 mm cut has a percentage of lime (41.34) intermediate between those of 30-50 mm fractions (43.94) and 20-30 mm (40.62). This value is in affinity with the chemical composition of 5-20 mm fractions .This last fraction contains considerable amounts of shale and clay soil which explains the high percentages of silica (SiO_2), alumina (Al_2O_3), ferric oxide (Fe_2O_3) and magnesia (MgO), which lower the lime (CaO) content in the dirty barren. It results therefore that the clods of clay soils present within the cut 5/50 mm and 30-50 mm fractions, 20-30 mm and 5-20 mm can contain quartz (SiO_2), kaolinite ($2SiO_2$, Al_2O_3 $2H_2O$)

and siderite (FeO, CO_2) and or magnetite; which are respectively source of silica, alumina, and ferric oxide. Siderite is decarbonated in hematite following the equation:

$$4FeCO_3 (s) + O_2 (g) \rightarrow 2Fe_2O_3 (s) + 4CO_2 (g)$$

The magnesia content is due to the presence of dolomite $MgCa(CO_3)_2$ within the materials. The latter is then decarbonated following the equation:

$$MgCa(CO_3)_2 (s) \rightarrow MgO (s) + CaO (s) + 2CO_2 (g)$$

0/5 mm cut

The percentages of lime determined by complexometry and the 0/5 mm cut, 3-5 mm fraction and fine tailings loss upon ignition are shown on Table 2. This table also shows the chemical composition of these material determined by X-ray fluorescence spectrometry each value is the average of consistent 13 tests.

Table 2. Chemical Composition of fine tailings and fine particles

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	TiO_2	P_2O_5	Mn_2O_3	PAF	Total
0/5 cut	27.52	8.06	9.00	24.82	1.67	0.38	0.32	0.55	1.50	0.13	0.13	25.97	99.99
3-5 Fraction	28.59	8.05	7.96	26.78	1.91	0.40	0.44	0.46	1.36	0.14	0.11	23.82	99.99
Fine tailings	10.36	3.62	2.55	43.98	2.58	0.39	0.38	0.12	0.44	0.15	0.04	35.40	99.99

The 0/5 mm cut is less rich in lime than 3-5 mm fraction. This is because the 0/5 mm cut contains about 40% of fine particles (less than or equal to 3 mm), which consist essentially of clay clods rich in silica, alumina and ferric oxide. The silica content is higher than that of lime and the loss upon ignition in the samples of 0/5 mm cut and 3-5 mm fraction.

Indeed, analysis of these materials shows that they are essentially rich in silica and lime and in the second degree of alumina and ferric oxide. The high concentration of silicon oxide is due to the presence of quartz in the two materials. As for calcite, it is a source of calcium oxide, which is the percentage of the loss upon ignition close to those of lime and of course a significant presence of organic matter. The high levels of alumina and ferric oxide may be due to the presence of kaolinite and magnetite in the material.

Valorization Test

For the different valorization tests, laboratory analyses were conducted on the mixtures of byproducts powders and usual raw materials (marble and fine tailings) at different proportions.

The incorporation of the 5-20 mm fraction within the marble gives a scanty lime material of (49.20%) for a composition containing less than 1/5 weight of 5-20 mm fraction. This means that this fraction cannot be introduced into the marble at very low proportions.

This 20-30 mm fraction may be introduced into the marble by substituting 1/5 of it tonnage during the material resumption of the plant. Nevertheless it has a chance to be more expensive since it represents only 27.40% of the tonnage of the 5/50 mm cut. Besides its use, it absolutely requires additional screening at the quarry.

For the 30-50 mm fraction, a proportion ranging from 1/5 to 1/4 in the clean marble gives an acceptable percentage of lime (50,10% to 50,51%). The usage of this cut off would increase the daily production of the quarry of about 42.5 tones which corresponds to an increase of approximately 4% of the raw material product rate to primary crushing plant. However many parameters still have to be checked:

- The 30-50 mm fraction is one of the fractions derived from the screening of the 5/50 mm cut. Its usage requires absolutely an extra screening exercise at the quarry. It is therefore mandatory to assess the difference between the gain provided by the use of this cut for the raw manufacture and means involved for installing the screen;

- The dust that falls on the quarry extractor are turn into mud during the rainy season which may change considerably the chemical and mass compositions of 5/50 mm and 0/5 mm cuts and much obviously those of the 30-50 mm fraction.

