COST EVALUATION OF PRODUCING DIFFERENT AGGREGATE SIZES IN SELECTED QUARRIES IN ONDO STATE NIGERIA

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ABSTRACT: *This research centres on cost evaluation of producing aggregate sizes in selected quarries in Ondo State, Nigeria. In this study, two granite quarries out of the quarrying companies in Ondo State are used as case studies. In order to achieve the aim of this research physical properties of aggregate and stages involve in aggregate production were discussed. Also, structured questionnaires were distributed to the mangers and other management staff in the selected quarries to acquire the total cost implication of producing 1 ton of granite aggregate. The data acquired was subjected to basic economic evaluation. The results show that the monthly operation costfor Quarry A is ₦ 30,618,000, while that of Quarry B is ₦10,164,000. The total production in volume value is₦ 67,242,000 for A and that of B is ₦32,625,000. Base on the above values the profit for A is ₦37,242,000 while that of B is ₦22,241,000. These translate to 122% profit for A and 219% profit for B. It is recommended that the cost price of granite aggregates in Nigeria can be reviewed to make it reachable for masses. This will eradicate the use of natural gravels that are not free from clays coating and other fine materials that could affect hydration and bond of cement paste which can lead to building or structure collapse.*

KEYWORDS; Quarry, Aggregates, Cost Evaluation, Income, and Expenditure

INTRODUCTION

Quarry operation is the most common surface mining activities in Nigeria and in the world which involve 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 exploited for production of different sizes aggregates and slabs (Ashmole and Motloung, 2008).In locating economically viable deposit for aggregates production, the factors to be considered include, the available tonnage, mineable quality of aggregate, nearness to market or distance from major use areas, transportation cost, government regulation and operating cost. The energy required to crush rocks into aggregates is proportional to the amount of new surface area that is created; hence, a very important percentage of the energy consumed to produce construction aggregates is spent in producing non-commercial fines.

Aggregates are defined as inert, granular, and inorganic materials that normally consist of stone or stone-like solids. They can be used alone (in road bases and various types of fill) or can be used with cementing materials (such as asphalt cement or Portland cement) to form composite materials or concrete (Guimaraes *et al.*, 2007). The most popular use of aggregates is to form Portland cement concrete. The importance of using the right type and quality of aggregates cannot be overemphasized. Fine aggregates generally consist of natural sand or crushed stone with most particles smaller than 5 mm (Bamigboye *et al.,* 2016). Coarse aggregates is a combination of gravels or crushed stone with particles predominantly larger than 5 mm (0.2

in.) and generally between 9.5 mm and 37.5 mm (3⁄8 in. and 1½in.). Some natural aggregate deposits, called pit-run gravel, consist of gravel and sand that can be readily used in concrete after minimal processing. Aggregates must conform to certain standards for optimum engineering use i.e. they must be clean, hard, strong, durable particles free of absorbed chemicals, coatings of clay, and other fine materials in amounts that could affect hydration and bond of the cement paste (PCA, 2015). Aggregate particles that are friable or capable of being split are undesirable. Aggregates containing any appreciable amounts of shale or other shaly rocks, soft and porous materials, Coarse aggregate should be avoided; certain types of chert should be especially avoided since they have low resistance to weathering and can cause surface defects such as popouts. Identification of the constituents of an aggregate cannot alone provide a basis for predicting the behaviour of aggregates in service. Visual inspection will often disclose weaknesses in coarse aggregates. Service records are invaluable in evaluating aggregates (Vasarhely and Bobet, 2000).This research discusses cost evaluation in the total process of aggregate production from extraction through processing.

Classification of Aggregate

According to Zongjin (2014), aggregates can be divided into several categories according to different criteria.

In accordance with size:

    i.   Coarse aggregate: Aggregates predominately retained on the No. 4 (4.75 mm) sieve. For mass concrete, the maximum size can be as large as 150 mm.

    ii.   Fine aggregate (sand): Aggregates passing No.4 (4.75 mm) sieve and predominately retained on the No. 200 (75 μm) sieve.

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).

