PRODUCTION AND USES OF CRUSHED ROCK AGGREGATES: AN OVERVIEW

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Abstract

Crushed- rock aggregates are materials that form concrete, mortar or asphalt when mixed with appropriate portions of water and a binding agent like bitumen or cement. Crushed – rock aggregates are produced in quarries. In areas where natural sand and gravel aggregate deposits are insufficient to handle local demand, larger quarry rocks are processed in an impact crusher to create crushed-rock aggregate. In the quarry, the rocks are extracted and then transported to the rock crusher, which begins the process of crushing the larger quarried larger rock into more manageable pieces. As the rock pieces leave the rock crusher, they are sent on to a rock conveyor for transport to the impact crusher, where they will be broken down further. After being processed in the impact crusher, the aggregate is screened for sizing. The process might be handled in a screen shaker or during the washing process in an aggregate washer. They are used by construction companies to construct roads, bridges, dams and also environmentally to reduce the effect of flooding, improve agriculture and in making paper. Therefore, the use of aggregates cannot be overemphasized, it is very important in maintaining stability and increase in infrastructural facilities to improve life.

Keywords: Crushed-rock aggregate; quarry; strength and durability; production.

1.0 Introduction

Crushed – rock aggregates are materials that form concrete, mortar or asphalt when mixed with appropriate portions of water and a binding agent like bitumen and cement. Crushed – rock aggregates are the granular filler material such as sand, stone dust, gravel, crushed stone, crushed blast-furnace slag, etc. that are used with binder such as Portland cement to produce concrete or mortar. Aggregates may be natural such as gravels and sands and may also be product from crushed rocks as in quarries.

The absence of natural aggregate at cost effective transportation distances has prompted extensive use of manufactured aggregates. The US aggregate industry produces 1.1 billion tons of crushed stone per year with carbonates and granites accounting for 71% and 16% respectively (USGS, 2000). The extensive use of manufactured aggregates has required proper modification of characterization, design and construction practices. In addition, it has motivated studies to reduce energy consumption to attain optimal crusher design and operation and to minimize waste.

The use of crushed-rock aggregates for engineering construction depends on the strength and durability characteristics of the aggregates (Okeke, 2005). Aggregates range in size from large boulders (rip-rap) used as fill in large construction projects to finely-ground flour-sized particles used in paint, glass, plastic, medicine, agricultural feed and soil conditioners, and many other industrial and household products.

The construction aggregate sector is an important part of most modern developed economies, for example in the UK, aggregates account for approximately 85% of the non-energy minerals extracted. They are essential for constructing and maintaining what is literally the physical framework of the buildings and infrastructure on which our society depends (British Geological survey (BGS), 2013).

Aggregate manufacturing typically starts by blasting rock masses and is followed by a series of crushing stages.

Aggregates are materials either natural or manufactured, that are either crushed and combined with a binding agent to form bituminous or cement concrete, or treated alone to form products such as railroad ballast, filter beds or fluxed material (Langer, 1988).

Any naturally occurring geological material can be used as construction aggregate as long as it satisfies the requirements of the end-use specification. Crushed rock aggregate is produced from hard, strong rock formations including igneous (andesite, basalt, diorite, gabbro, granite, rhyolite, tuff), metamorphic (hornfels, gneiss, quartzite, schist) and sedimentary (sandstone, limestone) rock (BGS, 2013).

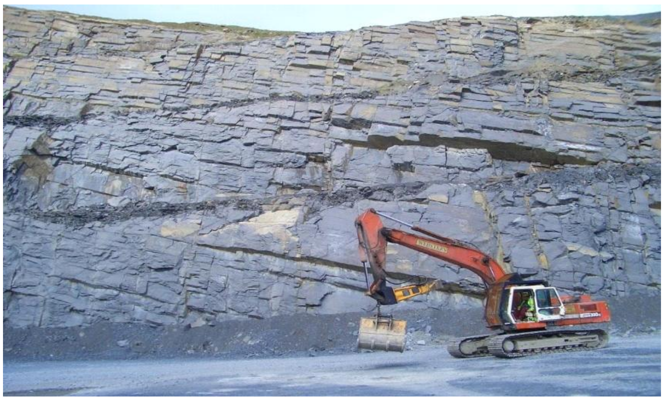

Figure 1. Sandstone quarry, Yorkshire, UK (Mitchell, 2018)

Most limestones and dolomites are hard and durable and useful for aggregate. The quality of the limestone resources and their ease and economy of working may be affected by a number of geological factors such as waste content, dolomitization and degree of faulting and folding. The suitability of sandstone for aggregate use depends on its strength, porosity and durability (Fig. 1).

