# Product Specification: A Critical Factor in Crushing Plant Design for Commercial Aggregate Quarries

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## ABSTRACT

Commercial quarries require prompt patronage for a better cash flow that will satisfy the prime objective of their establishment. Fonds and Pricey quarry is a 250T/H capacity quarry in Abuja and one of the many Nigerian quarries facing challenges of poor cash flow due to low sales with huge stock piles of untradeable products. This unpleasant situation threatens the viability of a quarry business. This paper reviewed the production process and financial situation of F & P quarry with the view to revitallize the business through crushing plant process re- engineering to boost the quarry's cash flow. Pareto analysis of the product sales was carried out and the complete sand making plant that would be amalgamated with the main crushing plant presented. This study showed that, most crushing plant designs give little or no consideration to crushed products demand and supply gap analysis; and there is a regional difference in the market potential for various quarry products, especially dust and ½" materials. A short and long term (models I and II) solutions were herein provided for old quarries facing similar business challenge and an improved crushing plant flow line for newly proposed aggregate quarries in Abuja that will guarantee better cash flow and consequent quick payback.

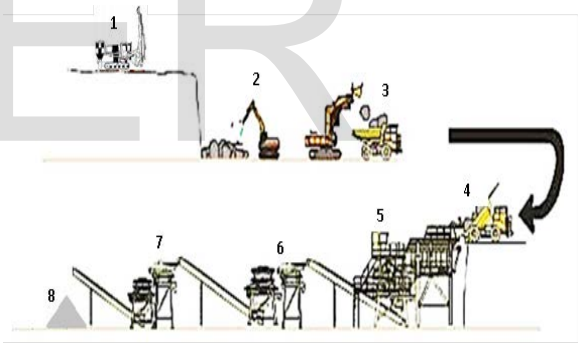
**Key words**: Cash flow, crushing plant, quarry products, vertical shaft impactor

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## 1.0 INTRODUCTION

### 1.1 Aggregate Quarrying Process and Quarry Products

Granite aggregate quarrying is a multistage process by which granite rock deposit is extracted from the ground and crushed to produce aggregate, which is then screened into the sizes required for immediate use, or for further processing, such as coating with bitumen to make asphalt for road construction (Figure 1).




1 = Drilling; 2 = Mechanical Breaking; 3 = Loading and Haulage; 4 = Dumping and Feeding; 5 = Primary Crushing; 6 = Secondary Crushing; 7 = Screening and Classification; 8 = Storage/ Stockpile.

**Figure 1: Aggregate Quarry Processes** [1]

Designing a typical aggregate quarry involves multidisciplinary efforts to guarantee technical feasibility and commercial viability of the project, most importantly a commercial quarry whose prime objective is high return on investment (ROI) or quick payback. In Nigeria, great number of aggregate quarries have been established to provide aggregate supplies to the construction industry; with Abuja and South- west region

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(Ibadan and Abeokuta axis) hosting about one hundred and thirty- five (135) quarries [2]. These quarries sourced for their crushing plants with higher emphasis on production capacity, with little or no consideration given to product size specification in high demand. Figure 2 is a Geological sketch map of Nigeria showing the major geological components; Basement, Younger Granites, and Sedimentary Basins.

An aggregate quarry typically produces the following products [3]:

1. Large size blocks blasted from quarry face, from approximately 0.5m$^3$ to 1.25m$^3$, are called Granite boulders and are used in coastal and river flood defence schemes to shore up sea fronts and river banks such as those products supplied for coastal work in Lekki, Lagos state.

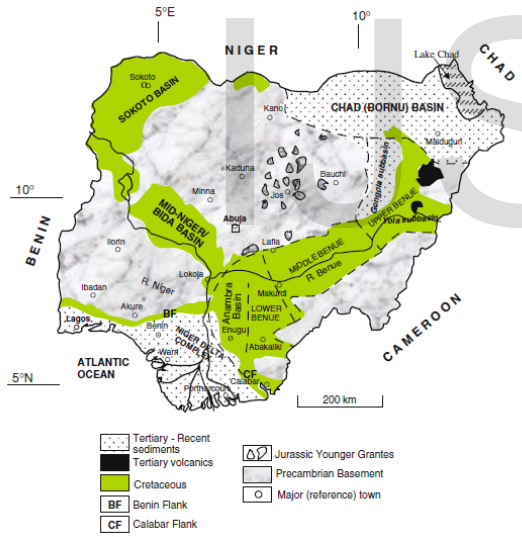



**Figure 2: Geological sketch map of Nigeria showing the major geological components; Basement, Younger Granites, and Sedimentary Basins** [4].