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. (Cinder, blast furnace slag, volcanic pumice).

    ii.   Normal weight aggregate: This type 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.

Physical Properties of Aggregates

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

Absorption, Porosity, and Permeability

The internal pore characteristics are very important properties of aggregates. 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 (David, 2015). Absorption relates to the particle's ability to take in a liquid. Porosity is a ratio of the volume of the pores to the total volume of the particle. Permeability 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.

Surface Texture

Surface texture is the pattern and the relative roughness or smoothness of the aggregate particle. Surface texture plays a big role in developing the bond between an aggregate particle and a cementing material. A rough surface texture gives the cementing material something to grip, producing a stronger bond, and thus creating a stronger hot mix asphalt or Portland cement concrete. Surface texture also affects the workability of hot mix asphalt, the asphalt requirements of hot mix asphalt, and the water requirements of Portland cement concrete. Some aggregates may initially have good surface texture, but may polish smooth later under traffic. These aggregates are unacceptable for final wearing surfaces. Limestone usually falls into this category. Dolomite does not, in general, when the magnesium content exceeds a minimum quantity of the material (Balamurali, 2014).

Strength and Elasticity

Strength is a measure of the ability of an aggregate particle to stand up to pulling or crushing forces. 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. The best results for Portland cement concrete may be obtained by compromising between high and low strength, and elasticity. This permits volumetric changes to take place more uniformly throughout the concrete.

Density And Specific Gravity

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

Definitions

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

$$D = \frac{Weight}{Vsolid} \tag{1}$$

Bulk density: the volume includes the pores inside a single aggregate.

$$BD = \frac{Weight}{Vsolid + Vpores} \tag{2}$$

BD can be either BD$_{SSD}$ or BD$_{AD}$ according to the moisture condition of aggregate when it is weighed.

Specific gravity (SG): mass of a given substance divided by unit mass of an equal volume of water (it is the density ratio of a substance to water). As an example, specific gravity information about a particular aggregate helps in determining the amount of asphalt needed in the hot mix asphalt. If an aggregate is highly absorptive, the aggregate continues to absorb asphalt, after initial mixing at the plant, until the mix cools down completely. This process leaves less asphalt for bonding purposes; therefore, a more porous aggregate requires more asphalt than a less porous aggregate. The porosity of the aggregate may be taken into consideration in determining the amount of asphalt required by applying the three types of specific gravity measurements.
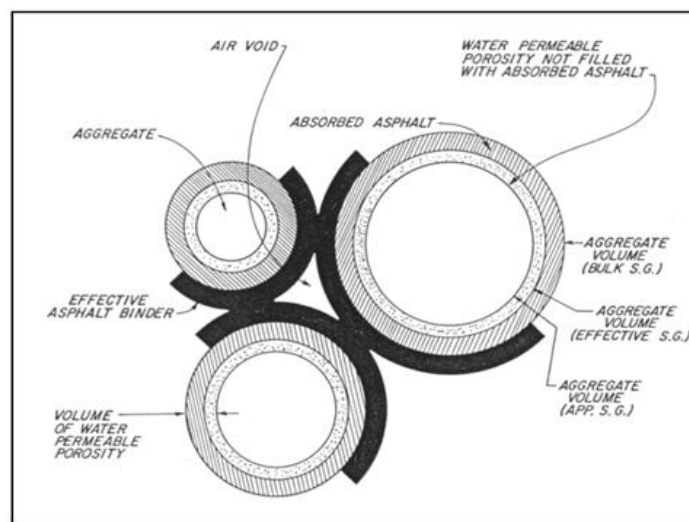

Fig. 1.0 Aggregate Specific Gravities (source: Balamurali, 2014).

In the Figure 1.0, the bulk specific gravity includes all the pores, the apparent specific gravity does not include any of the pores that would fill with water during a soaking, and the effective specific gravity excludes only those pores that would absorb asphalt. Correlation charts and tables provide guidance to asphalt quantities or acceptability of the aggregate.

