Comparative Analysis Between Afrimine Quarry and Jolex Construction Sited in Jos, Plateau State Nigeria, with Respect to Unit Production Cost in order to establish the Viability of Quarry Business

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Abstract

This research was aimed at establishing the viability of the quarry business using comparative analysis between Afrimine Quarry and Jolex Construction sited Plateau State. The results revealed that the total production of aggregates in volume value is ₦ 70,875,000 for 15,000 tons per month in **Afrimine Quarry** but the positive values of profit made in a month sums up to ₦**36,484,859.375** while the total production of aggregates in volume value is **67,500,000** for 9,000 tons per month in **Jolex Construction** but the positive values of profit for Jolex Construction sums up to ₦ **58,295,000.** After the research on both quarries it was observed that the unit production cost of Afrimine quarry was ₦ 2,291.61/ton and that of Jolex as ₦ 1022.78/ton, and the total production cost of Afrimine quarry was ₦ 34,389,140.63/month and that of Jolex was ₦ 9,205,000/month.

For every 15,000tons of aggregate, Afrimine quarry spends ₦ 70,875,000 and gets a profit of ₦ 36,485,859.38 whereas Jolex Construction quarry spends ₦ 67, 500,000 to produce 9,000 tons of aggregates and get a profit of ₦ 58,295,000. Therefore, one can conclude that Jolex construction quarry makes more profit than Afrimine quarry due to lower production cost on drilling and blasting.

Keyword

Afrimine, Jolex, Quarry, Drilling, Blasting

1. Introduction

Background of Study

In Nigeria, Quarry operation is the most prominent among other surface mining activities, unlike other part of the world in which every aspect surface mining is being carried out, in this case Quarry involves the production of dimension stones and aggregates for the purpose of construction, ornamental and interior decoration. Rocks such as granite, limestone, marble, dolomite etc. are mined for production of different sizes aggregates and slabs [1].

According to King, a quarry is a mine site from which dimension stone, rock, construction aggregate, riprap, sand, gravel, or slate have been excavated from the ground [2]. A quarry is example of an open-pit mine from which minerals are extracted while quarry operations involves not only extraction of material (rock) but also crushing and screening that makes the rock suitable for use as construction materials, industrial materials, agricultural materials etc.

The process of producing rock aggregates involves removal of overburden, drilling of holes for blasting, blasting of the drilled holes using explosives, hauling of the blasted rocks for crushing, crushing and screening of the materials into various sizes [3]. Each of this basic cycle operation needs to be subjected to economic analysis.

Complete task of planning and operating a granite quarry involves at least three components which include a technical component, a narrowly focused economic component and a more broadly based economic component, including financial and business elements that influence quarry performance within industry at large [4].

The technical component involves granite quarry layout, equipment productivities, alternative production schedules, and quarry operating requirements [5]. These requirements include the explosive usage per year, the number of person required, and the fuel usage per machine per operating hour.

The narrowly focused economic component includes operating and capital costs to the technical schedules. It examines unit costs, such as the fuel cost per liter, annual fuel cost for the whole mine, and labor cost per person per year as shown in Figure 1, below.

The process for granite quarrying operation is shown in Figure 1 below, but the first step in quarrying is to gain access to the granite deposit. This is achieved by removing the layer of earth, vegetation, and rock unsuitable for product. This is also called the removal of overburden using heavy equipment which eventually transfers it off the mine site for storage because of its potential use in the reclamation of the site.

After the face of the granite is exposed, the stone is removed from the quarry in benches, usually 8 to 12 feet square extending to 20 feet or more using a variety of techniques suitable to the geology and characteristics of the granite deposit. Quarrying operations typically include the drilling of holes on the bench, followed by blasting the holes using explosives. Once the holes on the bench are blasted, heavy equipment (excavator) will be used to remove the blasted rocks to for the purpose of grading and eventual hauled (transported) from the site using dump trucks which takes it to the crushing plant. The crushing plant is used to reduce the blasted rock into smaller sizes of 0-5 mm, 5-20 mm, 20-40 mm which is needed for the purpose of construction of bridges, tunnels, roads and building activities.

2. Literature Review

According to Saliu the production of granite aggregates involve blasting, removal of the blasted rocks using heavy machinery [6], securing of the blasted material into a vehicle for transport (hauling), and crushing the materials into various sizes (processing) but the complete task of planning and operating a granite quarry involves at least three components which include a technical component, a narrowly focused economic component and a more broadly based economic component, including financial and business elements that influence quarry performance within industry at large.

(Dolley describes the technical component which involves granite quarry layout, equipment productivities, alternative production schedules, and quarry operating requirements. These requirements include the explosive usage per year, the number of person required, and the fuel usage per machine per operating hour. This component of a quarry plan will be unchanged whether project is economical or not as they basically referred to as the fixed input.

The technical component as explained by Dolley also defines all of the important elements required for the implementation of a quarry project, but Jamie narrowly focused on the economic component which includes the operating and capital cost to the technical schedules in a quarry [7]. The alternative schedules and alternative equipment in economic terms can be seen from the price per tonnage in production of aggregates in a quarry. It also builds up and examines unit costs, such as the fuel cost per liter, annual fuel cost for the whole mine, and labor cost per person per year.

Most mine evaluation is limited to technical work, coupled with this narrowly focused economic phase which is based on economic, financial, and business component aimed at understanding the degree of viability of a granite quarrying plan and how the plan fits within a wider corporate context. Opafunso further explains the overall economic profitability of any quarry from a lender's point of view which is mainly tested through cash flow analysis [8].

The economic and financial parameters that can be used to build cash flow model are capital expenditure, variable operating cost, marginal cost, fixed operating cost, production rate and total cost.

2.1 Granite Quarrying Operations

The successful and economical working of granite quarries depends upon an intelligent application of knowledge of the structure of the rock and its natural divisions in the mass, as well as upon improved methods, tools, and machinery for quarrying. The topographical location of the quarry and its relation to facilities for transportation are important factors that affect the productiveness and greatly modify the actual cost of operations in a given place.