2. Hard core drawn either directly from the shot pile or/ and from products of primary crushing and is used as large scale fill on construction sites (fuel stations, swampy sites, dams etc.)

3. Materials screened by grizzly feeder immediately prior to primary crushing is called rejects or bye- pass which is usually employed as fill materials on construction sites or on haulage routes and pit floor in the quarry environment.

4. The direct unscreened output from a crushing plant contains a complex mix of sizes from fines to the maximum size the plant can pass and is called crusher run. This is used for construction fill and is common in South- Africa.

5. Screened out fine material from the secondary crusher is called blinding. Some screens have multiple decks and can screen out several grades of blinding. Blinding, because it is finer than crusher run, is used for final shaping up of construction sub- bases, particularly in road construction projects, where the sub-base is the last unbound layer before coated materials are laid.

6. Screened aggregate (ballast) for concrete. This aggregate is heated and mixed with bitumen, according to certain recipe proportions, to make surface dressing in road construction project.

7. Dust: This class of products is the finest of crushed products. Usually, there is regional difference in product demand between Abuja and South- west Nigeria (dust is in higher demand and 1/2‴ has negligible demand in Abuja while it is the other way round in South- west region). Reason being that, there are large deposits of river sand which is a good substitute for quarry dust within the South-west region which negatively impact on the economic importance of the quarry dust.

Depending on the size and type of crushers, screens, and conveyor systems; integration and amalgamation of these equipment, a crushing plant can be designed for certain minimum production capacity in tons per hour. A typical crushing plant product size distribution is shown in Table 1. However, with a thorough market survey of the product sizes in high demand in the locality where the quarry is proposed, the design can be tailored to satisfy the business objective. Unfortunately, this supply and demand gap analysis is not usually considered in the design of crushing plant. this is true of most quarries in Nigeria. This is why the

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quarries bear a high risk in achieving their forecast profitability. Return on investment (ROI) is not usually as evaluated in the feasibility report. Poor sales consequently affect the quarry's cash flow.

### 1.2 Case Study: Fonds and Pricey (F & P) Quarry, Abuja

Fonds and Pricey quarry site is located at Bmuko village, Pwambara in Bwari Area Council of Abuja, Nigeria. The quarry is adequately equipped with ancillary equipment as shown in Table2 and a 250T/H capacity Shanghai Zenith crushing plant with the component machines enlisted in Table 3 and the crushing plant flow line is as shown in Figure 3.

**Table 1: Typical Crushed Product Size Distribution**

| Size Class | % Distribution |
|---|---|
| 3/4' - 1' (19 - 25mm) | 25 - 35 |
| 1/2' - 3/4' (12.5 - 18.5mm) | 20 - 25 |
| 3/8' - 1/2' (10 - 12.5mm) | 20 - 25 |
| 0 - 3/8' (0 - 9.5mm) | 25 - 30 |

**Table 2: Ancillary Equipment in Fonds and Pricey Quarry**

| S/N | Brand | Description of Equipment | Model | Quantity |
|---|---|---|---|---|
| 1. | Yutong | Drilling machine | YTQ 165 | 1 |
| 2. | Yutong | Mining dump truck | YT 3621 | 3 |
| 3 | Yutong | Wheel loader | 966H | 1 |
| 4 | Yutong | Excavator | SC220.8 | 1 |
| 5 | Yutong | Excavator | SC360.8 | 1 |
| 6 | Yutong | Bulldozer | SD7 | 1 |
| 7 | CAT | Excavator | 336 D | 1 |
| 8 | CAT | Wheel loader | 980G | 1 |
| 9 | Atlas Copco | Drilling machine | T35 | 1 |