Aggregate Voids

There are aggregate particle voids, and there are voids between aggregate particles. As solid as aggregate may be to the naked eye, 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. The void within an aggregate particle is not the same as the void system which makes up the space between particles in an aggregate mass. The voids between the particles influence the design of hot mix asphalt or Portland cement concrete.

Hardness

The hardness of the minerals that make up the aggregate particles and the firmness with which the individual grains are cemented or interlocked help to control the resistance of the aggregate to abrasion and degradation. Soft aggregate particles are composed of minerals with a low

degree of hardness. Weak particles have poor cementation. None of this type is acceptable. The Mohs Hardness Scale is frequently used for determination of mineral hardness. Although there is no recognizable specification or requirement which pertains to Mohs Hardness Scale, the interpretation, concept, and use of this scale is useful for the field identification of potentially inferior aggregates (Neville, 2011).

Stages Involved In Aggregate Production

Aggregate production involve various stages which include the development of the quarry by taken the coordinate of the site, stripping, drilling, stemming, blasting (its accessories), mucking and loading, haulage and crushing. These stages also refer to unit of operation of mining. The sequence of unit of operation utilized to accomplish mine exploitation is called the cycle operation.

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.

Stripping Operation

As a first step, a producer is required to designate a detailed stripping procedure for each and every deposit that is mined. 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.

Drilling Operation

Drilling can be define as an artificial creation of cavity or hole in an ore body for samples collection for further analysis, for casing sinking and for placement explosive. 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. Drilling is of different types:

 i. Primary Drilling: This is done on insitu rock with drilling machine of different type sach as ROC 601, ROC 301, CM 348, which are powered by compressors. Primary drilling must give a definite operation in order to carry out primary blasting such as diameter of the holes, bench height of the rock, burden and spacing on the rock.

 ii. Secondary Drilling: This is done on already fragmented rock of larger sizes (boulders) for purpose of size reduction by the means of secondary blasting. It is carried out by using a Jack Hammer, which is powered by a pneumatic compressor. It is also give room for proper haulage to the crushing.

Blasting Operation

Blasting is defined as a fragmentation of rock by means of explosives and its accessories for the subsequent extraction or process (Sushil, 1997). After the blast holes have been drilled to the requirement, the next operation is to the 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. Both the low explosives and high explosives are used. The low explosive used is ANFO and the high explosive used is Gelatine dynamite. Increasing the quantity of fuel added to the ammonium nitrate will result into red fumes being produced after blasting. So, 96% of ammonium nitrate and 4% of diesel oil are mixed together to give the required ANFO. In other words, for every 25kg of explosive, 1.75 litres of diesel oil is added, Use a long bamboo rod to through the drill holes of about 6m depth. Make primer cartridge (i.e. explosive cartridge primer cord). Do the primer charge and insert an explosive cartridge primer into each drilled hole. Load the holes after primer charge with high explosives and ANFO. Stem/seal the holes with granite chips. Connect all the charged holes together (either in series or parallel). Insert MS Delay detonator in between each holes connected and clipped plain detonator with shock tube. Insert shock tubes into the Blasting Machine or Exploder and fire. Escape from danger area to safe place, 500m away using a fast moving vehicle. After the blast, go back and check the outcome (result).The quantity of explosive is also function of the drilling depth and rock mass (Sharma, 2012).

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. The back-hoe shovel (crawler mounted) is capable of removing hanging rocks on the quarry face.

Haulage of Material

The fragmented rocks are transported by haulage (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.

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 (Hadin, 2001).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:

Table 1.0: Different Aggregate Sizes by Method of Screening

¾ inch down (oversize)	32 – 70mm
¾ inch	19 – 25mm
½ inch	5 – 19mm
Stone dust	0 – 5mm

Cost Estimating

An estimate is a judgment, forecast or prediction. A cost therefore is a judgment or opinion of the cost of a process, project, product or services. It is a prediction or forecast of what a work output or work activity will cost (Rodney, 1991). According to the Society of Cost Estimating and Analysis (SCEA), estimating is the art of approximating the probable worth or cost of an activity based on information available at that time. Cost finding is the process by which the company obtain estimates of the costs of producing a product, providing a service, performing a function, or operating a department.