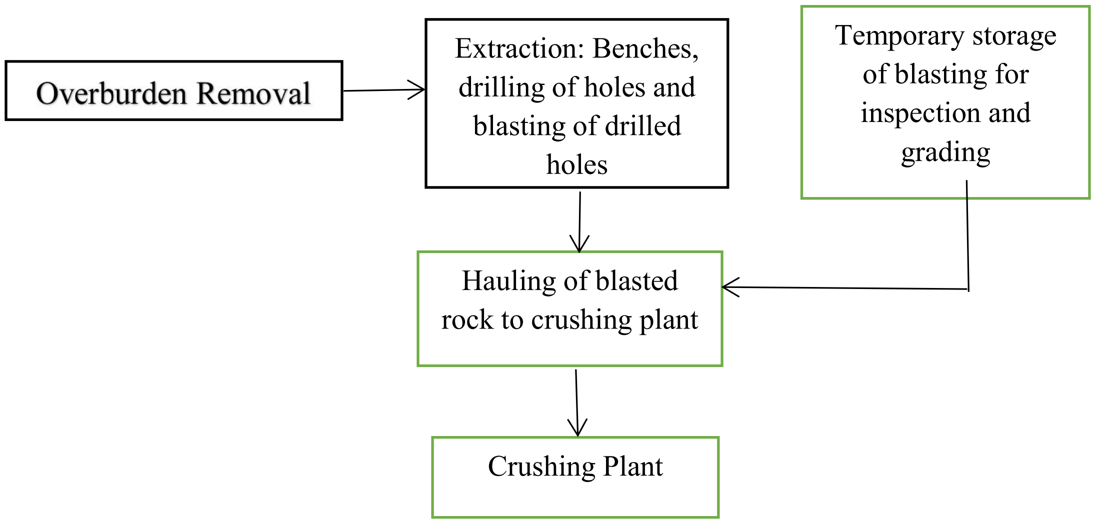

Figure 1. Process Flow Diagram for Granite Quarrying operations

The process for granite quarrying operation is shown in Figure 1 above, but the first step in quarrying is to gain access to the granite deposit. This is achieved by removing the layer of earth, vegetation, and rock unsuitable for product. This is also called the removal of overburden using heavy equipment which eventually transfers it off the mine site for storage because of its potential use in the reclamation of the site.

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2.2 Classification of Aggregate

According to Zongjin, aggregates can be divided into several categories according to different criteria [9].

2.2.1 In accordance with Sizes:

i. Coarse aggregate: The coarse aggregate are on the 4.75 mm sieve. For mass concrete, the maximum size can be as large as 150 mm.

ii. Fine aggregate (sand): The fine aggregates are those that pass through 4.75 mm sieve and also, are predominately retained on the 75 µm sieve.

2.2.2 In Accordance with Sources:

i. Natural aggregates: This kind of aggregate is taken from natural deposits without changing their nature during the process of production such as crushing and grinding. Some examples in this category are sand, crushed limestone, and gravel.

ii. Manufactured (synthetic) aggregates: This is a kind of man-made materials produced as a main product or as an industrial by-product. Examples are blast furnace slag, lightweight aggregate (e.g. expanded perlite), and heavy weight aggregates (e.g. iron ore or crushed steel).

2.2.3 In Accordance with Unit Weight

i. Light weight aggregate: This type of aggregate has a unit weight of less than 1120 kg/m^3. The corresponding concrete has a bulk density less than 1800 kg/m^3. (e.g Cinder, Blast furnace slag, Volcanic pumice).

ii. Normal weight aggregate: This type of aggregate has unit weight of 1520-1680 kg/m^3. The concrete made with this type of aggregate has a bulk density of 2300-2400 kg/m^3.

iii. Heavy weight aggregate: This has a unit weight that is greater than 2100 kg/m^3. The bulk density of the corresponding concrete is greater than 3200 kg/m^3.

2.3 Physical Properties of Aggregates

The physical properties of aggregates refer to the physical structure of the particles that make up the aggregate. The following physical properties are:

2.3.1 Absorption, Porosity, and Permeability

David suggested that the internal pore characteristics are very important properties of aggregates [10]. The size, the number, and the continuity of the pores through an aggregate particle may affect the strength of the aggregate, abrasion resistance, surface texture, specific gravity, bonding capabilities, and resistance to freezing and thawing action.

(i) Absorption: This refers to the particle's ability to take in liquid.

(ii) Porosity: This refers to the ratio of the volume of the pores of the particle to the total volume of the particle.

(iii) Permeability: It refers to the particle's ability to allow liquids to pass through. If the rock pores are not connected, a rock may have high porosity and low permeability.

2.3.2 Surface Texture

Balamurali, explains Surface texture as the roughness or smoothness of the aggregate particle [11]. This plays a big role in developing the bond between aggregate particle and a cementing material.

2.3.3 Strength and Elasticity

Strength is a measure of the ability of an aggregate particle to stand up to pulling or crushing forces while Elasticity measures the "stretch" in a particle. High strength and elasticity are desirable in aggregate base and surface courses. These qualities minimize the rate of disintegration and maximize the stability of the compacted material.

2.3.4 Density, Bulk Density and Specific Gravity

Density is the weight per unit volume of a substance while **Specific gravity** is the ratio of the density of the substance to the density of water.

Density (D): weight per unit volume (excluding the pores inside a single aggregate)

$$D = \frac{Weight}{V_{Solid}} \tag{1}$$

Where Vsolid means the Volume of Solid.

Bulk density (BD): This refers to the ratio of weight of a substance per volume of solid and volume of pores of the substance.

$$BD = \frac{Weight}{V_{Solid} + V_{Pores}} \tag{2}$$

$$SG = \frac{Density\ of\ Subs\tan ce}{Density\ of\ equal\ volume\ of\ water} \tag{3}$$

Other essential properties of the aggregates are:

(i) Aggregate Voids

Aggregate voids are porosity between aggregate particles. Most aggregate particles have voids which are natural pores that are filled with air or water. These voids or pores influence the specific gravity and absorption of the aggregate materials.

(ii) Hardness

Neville uses the Mohr scale of Hardness to explain the hardness of a material and this is frequently used for explaining mineral hardness [12]. The hardness of the minerals constitutes the aggregate particles and the firmness with which the individual grains are cemented or interlocked. This helps to control the resistance of the aggregate to abrasion and degradation. Soft aggregate particles are composed of minerals with a low degree of hardness. Basically, the Mohrs Hardness Scale is useful for the field identification of potentially inferior aggregates.

2.4 Stages Involved In Aggregate Production

The sequence of unit operation is utilized to accomplish mine exploitation and this is also called the cycle operation Aggregate production involve various stages which includes the following:

(i) The development of the quarry by taking the coordinate of the site

(ii) Stripping Operation

(iii) Stemming Operation

(iv) Drilling Operation

(v) Blasting (its accessories)

(vi) Mucking and loading

(vii) Haulage and crushing.

2.4.1 Development and Planning of the Mine

Mine development involves the excavations needed to establish the infrastructure necessary for stope production and to prepare for the future continuity of operations. The planning of the mine site is done by the Mining Engineer and other partnering professionals involved in the process.

2.4.2 Stripping Operation

Sharma explains Stripping Operation as the process of removing over burden (waste material) from the surface of the mine site in order to reveal he underlying ore body. If the over burden is much and the cost of removal is at the high side, such operation is seen as unprofitable for the miner [13]. The overburden is stripped with an excavator and is placed in large dump trucks known as haul trucks. Haul trucks are designed for earth moving across rugged environment.