**Table 3: Main machines in Shanghai Zenith Crushing plant of F & P Quarry, Abuja**

| S/N | Main machine | Model | Quantity |
|---|---|---|---|
| | Hopper | LC 4×4m | 1 |
| I. | Vibrating Feeder | GZD 1300×4900 | 1 |
| II | Jaw crusher | PEW 860 | 1 |
| III | Vibrating Feeder | GZG 300 | 1 |
| IV. | Cone crusher | S51" (Std) | 1 |
| V | Cone crusher | S 51 (Sht) | 1 |
| VI | Vibrating Screens (Primary Screens) | 2YK 1860 | 2 |
| VII | Vibrating Screen (Secondary Screen) | 2YK 1860 | 1 |
| IX | Belt Conveyor | Varying sizes | 1 - 10 |

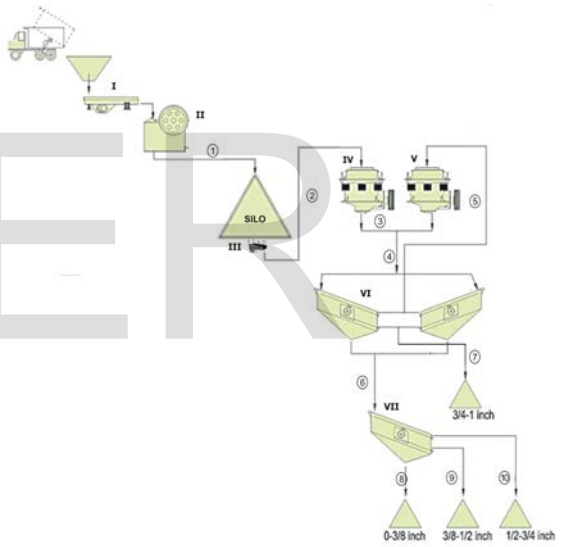



**Figure 3: F & P Quarry's Crushing Plant Flow Line**

In F & P quarry, crushable boulders are conveyed from the quarry face (upstream section) to the crushing plant (downstream). The boulders are dumped in the hopper from where the materials are then gradually fed into the jaw crusher (primary crusher) by the grizzly feeder for primary crushing. The products from primary crushing are piled on a silo with a small vibrating feeder installed below the silo to feed the secondary crusher (primary cone crusher). The products of the secondary crusher are screened by two vibrating screens (primary screens) serving as scalpers; from where over size

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materials (3/4" – 1") are returned to tertiary crusher (secondary cone crusher) for further size reduction, while, the ¾" materials are stacked and fine materials (0 - < ¾") are conveyed to secondary screen for final classification of the products.

A Quarry Report System (QRS) is established in F& P quarry to capture real time performance metrics from where the actual plant output is estimated together with other plant performance metrics (availability, utilization, efficiency, and overall equipment effectiveness, OEE) for the purpose of benchmarking the entire quarry operations. Also, the sales and account departments keep daily records of business transactions. These records are evaluated and analyzed to ensure financial threshold compliance.

## 2.0 PROBLEM STATEMENT:

The sales report for the quarry in the first six months of operation was instructive of a deficient business transaction, characterized by high stockpiles of untradeable products (1/2" and 3/8") and a low supply of dust with consequent customer DISSATISFACTION. Though, the ancillary equipment and the crushing plant were recording high performances in terms of Availability, Utilization and Efficiency. The overall equipment effectiveness OEE for the period under review was close to global best standard (85%) [5], but the quarry could not cash- in appropriately due to low sales. This unpleasant market situation informed the decision of the management board of F & P quarry to review the existing production process with the view to optimize the operation.

## 3.0 OPTIMIZATION STRATEGY

In consideration of a way out, the quarry report system (QRS) has been evaluated, from where the crushing plant outputs have been estimated. Also, the quarry's financial records were studied to investigate the products sales trend.