The most fully developed methods of costs finding are used to estimate the costs that have been incurred in a factory to manufacture a specific products. The simplest of these methods is known as **process costing**. In this method, the accountant first accumulates the costs of each production operation or process for a specified time frame. This sum is then restated as an average by dividing the total costs of production by total output in the period. The process costing can be used whenever the output of an individual processes is reasonably uniform or homogenous, as in cement manufacturing, flour milling, other relatively continuous production processes.

The second method is **job - order costing**, which is used when individual production centres or department work on a variety of products rather than just one during a typical time period. Two categories of factory cost are recognised under this method: prime cost and factory overhead costs. Prime costs are those that can be traced directly to a specific batch, or job lot of products (Pava, 2014). These are the direct labour and direct materials cost of production. Overhead costs, on the other hand, are those that can be traced only to the departmental operations or to the factory as a whole and not to individual job – orders the salary of a departmental operations or to the factory as a whole and not to individual job – orders the salary of a departmental supervisor is an example of an overhead cost. Direct materials and labour costs are recorded on the job – order cost sheets for each job. Although not traceable to individual jobs, overhead costs are generally assigned to them by means of overhead rates i.e. the ratio of total overhead costs to total production volume for a time given period (Robert and Lesile, 2000).

The third method of cost finding, **activity-based costing**, is based on the fact that many costs are driven by factors other than product volume. The first task is to identify the activities that drive costs. The next step is to estimate the costs that are driven by each activity and to state them as averages per unit of activity. Management can use these averages to guide its efforts to reduce costs.

METHODOLOGY

Description of the Study Areas

The two quarries sites used as a case study in this research lies between 6°N - 7°N, and 4°E - 6°E at an altitude of between 0 to 1365m. QuarryA is sited in Ijare town while Quarry B is sited in Iju -Itaogbolu(along Itaogbolu – Akure road) all in Ondo State. Both quarries are sited

in towns that are closed to the state capital – Akure. The stones are reputed to have compressive strength of between 164 and 173MPa while the tensile strength is between 10.78 and 12MPa.
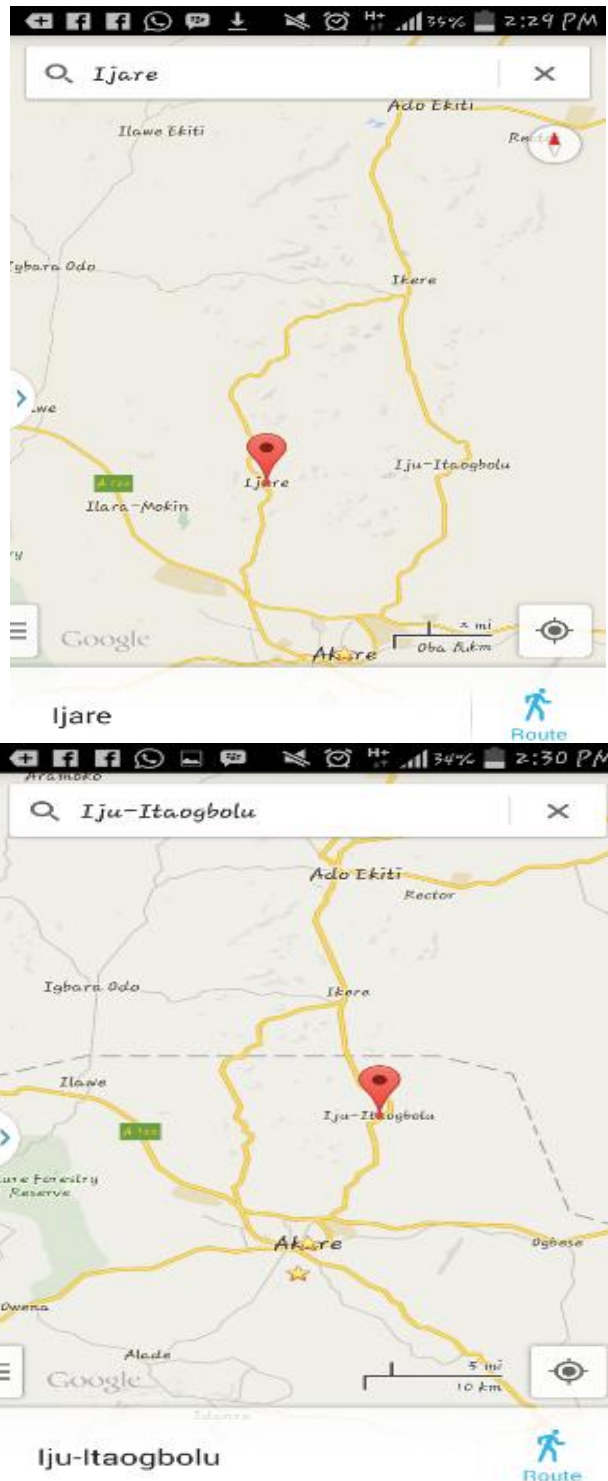