Overburden is a waste rock consisting of consolidated and unconsolidated material that must be removed to expose the underlying ore body. It is desirable to remove as little overburden as possible in order to access the ore of interest.

2.4.3 Drilling Operation

Drilling can be define as an artificial creation of cavity or hole in an ore body for sample collection, further analysis, casing sinking and for placement of explosives. Drilling is very important in mining and it determines the cost of production. Some factors influencing the rate of bit penetration includes: type and size of drill, bit size; bit type and condition, drill mounting, torque capacity, compressor pressure, flushing medium, lubrication, thrust, rotational speed, rock type and structure.

2.4.4 Blasting Operation

Sharma reported that Blasting is defined as a fragmentation of rock by means of explosives and its accessories for the subsequent extraction or process. After the blast holes have been drilled to the requirement, the next operation is to charge the holes with explosives and blast. The size of the drilling bit is a major factor in the choice of explosive to be used.

2.4.5 Loading

After blasting operation has been carried out, the fragmented rock materials are usually loaded into dump trucks and tippers. Both front – end loader and back – hoe shovel are used for loading fragmented rock materials into dump trucks for haulage.

2.4.6 Haulage of Material

The fragmented rocks are transported by haulage truck (primarily horizontal movement) to the primary crusher. As the blasting cannot be absolutely perfect, boulders bigger than the normal requirement (1.5m) are kept aside for secondary blasting so that they can pass through the hopper to the jaw crusher.

2.4.7 Crushing Process

Crushing is the process of reducing blasted rocks into smaller sizes needed for use such as in construction of bridges, tunnels, roads and building activities [14]. Crushing of fragmented rocks are unit of communition and particle sizing. The crushing plant is an assemblage of primary crusher and secondary crusher. The following product sizes (granite) can be obtained by methods of screening immediately after crushing.

2.5 Cost Estimate and Profit/Loss Calculation

$$Let\ Overall\ \mathrm{Cos}t = \mathrm{Pr}odution\ \mathrm{Cos}t + Government\ \mathrm{Re}venue \tag{4}$$

$$\mathrm{Cos}t\ per\ tonne = \frac{\mathrm{Pr}oduction\,\mathrm{Cos}t}{Total\ Output} \tag{5}$$

$$Total\ \mathrm{Re}venue = Output\ per\ annum \times Selling\ price\ per\ t\,on \tag{6}$$

$$\mathrm{Pr}ofit = Total\ revenue - \mathrm{Pr}oduction\ \mathrm{Cos}t \tag{7}$$

Estimation Techniques

Average Operating Cost

Total cost realized from ton produce per day

$$\mathrm{Pr}ofit = \mathrm{Re}venue - \mathrm{Pr}oduction\ \mathrm{Cos}t \tag{8}$$

Note- To calculate for the estimation and profit, the following are required; capital, life span, cost per year, production cost, cost per ton, revenue and profit.

2.6 Unit Operation in the Crushing Plant

The various Unit Operations in the Crushing Plant involves the operation of Communition.

2.6.1 Comminution

Balasubramanian reported that Comminution is particle size reduction of materials. It may be carried out on either dry materials or slurries. Crushing and grinding are the two primary comminution processes. Crushing is normally carried out on "run-of-mine" ore, while grinding (normally carried out after crushing) may be conducted on dry or slurred material. In comminution, the size reduction of particles is done by three types of forces: Compression, Impact and Attrition.

2.6.2 Compression and Impact Forces

They are extensively used in crushing operations while attrition is the dominant force in grinding. The primarily used equipment in crushing are- Jaw crushers, Gyratory crushers and Cone crushers whereas rod mills and ball mills are closed circuited with a classifier unit generally employed for grinding purposes in a mineral processing plant. Crushing is a dry process whereas grinding is generally performed wet and hence is more energy intensive. There are several types of crushers available in processing. All crushers have limited reduction ratio meaning that size reduction will take place in different stages.

2.6.3 Feed Material

All operations in size reduction, both crushing and grinding are of course determined by the feed characteristics of the minerals (rock/ore) moving into the circuit. The key parameters we need are the "Crushability or Grindability", also called work index and the "wear profile" called abrasion index.

2.6.4 Crushing of Rock

Crushing is the largest process operation in minerals processing. The goal is to produce rock or (more seldom) mineral fractions to be used as rock fill or ballast material for concrete and asphalt production. Quality parameters are normally strength, size and shape. The kinds of materials processed are Limestone, Granite, Gabbro, Basalt, River Stone, Coal Gangue, Quartz, Diabase, Iron Ore, Copper Ore, Zinc Ore and Manganese Ore.

2.6.5 Types of Crushers

A Crusher is a machine designed to reduce large rocks into smaller rocks, gravel, or rock dust. Crushers may be used to reduce the size, or change the form, of waste materials so they can be more easily disposed of or recycled, or to reduce the size of a solid mix of raw materials (as in rock ore), so that pieces of different composition can be differentiated.

Crushing is the process of transferring a force amplified by mechanical advantage through a material made of molecules that bond together more strongly, and resist deformation more, than those in the material being crushed do. Balasubramanian suggested that crushing devices hold material between two parallel or tangent solid surfaces, and apply sufficient force to bring the surfaces together to generate enough energy within the material being crushed so that its molecules separate from (fracturing), or change alignment in relation to (deformation), each other.

(i) Jaw Crusher

A jaw crusher is generally used as a primary crusher in a crushing circuit. Product is fed into the top of the jaw crusher by a vibrating grizzly feeder. The eccentric rotating drive shaft causes the movable jaw to oscillate crushing the aggregate against a fixed jaw. Jaw crushers are run on belt drives driven by an electric motor or diesel engine. Jaw crushers are used extensively throughout the aggregate and mineral processing industry. Balasubramanian explains the Operating Principle of Jaw Crusher is according to the principle of pressure crushing.

The crushing material is crushed in the wedge-shaped pit between the fixed crusher jaw and the crusher jaw articulated on an eccentric shaft. The material is crushed by the elliptic course of movement and transported downwards. This occurs until the material is smaller than the set crushing size. The feed cavity of the Jaw Crusher consist of moveable jaw and fixed jaw, which imitate the movement of the animal's two jaws to complete the materials' crushing . Jaw Crushers have found their extensive application for the mid crushing of the various ores and large-size materials block in the field of mining, smelting, building material, highway, railway, water conservancy and chemical industry, etc.

(ii) Gyratory Crusher

A Gyratory Crusher is similar in basic concept to a jaw crusher, consisting of a concave surface and a conical head; both surfaces are typically lined with manganese steel surfaces. The inner cone has a slight circular movement, but does not rotate; the movement is generated by an eccentric arrangement.