Many types of sandstone are too porous and weak to be used other than as sources of constructional fill. In general, older more indurated sandstone exhibit higher strengths and are suitable for more demanding aggregate uses. Igneous rocks tend to produce strong aggregates with a degree of skid resistance and are hence suitable for many road surfacing applications, as well as for use in the lower parts of the road pavement. The high strength and attrition resistance of certain igneous rocks results in their use as railway ballast (BGS, 2013).

Most natural aggregates are derived from crushed stone and sand and gravel recovered from widespread naturally occurring mineral deposits (rocks). The three broad geological classifications of these deposits are;

i. Igneous rocks: These rocks are primarily crystalline and are formed by the cooking of molten rock material beneath the earth's crust (magma).

ii. Sedimentary rocks: These rocks are formed from deposited insoluble material (e.g. the remains of existing rock deposited on the bottom of an ocean or lake). This material is transformed to rock by heat and pressure. Sedimentary rocks are layered in appearance and are further classified based on their predominant mineral as calcareous (limestone, chalk, etc.), siliceous (chert, sandstone etc.) or argillaceous (shale etc.).

iii. Metamorphic rocks: These are Igneous or sedimentary rocks that have been subjected to heat and/or pressure great enough to change their mineral structure so as to be different from the original rock.

Manufactured rock typically consists of industrial by-products such as slag (by-product of the metallurgical processing typically produced from processing steel, tin and copper) or specifically rock that is produced to have a particular physical characteristic not found in natural rock (such as the low density of lightweight aggregates).

Other aggregates come from either Natural (pit and quarry) or contrived (recycle) sources.

Sand and Gravel mine (pit): Aggregates that come from unconsolidated sand and gravel deposits; typically deposited by streams (alluvium) or glaciers.

Quarry: Aggregates that come from bedrock deposits. Bedrock, which is consolidated rock includes; basalt, quartzite, Gabbro etc.

Recycle: Products that include crushed concrete, bituminous or demolition debris and in some instances taconite tailings.

Anosike (2011); Duggal (2008); Ezeokwonkwo (2013) classified aggregate based on the source (Natural and artificial aggregates); According to mineralogical composition (aggregate may be classified as siliceous or calcareous); According to mode of preparation (in this situation distinction is made between aggregates reduced to its present size by natural agents and crushed aggregates obtained by a deliberate fragmentation of rock); According to size (divided again into coarse and fine aggregates). CORBON and NIOB, (2014) classified aggregate only in terms of size.

Finally, UNESCONT & VERP (2008) classified aggregate based on origin with other subdivisions.

i. **Class A:** crushed igneous bedrock (specifically; basalt, Gabbro, granite, Rhyolite, diorite and andesite) and rock from the Sioux Quartzite formation.

ii. **Class B:** Crushed rock from all other bedrock sources as carbonate and metamorphic rocks (gneiss or schist).

iii. **Class C:** Consists of natural or partly crushed natural gravel obtained from a natural gravel deposit.

iv. **Class D:** 100 percent crushed natural gravel.

v. **Class E:** Consists of a mixture of any two or more of the following: class A, class B, and/or class D.

vi. **Class R:** Consists of aggregates obtained from recycling concrete, which shall be crushed to the specified gradation.

2.0 Quality and uses of aggregates

2.1 Overview

The properties of crushed rock result from the origin and mineralogy of the source rock and its subsequent alteration and weathering. Some important properties of a rock are the type, size, shape, orientation, and proportions of mineral grains; the type of contacts between the mineral grains; the layering of minerals; and the presence and interconnectedness of voids (Dolar-

Mantuani, 1983). In the various ways in which aggregate is used it is exposed to a variety of stresses, and the response of the structure in which it is used will largely depend upon the properties of the aggregate. It needs to resist heavy loads, high impacts and severe abrasion, and it needs to be durable in the prevailing environmental conditions.

In general, aggregates should be hard and tough enough to resist crushing, degradation and disintegration from any associated activities. About 52% of all construction aggregate is crushed stone, while 48% of the remaining is sand and gravel (AASHTO, 2001). A mineral aggregate is used to denote a rock product as aggregate. Coarse aggregates used in concrete as crushed rocks or natural rock fragments such as gravel or pebbles that passes 60mm sieve but is retained by 5mm sieve. Aggregates (fine coarse crushed and artificial) are parts of construction materials include; other construction materials, dimension stones, roofing stones, embankment materials etc. the purposes of this study are to explore the production and uses of crushed rock aggregates.

Crushed-rock aggregate is the sized or crushed and sized rock material used in rigid and flexible highway pavements. They are also materials that form concrete, mortar or asphalt when mixed with appropriate portions of water and a binding agent like bitumen (Clutterbuck et al., 1982).