Fig 2: Map of Ondo State (Google Map 2015).

Data Collection

Questionnaire were administered to the two quarries to acquire necessary data such as personnel, production schedule, production rate, production cost, remuneration/emoluments with their salary and so on.

Data Analysis and Presentation

Data obtained from the company were critically analysed, examined and processed. Statistical analysis were carried out on the data and presented with the use of some statistical tools. These tools include the following: Bar chart, Pie Chart, Analysis of variance, Correlation analysis. All these methods are the most appropriate because the information gathered from respondent deals with qualitative product produced in tons/annum and sales made in Naira and cost of production.

Definition of some Economic Terms

(a) Total Revenue: This denotes the total productivity of ore reserve in sales of output.

(b) Total Capital Cost: This is the total investment or amount of money needed to finance the purchasing of capital goods such as factory machines and equipment.

(c) Total Fixed Cost: This is a type of cost that does not vary with the quantity produced and in short run does not alter with the changes in the amount produced.

(d) Total Variable Cost: On the other hand, this cost varies with changes in the level of output. These include raw material expenses, labour wages, drilling and blasting costs etc.

(e) Marginal Cost: This is the cost incurred as additional cost to total cost in producing one more unit of output. It first decline as production expands but ultimately begin to rise.

(f) Marginal Revenue: This is addition made to the total revenue by sale of one more unit of output.

(g) Production Cost: This is the cost incurred during the production. It varies significantly depending on the available inputs needed for production to take place. For production to take place, money is expended on the following:

  i. Labour/ salary of employees;

 ii. Energy costs, fuel consumption, explosive and power supply;

iii. Equipment costs, repairs and maintenance costs;

iv. Miscellaneous costs and;

 v. Government revenue, taxes and royalty.

(h) Total Cost: This is the total expenses incurred in reaching a particular level of output.

(i) Taxation or Government revenue: It is paid to boost local government, state and federal government depending on what demand e.g. federal ministry of mines and steel development takes royalty.

Cost Estimate and Profit/Loss Calculation

Let Overall cost $= Production\ cost\ + governemnt\ revenue$ ……...(3)

Cost per tonne $= \frac{production\ cost}{Total\ output}$ …………………………………………..…(4)

Total revenue $= output\ per\ annum\ \times selling\ price\ per\ ton$ ………(5)

Profit $= total revenue - production cost$………………………………. (6)

Estimation Techniques

Average Operating Cost

Total cost realized from ton produce per day

Profit = Revenue – Production Cost

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.

RESULTS

The data collected were analysed and presented in the tables below.