As with the Jaw Crusher, material travels downward between the two surfaces being progressively crushed until it is small enough to fall out through the gap between the two surfaces. The Gyratory crushers are robust crushers with modern features. They are designed to give optimal capacity in primary crushing, increasing the total capacity in the mining crushing process. These crushers have a large feed opening and a grooved mantle, making them suitable for crushing large boulders.

(iii) Cone Crusher

With respect to the recent development of mining techniques, the cone crusher is subjected to four classifications such as compound cone crusher, spring cone crusher, hydraulic cone crusher and gyratory crusher. With regards to different models, the cone crusher is subdivided into Symons Cone Crusher, Single Cylinder Hydraulic Cone Crusher, and Multi-cylinder hydraulic cone crusher， gyratory crusher， etc. A cone crusher can be liken to a gyratory crusher, with minima slopes in the crushing chamber and more of a parallel zone between crushing zones.

The working principle of Cone Crusher is controlled by pressure crushing in an opening and closing crushing gap between the bowl liner and mantle. The opening and closing are controlled simultaneously on the opposite sides of the crushing chamber. A cone crusher crushes rock by compacting the rock between an eccentrically gyrating spindle, which is enclosed by a wear resistant mantle, and the enclosing concave hopper, covered by a manganese concave or a bowl liner. As rock enters the top of the cone crusher, it becomes wedged and squeezed between the mantle and the bowl liner or concave.

Table 1. Typical uses of commonly used crushers

Type	Hardness	Abrasion Limit	Moisture Content	Reduction Ratio	Main Use
Jaw Crusher	Soft to hard	No limit	Dry to slightly wet, not sticky	3/1 to 5/1	Heavy mining, Quarried materials, sand & gravel, recycling.
Gyratory Crusher	Dry to slightly wet, not sticky	Abrasive	Dry to slightly wet, not sticky	4/1 to 7/1	Heavy mining, Quarried materials.
Cone Crusher	Medium hard to very hard	Abrasive	Dry or wet, not sticky	3/1 to 5/1	Quarried materials, Sand & gravel
Compound Crusher	Medium hard to very hard	Abrasive	Dry or wet, not sticky	3/1 to 5/1	Mine, Building Materials
Horizontal Shaft Impactors	Soft to medium hard	Slightly abrasive	Dry or wet, not sticky	10/1 to 25/1	Quarried materials, sand & gravel, recycling
Vertical shaft impactors (shoe and anvil)	Medium hard to very hard	Slightly abrasive	Dry or wet, not sticky	6/1 to 8/1	Sand & gravel, recycling
Vertical shaft impactors (autogenous)	Soft to very hard	No limit	Dry or wet, not sticky	2/1 to 5/1	Quarried materials, sand & gravel
Mineral sizers	Hard to Soft	Abrasive	Dry or wet and sticky	2/1 to 5/1	Heavy mining

Table 1 shows the main usefulness of each time of crushers.

3. Materials and Method

3.1 Location and Accessibility

Afri-Mine quarry is located at Jos-South, Plateau State around Mararaba'n Jama'a. It has coordinates between latitudes N09° 40'00'' – N09° 44'00'' and longitude E08° 51'00'' – E08° 55'00''. (Offiah *et al*., 2011). Jolex construction company is located at Bassa L.G.A between latitude N10^0 02'44''-N10^0 02'44'' and longitude E08^0 51'20''-E08^0 51'24''. The both quarries have good accessibility.

3.2 Instrument / Materials Used for data Collection

The instrument and materials used for this research include:

1.A Global Positioning System (GPS) was used for taking coordinates

2.Recording notebook was used for jotting down various observations in the quarry.

3.Digital camera

3.3 Methods

3.3.1 Determination of the Unit of Operation in Both Quarries

The unit of operation in this research was obtained through observation in both Afrimine quarry and Jolex Construction; data that concerned each unit was obtained through the company's administration. The units of operation include drilling unit, blasting unit, loading and hauling unit, crushing unit, processing and sales unit. The obtained data from each unit was analyzed using tables and charts.

3.3.2 Cost Estimate and Profit/Loss Calculation

$$Let\ Overall\ \mathrm{Cos}t = \mathrm{Pr}odution\ \mathrm{Cos}t + Government\ \mathrm{Re}venue \tag{9}$$

$$\mathrm{Cos}t\ per\ tonne = \frac{\mathrm{Pr}oduction\,\mathrm{Cos}t}{Total\ Output} \tag{10}$$

$$Total\ \mathrm{Re}venue = Output\ per\ annum \times Selling\ price\ per\ t\,on \tag{11}$$

$$\mathrm{Pr}ofit = Total\ revenue - \mathrm{Pr}oduction\ \mathrm{Cos}t \tag{12}$$

3.3.3 Estimation Techniques

Average Operating Cost

Total cost realized from ton produce per day

$$\text{Profit} = \text{Revenue} - \text{Production Cost} \tag{13}$$

Note- To calculate for the estimation and profit, the following are required; capital, life span, cost per year, production cost, cost per ton, revenue and profit.

3.3.4 Determination of Overall Production

At Afrimines quarry, production of aggregate is 625 tons per day, and they work for six (6) days in a week, hence in a week they produce;

$$625(tons) \times 6(days) = 3750 tons / week \tag{14}$$

In a month;

$$3750(tons) \times 4(weeks) = 15,000 tons / month \tag{15}$$

At Jolex quarry, production of aggregates is 375 tons per day, they work for six (6) days in a week, hence in a week they produce;

$$375(tons) \times 6(days) = 2250 tons \tag{16}$$

In a month;

$$2250(tons) \times 4(weeks) = 9000 tons / month \tag{17}$$

3.3.5 Determination of the Overall Production Cost of Aggregates in Both Quarries

The determination of the various production in both Afrimine and Jolex Construction was calculated on 15,000 tons of aggregate production from Afrimine quarry per month and 12,000 tons of aggregate production from Jolex Construction per month. The

mathematical equations used for the calculation of unit production of aggregates per month are:

a) Average Production Cost Per Ton (APCT): This helps to give an average of the prices of various aggregates produced in the quarry.

$$APCT = \frac{\text{Production Cost}}{\text{Total mumber of Output}} \tag{18}$$

$$2250(tons) \times 4(weeks) = 9000 tons / month \tag{19}$$

b) Average Production Cost of total aggregate in a month (APCTAM): This equation helps to tell the total amount of aggregate produced in a month. It is gotten by multiplying the cost per ton by the total amount of aggregates produced in a month.

$$APCTAM = TCPT \times TAAM \tag{20}$$

Where TCPT= Total Cost Per Ton

TAAM= Total Amount of aggregates produced in a month

c) Positive Contributions per month (PCM): This gives the profit made in a month from a quarry. It is calculated using the equation below:

$$PCM = TPV - TMEQ \tag{21}$$

Where TPV = Total Production in Volume (**APCTAM**)