2.2 Who uses crushed-rock aggregates?

- Asphalt pavement and concrete industry
- Ready-mixed concrete industry
- Precast concrete products industry
- Building contractors
- Homeowners
- State and local government
- Agriculture

A wide variety of product from mining and crushing of rocks form primary raw materials in many industrial applications (Ellen, 2010). Aggregates have an amazing variety of uses. Imagine our lives without roads, bridges, streets, bricks, concrete, wallboard and roofing tiles or without paint, glass, plastics and medicine. Every small town or big city and every road connecting them were built and are maintained with aggregates. More than 90 percent of asphalt pavements and 80 percent of concrete are aggregates. Paint, papers, plastics and glass also require sand, gravel or crushed stone as a constituent.

When ground into powder, limestone is used as an important mineral supplement in agriculture, medicine and household products. Aggregates are also used more and more to protect our environment.

Soil erosion-control programs, water purification and reduction of sulphur dioxide emissions generated by electric power plants are just a few examples of such uses.

Due to the relatively high hydraulic conductivity value as compared to most soils, aggregates are widely used in drainage applications such as foundation and French drains, septic drain fields, retaining wall drains and rode side edge drains.

Crushed-rock aggregates are also used as base material under foundations, roads and railroads.

2.3 Uses of aggregate in construction projects

- Road construction
- Driveways
- Drainage and septic systems
- Concrete
- Pathways and parks
- Landscaping

Terrazzo floors are usually made by mixing one part of Portland cement and two parts of crushed rocks by volume. The hardened concrete or terrazzo is then grounded by polishing wheels. The aggregates usually vary from 3 – 12mm in size. The colour is of particular importance as terrazzo is used for decoration. Various types of rocks that may be used for terrazzo includes marble, dolomites and mixture of both called dolomite marble.

Highway or runway aggregates used in a highway/runway pavement are subject to abrasion caused by horizontal forces including wheels of an automobile or airplanes. Aggregates used as road stones must as well as having strength, have high resistance to impact and abrasion, polishing and skidding. It must be impermeable, chemically inert and possess a low coefficient of expansion. The principal tests used to assess the quality of highway pavement (road stones) are:

- The aggregate crushing tests
- The aggregate impact tests
- The aggregate abrasion
- The aggregate polish stone test
- The aggregate water absorption, specific gravity and density test.

The best rocks to be used as highway pavement materials are andesite, diorite. They may also be called road stones because their abrasion resistance is low.

Railway aggregates are materials that support the track under the railway track that transfer the train’s load to the subgrade. Generally, ballast is composed of crushed mild stone, crushed ballast furnace or uncrushed gravel and sandstone.

2.4 Environmental uses of crushed-rock aggregates

Crushed–rock aggregates are used in numerous environmental applications that protect and improve our environment:

- Fluid bed smoke stack scrubbers use limestone to neutralize acid emissions prior to release into the atmosphere

- Quarried limestone (agricultural lime) is used to improve agricultural soil condition and produce organic fertilizers
- Quarried rock in the form of rip-rap and gabion baskets is used to protect shorelines from erosion and filter storm water basins.

2.5 Crushed-rock aggregate trend and issues

- Demand for aggregates is likely to continue
- Zoning and land use: protecting aggregate resources from conflicting land use and zoning changes is important for maintaining future supply.
- Quality specification: as higher quality aggregates are required, fewer aggregate deposits quality.
- Population growth: this will increase competition for land use and increase aggregate demand.

3.0 Production of crushed- rock aggregates

List of some companies that produce crushed- rock in Nigeria

S/N	Name of company	Parent rock or rock type from which the aggregates are produced	Location
1	Setraco Nigeria Ltd.	Granite	Abuja
2	Crushed Rock Industries (Nigeria) Ltd.	Granite	Ishiagu (Ebonyi State), Abuja and Portharcourt
3	Tafotech Company Limited	Granite	Ibadan
4	Crushed Rock Nigeria Ltd.	Granite	Akamkpa (Cross River State)

3.1 Extraction

With the exception of slag and other manufactured aggregates, most materials for aggregate production come from bedrock or unconsolidated deposits. Some of the methods involved in the production of aggregates are mining and quarrying.

Surface mining with either strip mining or open pit; here draglines and large stripping shovels is employed to remove overburdens and expose a relatively horizontal or vertical overcrop. Sometimes it is only a few tens of meters and also the use of hand trucks, excavators and high capacity conveyors to mine the aggregates.

In addition to surface mining, underground mining can take place in coal mine operation as well as aggregate mining; which are room and pillar and long wall mining.