Table 2: Operating Expenses on Aggregate Production per month at Quarry A and B

Particulars	Amount (₦) for A	Amount (₦) for B
Salary	7,500,000.00	1,700,000.00
Explosive	4,000,000.00	700,000.00
Lubricant	300,000.00	270,000.00
Diesel	3,900,000.00	1,000,000.00
Average Cost of Maintenance	8,000,000.00	3,500,000.00
Cost of Equipment	5,200,000.00	2,400,000.00
Land Rentage	10,000.00	10,000.00
Miscellaneous	250,000.00	100,000.00
Total (VAT)	**29,160,000.00**	**9,680,000.00**
5% VAT	1,458,000.00	484,000.00
TOTAL	**30,618,000.00**	**10,164,000.00**

Table 3: Income on Aggregate Production per month at Quarry A and B

Particulars	Amount (₦) for A	Amount (₦) for B
1 Ton of Aggregate	2,175	2,175
31,200 Tons of Aggregates at A and 15,000 Ton of Aggregate at B	67,860,000	32,625,000

½ inches = 2,600

¾ inches = 2,600

1½ inches = 2000

Stone Dust = 1,500

$$1 \text{ Ton of Aggregate} = \frac{2,600 + 2,600 + 2000 + 1,500}{4} = \frac{8,700}{4} = 2,175$$

For A, 31,200 Ton of Aggregate $= 2,175 \times 31,200 = ₦\ 67,860,000.$

For B, 15,000 Ton of Aggregate $= 2,175 \times 15,000 = ₦32,625,000.$

Table 4: Positive Contribution on Aggregate Production per month at Quarry A and B

Items	Amount (₦) for A	Amount (₦) for B
Total Production volume in value	67,860,000	32,625,000.00
Less direct expenses and less cost of asset usage	30,618,000	10,164,000.00
Positive Contribution	**37,242,000**	**22,461,000.00**

Percentage Profit for Quarry A and Quarry B

$$\frac{profit}{cost\ price} \times 100$$

For Quarry A:

$$\frac{37,242,000}{30,618,000} \times 100 = 122\%$$

For Quarry B:
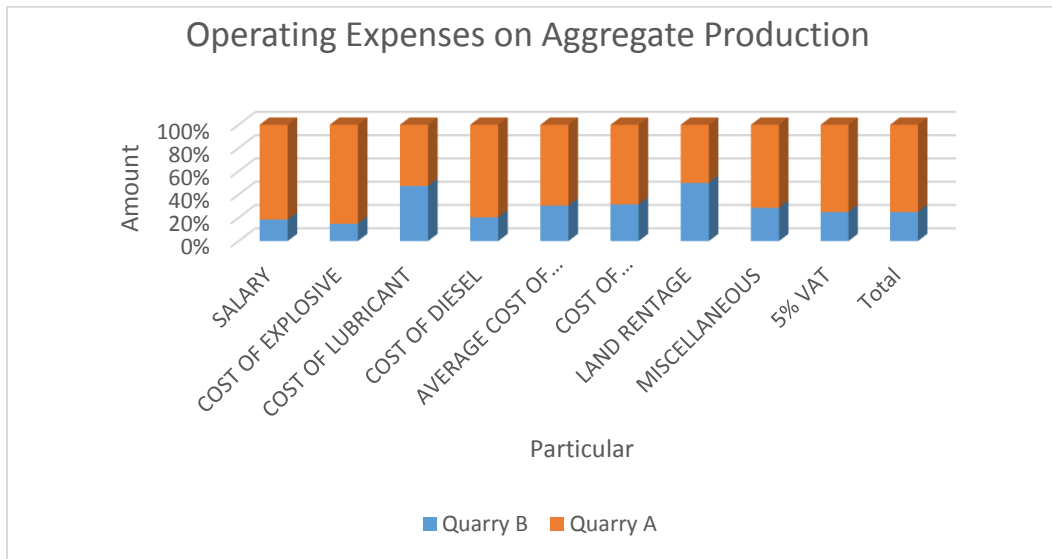
$$\frac{22,241,000}{10,164,000} \times 100 = 219\%$$