TMEQ = Total Month Expenses in a Quarry

d) Cost Estimate and Profit/Loss Calculation

$$\text{Let Overall Cost} = \text{Production Cost} + \text{Government Revenue} \tag{22}$$

$$\text{Cost per tonne} = \frac{\text{Production Cost}}{\text{Total Output}} \tag{23}$$

$$\text{Hence; Total Revenue} = \text{Output per annum} \times \text{Selling price per ton} \tag{24}$$

$$\Pr ofit\ Total\ revenue - \Pr oduction\ \text{Cos}t \tag{25}$$

e) Percentage Profit (PP): This gave the percentage profit made by the both quarries in a month.

$$PP = \frac{\Pr ofit}{\text{Cos}t\ profit} \times 100\% \tag{26}$$

f) Percentage of particulars: This gave the percentage difference of each particulars made by both quarries in a month. It helps to compare where each company spends more or less.

$$pop = \frac{particulars}{total\ production\ \cos t} \times 100\% \tag{27}$$

3.3.6 Determination of the Unit Cost Production of Granite

The unit cost production is the total amount of expenses incurred by a company to produce a certain quantity of goods or services and then divide the total amount by the quantity produced i.e;

$$UCOP = \frac{Total\ amount\ of\ \exp enses\ for\ production}{Total\ amount\ quantity\ produced} \tag{28}$$

The unit cost production is a crucial cost measure in operational analysis of a company. Identifying and analyzing a company's unit cost is a quick way to check if a company is producing efficiently, which in turn helps to check/investigate the company viability.

4. Presentation of Results and Interpretation

4.1 Results Presentation

This chapter presents the data obtained from the various data collected during the course of carrying out this research in Afrimine Quarry Jolex Construction.

Table 2. Operating expenses on aggregate production per month at Afrimine Quarry

Particulars	Afrimine (N/month)	Percentage of particulars to total (%)
Salary	1,700,000	4.94
Drilling and Blasting	19,500,000	56.7
Diesel	1,000,000	2.90
Av. Maintenance	3,981,122.5	11.58
Land Rental	250,000	0.73
Lubricant	300,000	0.87
Cost of Equipment	6,000,000	17.45
Miscellaneous	245,440	0.71
Total (VAT)	32,751,562.5	95.24
5% VAT	1,637,578.125	4.76
Total	**34,389,140.625**	**100**

According to Table 2, this is the expenses per month for the production.

Table 3. Afrimine prices for different sizes of aggregates

Items	Prices (N)
1/2 inch	5,200
3/4 inch	5,200
1½	5,200
Stone Dust	3,300

Table 3 shows that the prices for each of the items.

From Equation 6

$$APCT = \frac{\Pr oduction\ \ Cos t}{Tptal\ No\ of\ \ Output} \qquad (29)$$

$$1\ ton \text{ of aggregate} = \frac{5,200+5200+5200+3200}{4} \qquad (30)$$
$$= \text{N } 4,725$$

From equation 7; APCT=TCPT $\times$ TAAM

For 15,000 tons produced by Afrimine per month

$$= 4725 \times 15000$$
$$= N70,875,000$$

Table 4. Income on Aggregate Production per month

Item	Amount for Afrimine (N)
1 ton of aggregate	4,725
15,000 tons of aggregate	70,875,000

Table 4 shows of the amount of Afrimine with each item.

From equation 8, $PCM\ = TPV - TMEQ = N36,485,859.375$

Table 5. Positive Contribution on Aggregate Production per month

Items	Amount (N)
Total Production Volume in Value	70,875,000
Less direct expenses and less cost of asset usage	34,389,140.625
Positive Contribution	**36,485,859.375**

Table 5 mentioned about the positive contribution for the production per month.

But from Equation 9, $PP = \frac{\Pr ofit}{Cos t\ profit} \times 100\%$ (31)

$$= \frac{36,485,859.375}{34,389,140.625} \times 100\%$$
$$= 106\%$$

Table 6. Operating expenses on aggregate production per month at Jolex Construction Quarry

Particulars	Jolex (N/month)	Percentage of particulars to total (%)
Salary	1,000,000	10.86
Drilling and Blasting	3,000,000	32.60
Diesel	1,763,000	19.15
Av. Maintenance	957,000.00	10.39
Land Rental	166,666.67	1.81
Lubricant	580,000.00	6.30
Cost of Equipment	1,000,000	10.86
Miscellaneous	300,000.00	3.26
Total (VAT)	8,766,666.67	95.24
5% VAT	438,333.33	4.76
Total	**9,205,000.00**	**100**

Table 6 is mentioning about the operating expenses for the product such as salary, petrol oil and etc.

Table 7. Jolex Construction prices for different sizes of aggregate

Aggregate type	**Jolex (N/ton)**
3/4 inch	8000
½ inch	8000
3/8 inch	7000
Stone dust	7000
Stone base	7500

Table 7 is showing the construction price for each aggregate type of Jolex.

Using equation 6 $APCT = \frac{Production\ Cost}{Total\ No.\ of\ Output}$

$$1\ ton\ of\ aggregate = \frac{8000+8000+7000+7000+7500}{5} \quad (32)$$

=₦7500

From equation 7, $ACPT = TCPT \times TAAM$

For 9000 tons produced by Jolex Construction per month

$= 9000 \times 7500$

=₦67,500,000

Table 8. Income of aggregate per month

Items	Amt of Tons of aggregate for Jolex Constr. (₦)
1 ton of Aggregate	7500
9,000 tons of aggregate	67,500,000

Table 8 is mentioning about the number of tons of aggregate for Jolex construction.

Table 9. Positive Contribution on Aggregate Production per month in Jolex

Items	Amount for Jolex(₦)
Total prod. in value	67,500,000
Less expenses	9,205,000.00
Positive contribution	**58,295,000**

Table 9 is showing the amount for Jolex with the positive contribution on aggregate production for each month. Using equation 9, *PCM=TPV-TMEQ=₦58,295,000.*

4.2 Interpretation of Results

The data obtained from Afrimine quarry and Jolex Construction were critically analyzed, examined and processed. Statistical tools such as Bar chart, and tables were used to analyze and discuss the data and information.

From Table 2 above, the following are thus discussed below:

4.2.1 Interpretation of Results Obtained from Afrimine

1. Afrimine Salary Structure

Laborers are paid N60, 000 -N120, 000 depending on the number of years in service and rank. The technical personnel are paid N250, 000 – N400, 000 monthly salaries but the total cost of man power on a monthly basis is N1, 700, 000

2. Diesel Consumption in Afrimine

Diesel consumption of the various equipment's

Dumb trucks ——— 50 liters

Excavator ——— 90 liters

Generator ——— 520 liters

Pay loader ——— 90 liters

Rock drill ——— 110 liters

Total liters of diesel consumed per week (For 20,000 tons/week)

$= 50 + 90 + 520 + 90 + 110 = 860$ litres/week

1 litre of diesel = N290 $\rightarrow$ 860 $\times$ 290 = N249,400

In a month = N249,400×4=997,000»N1,000,000

3. Land Rental

The total cost of leasing the land to Afrimine cost a total of N300, 000 which turns to the sum of N25, 000 per month.