The 5/50 mm cut could be used for the raw manufacture for well-defined proportions. In making the compositions in the proportions 4/5 (marble) and 1/5 (5/50 mm cut), that is to say by taking four marble buckets and a sterile big bucket on resume at the factory; it has the material having substantially 50% lime. Consumption of this material would increase the rate of raw material products at the quarry crushing plant since the material here does not require screening. In addition to the entire big sterile product could be consumed because the quantity produced is only 1/8 of the total production of the clean marble. It increases by about 9% of the tonnage of raw material products at the quarry crushing workshop.

The Figuil plant consumes an average of about 280 tons of marble per day. By substituting 1/5 of this tonnage by large sterile. A gain of 56 tons of marble shall therefore be obtained.

Analyses were made on material from the polluted area. However, if the material conveyed to the crushing workshop came from the area rich in marble (zone containing 90 to 100% of marble), we would have in the chemical composition of the marble about 55% lime. In this case, the lime content in the 5/50 mm cut predisposes the raw manufacturing without the need to incorporate the clean marble.

For a composition of matter (fine sterile and fine particles) having about 40% of lime, 0/5 mm and 3-5 mm fraction cut can both be incorporated into the sterile end in the proportions 1/5.

However, when the marbles are used in an excess proportion 5% by weight (main component), they must meet the following specifications [9]:

- Limestone content: $CaCO_3 \geq 75\%$ by weight;

- Clay content: methylene blue adsorption ≤ 1.20 g / 100 g;

- Content of organic matter (TOC) ≤ 0.50 mass%.

Furthermore, previous studies done on the 0/5 mm cut at the Bidzar quarry demonstrated that the latter was made up of organic content (TOC) greater than 0.50% by mass, therefore the 0/5 mm cut could not be incorporated into the fine tailings used as additions to the cement. A concrete made with cement contain a high proportions of limestone with high organic content may not accuse a high resistance to freeze-thaw [10, 11].

Approximately 68 tons of 3-5 mm fractions could be produced per day at the Bidzar quarry if a screen sieving of 0/5 mm cut is installed. This fraction represents about 60% of the tonnage of the 0/5 mm cut, about 60% of the production of fine tailings, and 6.48% of the total production of the crusher. By incorporating the fraction 3-5 mm in the fine tailings to 1/5 of the mass of the latter, about 41% would be used (28 tons) of the entire 3-5 mm fraction produced in the crushing plant, if an additional screen quarry is installed.

However, the clay content and the organic matter content of this particle size fraction have not been determined. If these levels had been determined and that they respect the French standard NF P 15-301 (methylene blue adsorption ≤ 1.20 g/100 g and TOC ≤ 0.50 mass%) would use the 3- 5 mm fraction at the Figuil factory. This plant consumes an average of 170 tons of waste per day. By Substituting 1/5 of this tonnage by the 3-5 mm fraction from the ground, a gain of about 34 tons of material shall be obtained.

CONCLUSION

The results of the analysis of by-products of the Bidzar quarry have permitted to carry out important tests by performing compositions of matter by incorporating proportions and different sizes as for the first instant the large sterile in the clean marble and on the other hand fine particles in the fine tailings.

In view of the results of these tests, the by-products of the Bidzar quarry are adapted to be used for the production of cement at the Figuil factory in proportions and well-defined grain sizes. In fact, a material composed of 20% of 5/50 mm cut and 80% of clean marble cut contains about 50% lime and can be used for raw manufacture. A material composed of 20% of fraction 3-5 mm and 80% of fine tailings contains about 41% of lime, so this fraction could be incorporated into the fine tailings used as additions to the cement, if it adsorbs more than 1,20 g methylene blue for a mass of 100 g and has an organic content exceeding 0.50% by mass.

This conclusion is qualified by the quality of slaughter shots, seasonal change, and especially changes in properties and chemical composition of materials due to their origin in different fronts and heterogeneity of the various rock.

It would be interesting to extend this study by determining the levels of limestone, clay and organic matter on materials from the quarry all fronts and at all seasons of the year in order to better interpret the results and optimize performance the quarry valuing all products from the primary crushing and slaughter shots. We could also determine any possible influence that might have minor elements constituting these products on the raw quality and or cement.

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