Fig. 3: Comparison of Operating Expenses in Aggregate Production per Month at Quarry B and Quarry A
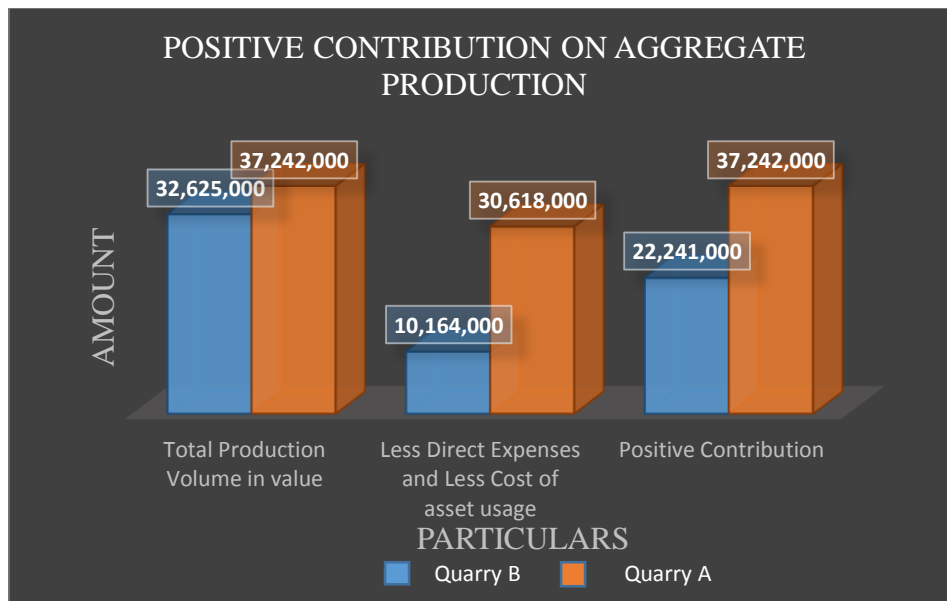

Fig. 4: Comparison of Positive Contribution on Aggregate Production per month at Quarry B and Quarry A

DISCUSSIONS

Tables2 shows the operating expenses on aggregate production per month at Quarry A and Quarry B 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, Cost of Equipment used per month, Land rentage of the quarry, miscellaneous, and 5% VAT, which are used to derive the cost incurred or less direct expenses from the operating expenses per month. The table shows the comparison of operating expenses on aggregate production per month at Quarry A and Quarry B, it can be deduced that

Quarry A has the highest salary paid, Explosive used, cost of equipment, lubricant used and even the total cost incurred compared to Quarry B which can lead to improving the aggregate production. Tables3 shows the income on aggregate production per month at Quarry A and Quarry B; on the Tons of Aggregate mined per month which gives the total production per month.Tables4 shows 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, which reveals that Quarry A has the highest positive contribution with ₦37,242,000 compared to Quarry B with ₦ 22,461,000.

Figure 3 shows the graph of operating expenses on aggregate production: in terms of salary, Quarry A has the highest salary paid, Explosive used, cost of equipment, lubricant used and even the total cost incurred with ₦30,618,000 compared to Quarry B with ₦10,164,000 which can lead to improving the aggregate production. Figure 4 shows the graph of positive Contribution of aggregate production, which include; the total production volume in value for Quarry A with ₦37,242,000 is higher than Quarry B with ₦32,625,000; less direct expenses and less cost of asset usage for Quarry A with ₦30,618,000 is higher than Quarry B with ₦10,164,000; the positive contribution for Quarry A with ₦37,241,000 is higher than Quarry B with ₦22,241,000.

CONCLUSION

This research examines the cost of production of granite aggregates for Quarry A and Quarry Bout of quarries sited in Ondo State Nigeria. The results revealed that the total production in volume value is ₦ 67,242,000 for Quarry A and that of Quarry B is ₦ 32,625,000. Base on the above values the profit for Quarry A is 37,242,000 while that Quarry B is ₦22,241,000. From the above results, it revealed that both quarries are making good profits; however, Quarry A is making a little above 100% of their monthly input as profit while Quarry B is making more than 200% of their input as profit.

RECOMMENDATION

Base on the outcome of this research, it is recommended that the cost price of granite aggregates in Nigeria can be reviewed to make it affordable for masses. This will eradicate the use of natural gravels that are not free from clays coating and other fine materials that could affect hydration and bond of cement paste which can lead to building or structure collapse.

Acknowledgement

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