4. Drilling and Blasting

Drilling and blasting at Afrimines quarry is being contracted out to another company (Duwan P.L.C) which handles everything concerning that aspect including maintenance cost, wear and tear of equipment, fueling e.t.c.

For every one ton of aggregate drilled and blasted, Afrimines pays the company 1300 naira. I.e;

In a week Afrimines produces 3750 tons of aggregates,hence;

$1300 \times 3750 = 4,875,000$

In a month; $4875000 \times 4 = 19,500,000\, N$

A. Interpretation of Results Using Graphs and Charts

1. Operating Expenses of Aggregate Production per Month

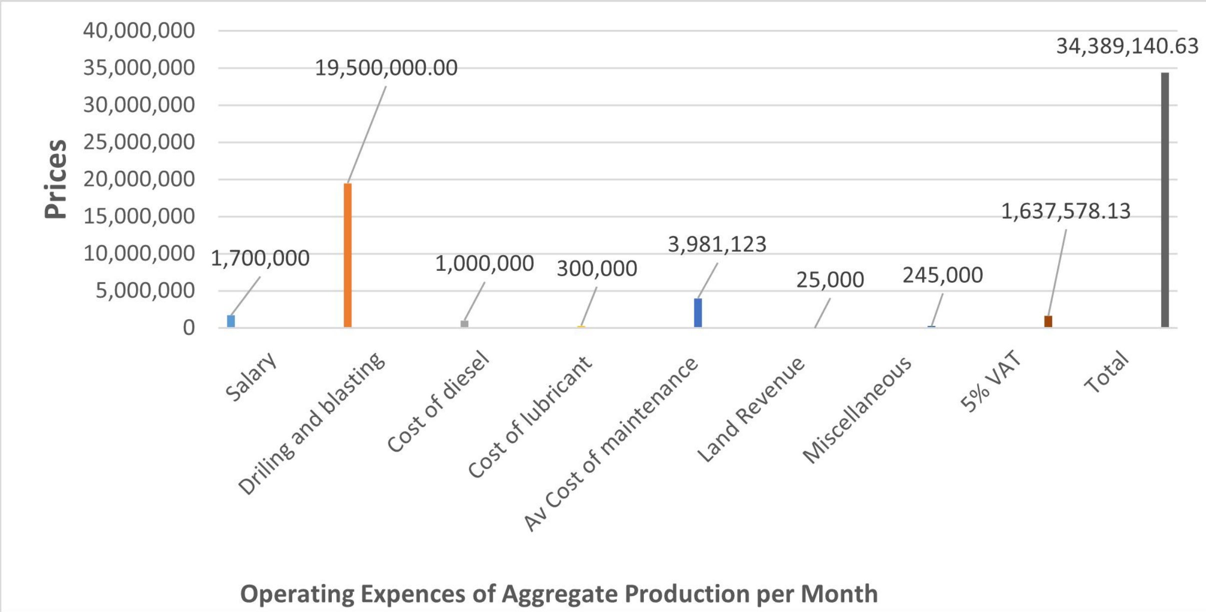

Figure 2. Shows the operating expenses of aggregate production for Afrimine

Figure 2 is mentioning regarding operating expenses on aggregate production per month against prices.

2. Positive Contribution of Aggregates Production Against its Prices

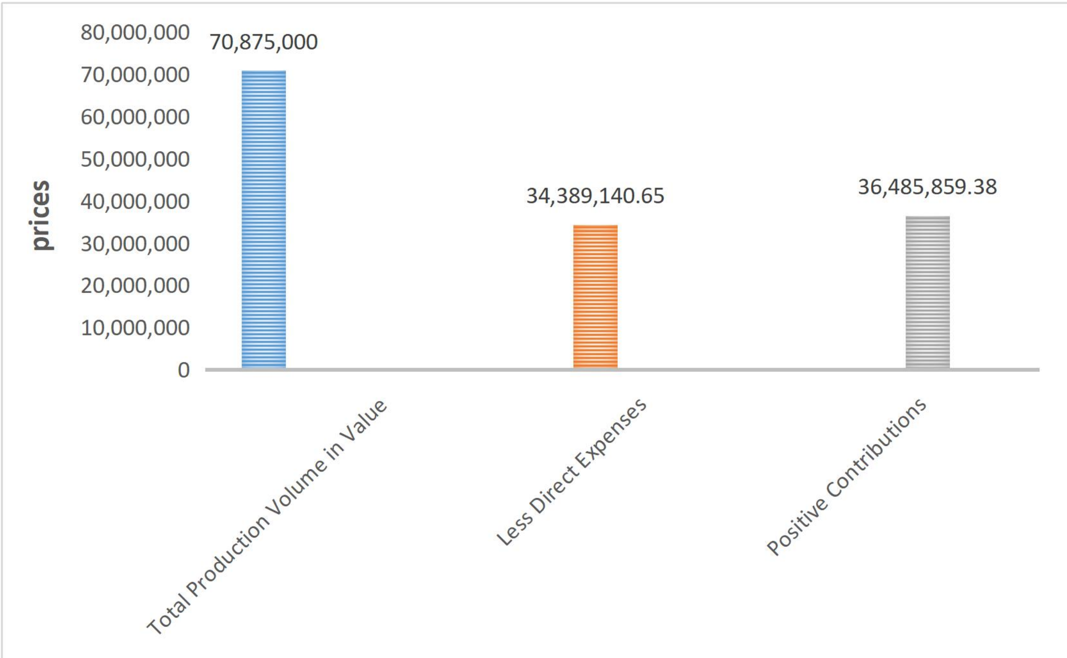

Figure 3. Positive contribution of aggregates production against it prices.

Figure 3 mentioned about the positive contribution of aggregates production against it prices.