### 3.1 Plant Output

The actual plant output was estimated from the QRS established at the quarry site to evaluate the daily production of the facility. The number of trips of averagely loaded trucks of blasted product conveyed to the crushing plant for processing is recorded and the average tonnage of materials carried by the trucks is also determined. The total daily production is calculated by multiplying the average weight of material by the daily number of trips

$$P_d = V_a \times N \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where, $P_d$ is total daily production, $V_a$ is average tonnage of loaded truck conveyed to the crushing plant, and $N$ is the total number of trips made by trucks daily.

From the QRS, it was gathered that for 142 working days, about 195,960 tons of quarriable materials was crushed and screened for sales.

### 3.2 Crushed Product Sales

The financial record revealed about 118,359.84 tons sold with huge stockpiles of ½" and 3/8" but no stock of ¾" and dust. This implies that 60.4% of the total production has been sold while 39.6% attracts no buyer. This large tonnage of leftover is capable of threatening the business goal, as income is delayed. Running capital becomes squeezed leading to high operating expenditure due to poor cash flow, because most operating expenditure is on credit. Plant operating area becomes tighter, hindering the ease of handling crushed products and this could lead to high operating cost. All these greatly impact on viability of the business.

Pareto analysis of the product sales revealed that there is need to acquire a sand making machine – Vertical Shaft Impactor (VSI) to further convert or treat the huge stockpiles of ½" and 3/8" materials to pure and mixed dust to boost the supply of dust to customers for better customer satisfaction and quicker return. Moreover, there was no prospect for ½" and 3/8" products market which equally bothers the quarry's management about the space for continuous stacking of the unsaleable materials. Consequently, this will affect the product handling system within the crushing plant environment.

## 4.0 SHORT- TERM SOLUTION

A VSI of 60T/H have been selected with other supporting items as listed in Table 4 and shown in Figure 4 to form a complete sand making plant that would be amalgamated with the main crushing plant in the nearest future as illustrated in Figure 5. The arrangement is to have the sand making machine setup very close to the main crushing plant for easier amalgamation in future. The sand making plant has a hopper to collect loads of

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unsaleable products transferred with the aid of trucks or wheel loader (used as LHD). The materials are supplied to VSI by combining the functions of vibrating feeder and conveyor belt system. Just like in the main crushing plant, all ground materials are conveyed to a vibrating screen that serves both as a scalper and classifier. The screen has two decks which implies that it would produce three (3) kinds of products (pure dust; mixed dust; and bigger sized material, which is a little less than the feed size), the bigger sized materials are recycled for further size reduction until they exit the VSI as either pure or mixed dust. All the transfer of materials is via conveyor belt system.

**Table 4: Support items in Shanghai Zenith Sand Making Plant of F & P Quarry**

| S/N | Description of Items | Model | Quantity |
|---|---|---|---|
| i | Hopper | $20m^3$ | 1 |
| ii. | Small Feeder | GZG- 100 | 1 |
| iii | VSI | B- 9526 | 1 |
| iv | Vibrating Screens (Primary Screens) | 2YK 2460 | 1 |
| $b_{(i-iv)}$ | Belt Conveyor | Varying sizes | 4 |