3. Prices of Different Aggregates Crushed in Afrimin

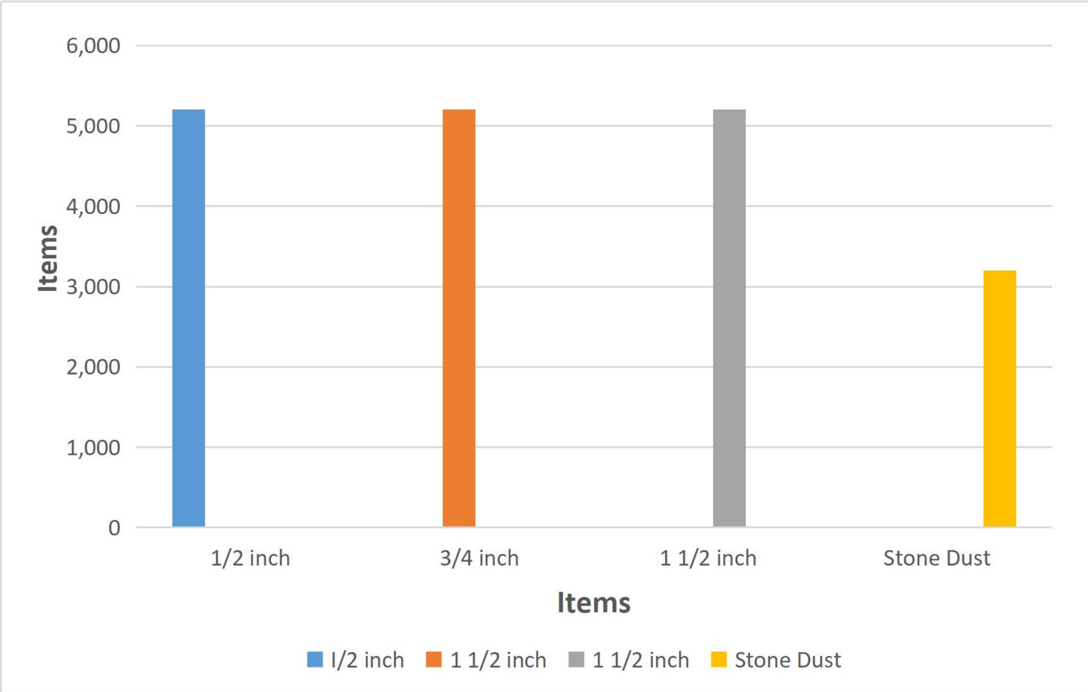

Figure 4. Prices of Different Aggregates Crushed in Afrimine

Figure 4 shows the differences between the prices of the crush in Afrimine.

4. Salary Structure of Afrimine Quarry

Salary distribution of Afrimine quarry is shown in figure 5

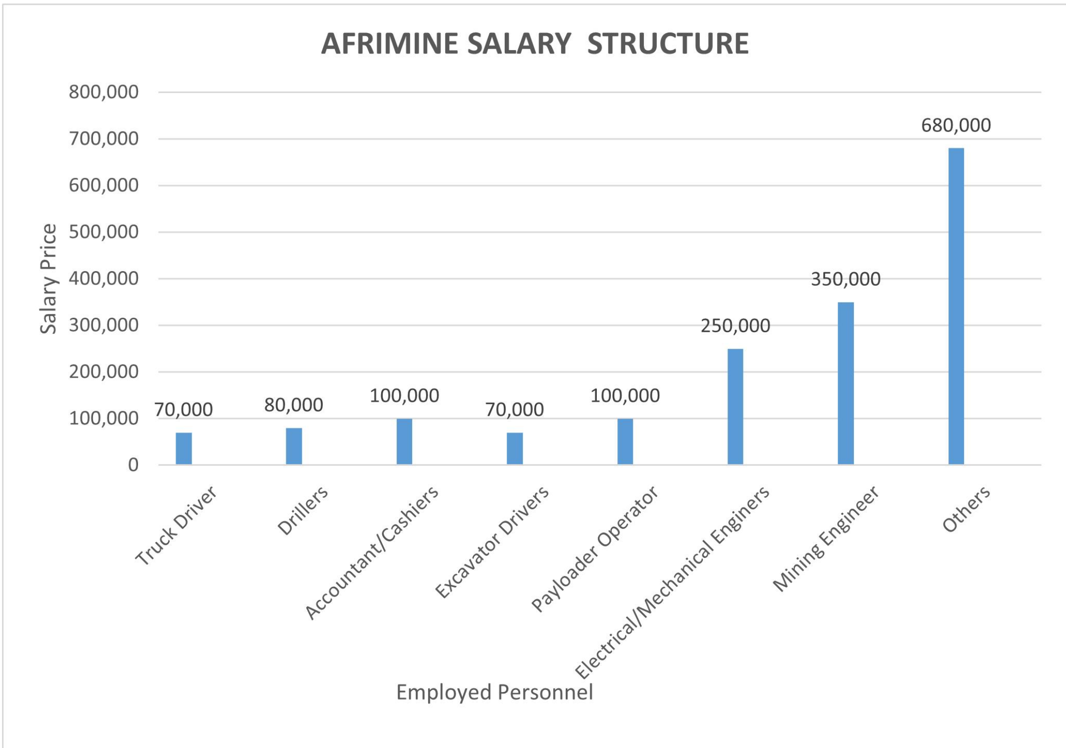

Figure 5. Salary distribution of Afrimine quarry

According to figure 5, there were few positions in the Afrimine quarry.

4.2.2. Interpretation of results obtained from Jolex Construction

1. Jolex Construction Workers Salary

4 laborers at crushing plant are paid ₦40,000 each,

Therefore: $4\times$ 40,000=₦160,000

Also, 3 truck drivers are paid N40, 000 each

$3\times$ 40,000=₦120,000

Whereas Rock drill, Pay loader and excavator operators are paid ₦55, 000 each.

Which implies that, 3×55, 000=₦165,000 is been paid for all the operators. Other workers paid include:

Panel room operator=₦40,000

Crusher operator=₦40,000

Mechanic=₦50,000

Asst. Mech. =₦35,000

Cashier=₦30,000

Accountant=₦40,000

Plant manager=₦200,000

3 guard=₦20,000 each

:. $3\times$ 20,000=₦60,000

3civil defense = ₦20,000 each

:. $3\times$ 20,000=₦60,000

2. Equipment Rental for Jolex Construction

Jolex Construction due rent out some of their equipment which has affected their profit margin positively. Some of the equipment been rent out are

Wagon drill = ₦100, 000 per day

Excavator = ₦ 50, 000 per day

Compressor = ₦80, 000 per day

Pay loader=₦70, 000 to ₦ 80,000

Workmanship

Operator =₦5, 0000

Mechanic =₦30, 000

Drill rate per meter.

1m= ₦3000, 4m = ₦12, 000.

Cost of drilling 100 holes of 4m per blast

This implies that: 3000 X 4 X 100= ₦ 1,200,000 for the cost of drilling per blast

Table 5: Selling price per ton of aggregate for Jolex Construction

3. Jolex Construction Production Cost

Drilling and blasting

They make use of wagon drill for drilling of shot holes.

The Wagon drill consumes 220 liters per 25 holes of 4m depth & 78mm width

4. Cost of Drilling and Blasting 100 holes

(a) High Explosives

1 carton =25kg which contains 16 pieces of 60mm explosives.

1kg = ₦ 950

Each hole carries 7 explosive

250 holes =1750 high explosive

Cost of 1 carton=N950 x 25= ₦ 23,750

Cost of 250 holes= 43.75 x N23, 750

= N1, 039, 062.5

(b) Detonating Cord

1m = N160 1 carton=1000m

1 roll =250m

250 holes will consume (250 x 4 x 2) + Xm

= 2000m+ X, X =100m- 150m. (X is the extra detonating code for tightening nuts)

Therefore 1950m will cost 1950 x N160

=₦ 312, 000

(c) Electric Detonator

N800 each

2 per blast = N1600.

Delay relay N700 each, they use 10 pieces per blast.

100 holes. =N7000

(d) Firing Cable

1 roll= 500m =N75, 000 for 10 blast.

Per blast = 75,000/10 =N7, 500

5. Jolex Royalties

(a) Land Owner = N2, 000,000 per annum

(b) Rock Lease = N250, 000 per blast

6. Jolex Fuel Consumption (on daily basis)

Excavator =90 liter=₦ 20, 250

3 dumb trucks=3x30 liter=₦ 20, 250

Pay loader =60 liter =₦ 13, 500

Generator =90 liter=₦ 20, 250

Total cost =₦ 74, 250 daily

Transformer=N80, 000/month

Interpretation of Results Using Chart

1. Jolex Salary Structure

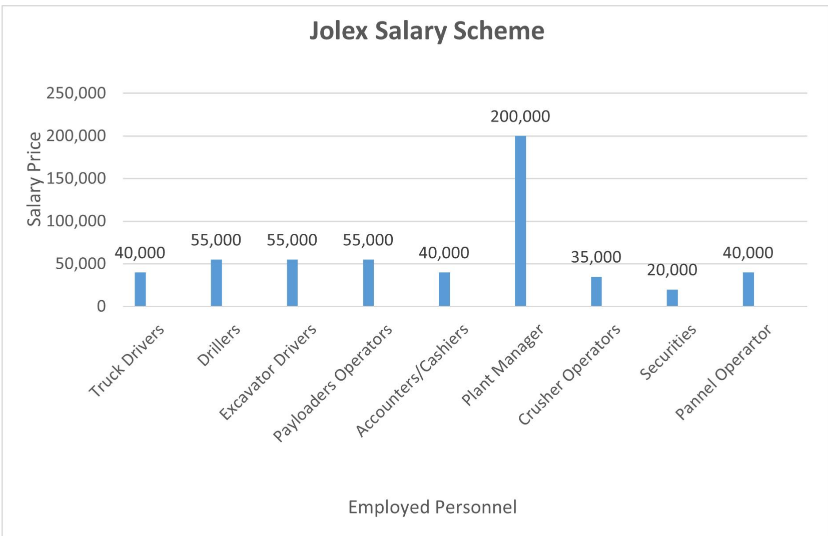

Figure 6. Jolex Salary Structure

According to Figure 6, there were few salaries range between each position such as the highest salary was the Plant Manager with $200,000.

4.2.3 The Unit Cost of Production for Jolex and Afrimines Quarry

$$unit\ \cos t\ of\ production = \frac{Total\ amount\ of\ \exp enses\ for\ production}{Total\ amount\ of\ quantity\ produced}$$

$$Unit \text{ cost of production for Afrimines quarry} = \frac{34,389,140.625}{15000} = 2,291.61 \quad \text{₦/ton}$$

$$unit \text{ cost production for Jolex} = \frac{9,205,000.00}{9000} = 1022.78 \quad \text{₦/ton}$$

4.3 Discussions of Results

Table 1 and **Table 5** show the operating expenses on aggregate production per month at Afrimine Quarry and Jolex Construction which includes; salary paid to the workers per month, Explosive used per month for blasting operation, Lubricant used for the equipment, Diesel used for the equipment, Average cost of maintaining the quarry site, Land rental of the quarry, and 5% VAT, which are used to derive the cost incurred or less direct expenses from the operating expenses per month.

Table 2 and **Table 6** show the various prices of the different aggregate sold in Afrimine Quarry and Jolex Construction. The prices ranges from N3300 for Stone Dust and N5, 200 for 1/2, 3/4 and 1 1/2 inch in Afrimine Quarry but between N7500 for Stone Base to N8,000 for other aggregate size in Jolex Construction.

Table 3 and **Table 7** shows the income on aggregate production per month at Afrimine Quarry and Jolex Construction on the Tons of Aggregate mined per month which gives the total production per month while **Table 4** and **Table 8** show the positive contribution on aggregate production for each quarry, which include the deduction of total production volume in value from less direct expenses to give the profit earned from aggregate production. The table also shows the comparison of positive contribution on aggregate production. This reveals the Afrimine makes the sum of ₦ 70,875,000 for every 15,000 tones crushed per month but has a monthly positive profit of ₦ **36,484,859.375** but Jolex Construction makes the sum of ₦ 67,500,00 for every 9,000 tones crushed per month but has a monthly profit of ₦ **58,295,000**

5. Conclusion and Recommendation

5.1 Conclusion

This research examines the unit production cost of granite in Afrimine Quarry and Jolex Construction sited in Plateau State Nigeria. The results revealed that the total production of aggregates in volume value is ₦ 70,875,000 for 15,000 tons per month in **Afrimine Quarry** but the positive values of profit made in a month sums up to ₦**36,484,859.375** while the total production of aggregates in volume value is **67,500,000** for 9,000 tons per month in **Jolex Construction** but the positive values of profit for Jolex Construction sums up to ₦ **58,295,000.**

After the research on both quarries it was observed that the unit production cost of Afrimine quarry was ₦ 2,291.61/ton and that of Jolex as ₦ 1022.78/ton, and the total production cost of Afrimine quarry was ₦ 34,389,140.63/month and that of Jolex was ₦ 9,205,000/month.

For every 15,000tons of aggregate, Afrimine quarry spends ₦ 70,875,000 and gets a profit of ₦ 36,485,859.38 whereas Jolex Construction quarry spends ₦ 67, 500,000 to produce 9,000 tons of aggregates and get a profit of ₦ 58,295,000.

Therefore, one can conclude that Jolex construction quarry makes more profit than Afrimine quarry due to lower production cost on drilling and blasting as seen in Table 4.1 and 4.5. Afrimine spends more money on drilling and blasting because they contract this operation to a third party thereby splitting their profit.

Quarries if properly managed, can be a very profitable business.

5.2 Recommendations

Some of the recommendations suggested after the research include:

i. Afrimine quarry should consider carrying out their drilling and blasting independently

ii. Afrimine should increase their man-power most especially in the drilling and blasting.

iii. Jolex construction Quarry should consider increasing their production so as to increase profit.

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