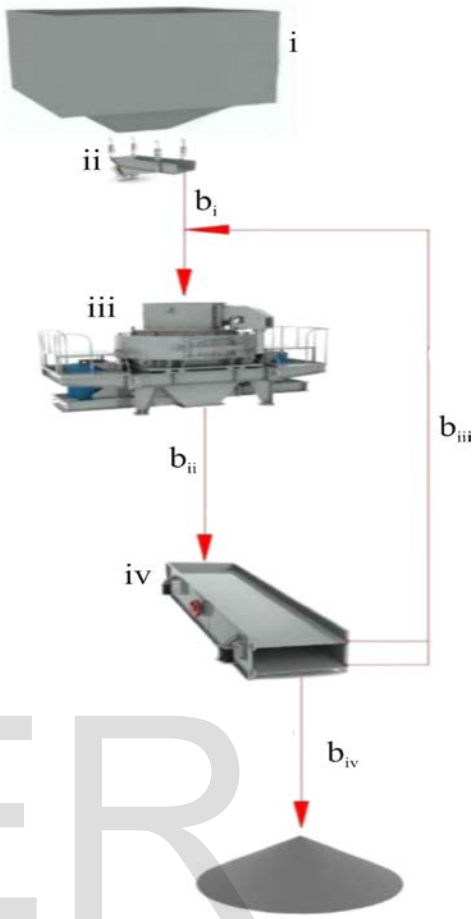



**Figure 4: Flow line of Sand Making Plant** [6]

### 4.1 Long Term Solution

The acquisition of VSI will certainly deplete the stockpiles of unsaleable materials after conversion. Certainly sometimes in future, it would no longer make good business sense to incur additional cost to retreat already finished product, rather it will enhance the business model to have designated products come out simultaneously. Figure 5 presents a proposed flow line of future amalgamation of the VSI with the main crushing plant by redirecting the conveyor belt supplying materials to the secondary vibrating screen (classifier) to the screen in the sand making plant. The secondary vibrating screen in the main crushing plant and the hopper with the feeder of sand making plant can then be dismantled and kept as spares to the whole new arrangement (Figure 6). Moreover, this final amalgamation will certainly increase the production capacity of the

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plant above the initial designed capacity of 250 T/H, if optimally fed.

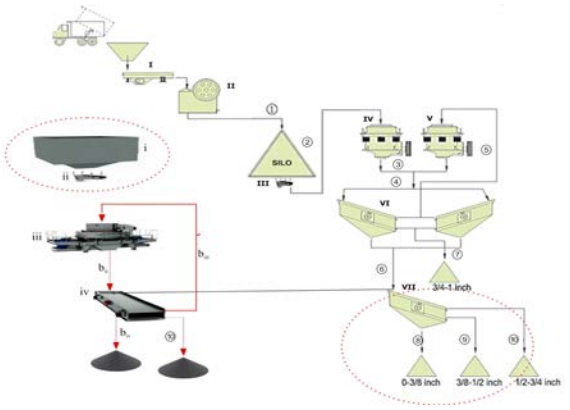



**Figure 5: Flow Line for Future Amalgamation of Sand Making Machine with the Main Crushing Plant (Model I).**

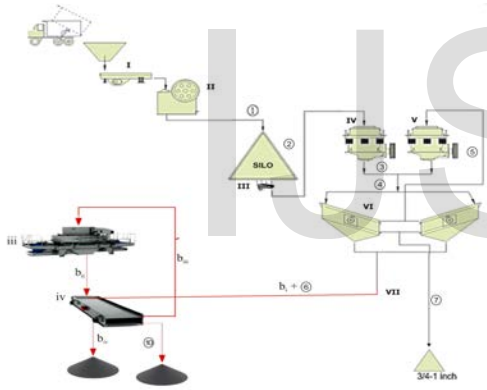



**Figure 6: Flow Line for Future Amalgamation of Sand Making Machine with the Main Crushing Plant (Model II).**

## 5.0 CONCLUSION AND RECOMMENDATIONS

The situation in F & P quarry affirms the significance of appropriate evaluation of the crushing plant design integrity to the viability of a commercial aggregate quarry, especially, the product size demand analysis. Past experience and investigations into the procedures for selection; sourcing; and supply of crushing plants revealed that:

i. Crushing plant suppliers have ready-made flow lines for various production capacities which cannot satisfy all business scenarios;

ii. The basic material characteristics for the crushing plant design are feed and product sizes; and plant average production capacity without adequate consideration of the product demand gap analysis; and

iii. There is regional difference in aggregate market demands; dust being in high demand in Abuja, and low demand in South- west region, whereas, ½" material sells more in South- west region, but low patronage in Abuja.

From the results of the investigation, the following recommendations are made:

i. Proper market evaluation regarding products demand (real size specifications)

ii. must be incorporated into the viability report of a quarry project;

iii. Crushing plant flow line should not be seen as a cap fits all;

iv. The flow line and machines that make up the plant should be based on products demand and supply gap analysis for quick payback;

v. The flow line proposed for future amalgamation can be adopted as the best aggregate production crushing plant line for Abuja and any other locality with similar market variables; and

vi. The flow line as represented in Figure 6 can be adopted for 300 T/H capacity aggregate quarry's crushing line.

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