The long wall mining involves the use of mechanized shearers to cut and remove the coal or aggregate as the case may be at the face, which can vary in length from 100-250meters.

Self-advancing, hydraulic powered supports temporarily hold up the roof while the coal is extracted. The roof over the area behind the face, from which the coal has been removed, is then allowed to collapse.

3.1.1 Quarrying:

Quarrying could be done in diverse methods such as hard rock mining, using rock drills explosion of dynamite and other sophisticated methods. The process could also be open pit or surface methods, underground and solution mining. The mining method used depends on the particular mineral, the nature of the deposit and the location of the deposit. Each mining method has its own impact on the environment (Ukpong, 2012).

The major extraction processes of aggregates are the quarrying methods. Quarrying is an act of exploring and exploiting stone from rock. It is a form of surface mining used when the rock is close to the surface of the land. Quarry is a type of open pit mine from which rocks or minerals are extracted. Quarries are generally used for extracting building materials such as dimension stone, construction aggregate, riprap, sand and gravel. They are often collocated with concrete and asphalt plants due to the requirement for large amounts of aggregate in those materials. Open mines that produce minerals are typically referred to as open pit mines.

Types of rock extracted from quarries include; chalk, china clay, cinder clay, coal, construction aggregate (sand and gravel), coquina, Diabase, Gabbro, Granite, Gritstone, Gypsium, Limestone, Marble, ores, phosphate rock, sandstone, slate etc.

3.1.2 Quarrying process

1. **Face profiling survey:** This is a detailed three-dimensional survey of quarry face. It allows the explosives engineers to design the blast and to plot where the shot holes should be drilled so that the blast can be carried out safely and efficiently.
2. **Drilling:** This is the drilling of the number of shot holes required, at the marked spots corresponding to the hole positions on the blast design, at the angles and depths required. This is done by the drilling contractor, using an air operated drilling rig.
3. **Shot holes survey:** This is to check that the drilled shot holes correspond to the blast design and the two surveys are combined to allow the blast engineer to work out how each shot hole is filled with explosives.
4. **Explosion:** The detonator card is placed in each hole. The holes are then loaded with high explosives to within a few meters of the top. The remaining depth is “streamed” with quarry dust or fine aggregate. The detonators are connected to the electric trigger wire and the circuit is checked. After the site is cleared, sirens are sounded and a final safety check is carried out before the fire is set off the explosive.
5. **Inspection of muck-heap:** This is to check that all the shot holes are fired correctly. The face shovel or loader then tidies up the shot pile and starts to load the dumper trucks that take the rock to the crusher. Boulders which are too big to go through the crusher are set aside for secondary breaking which is typically done using hydraulic digger fitted with a rock hammer, though crawler cranes with steel drop balls may be used in some quarries.

3.1.3 Crushing

The first stage in most operations is the reduction and sizing by crushing. Crushing is used to remove soft and friable particles from coarse aggregates. This process is sometimes the only means of making materials suitable for use. Unfortunately, with any process some acceptable material is always lost, and removal of all harmful particles may be difficult or expensive. Intensive particle-to-particle interaction takes place during crushing operations, particularly when crushers are choke-fed (Guimaraes et al., 2007).

Crushing can be done in three or four stages: Primary (First stage), Secondary (Second stage), Tertiary (third stage) and in some quarries, a quaternary (fourth stage). Crushed rock, or product, is transported along the process line on conveyor belts or down chutes.

The primary crusher is fed via a chute and vibrating feeder. The base of the feeder is made of steel "grizzly" bars and it is here that the first screening operation is actually done. Fine material and dust produced by the blast, along with any remaining subsoil or weathered rock from the top of the quarry face, drops through the bars onto a separate conveyor belt and onto a stockpile. This screened material is called scalping and is used as rock fill. The scalped product is crushed once to transform the block into broken stone. The process is repeated as many times as necessary to obtain the desired fragment size.

The output from the primary crusher is conveyed onto the primary stockpile from which the secondary crusher is fed. The resulting material is then screened by a screen house just after the secondary crusher to obtain aggregates of the desired grade. The larger pieces that are rejected are returned to the crusher and subsequently re-screened, with the process continued until the desired size is obtained.

Historically, cone and roll crushers were the most common choice crushers, but in recent years impact crushers that tend to produce a more particle shape, are more widely used.

Secondary, Tertiary and quaternary crushers are generally gyratory, or cone crushers. These operate on the principle of a steel mounted on an eccentric bearing and vertical shaft assembly. Rotation of the eccentric assembly makes the mantle gyrate within a static outer concave. There is a gap between the mantle and the concave. The shape of the gap is tapered towards the base. As the mantle gyrates inside the concave, the gap between it and the concave at any one point opens and closes on each gyration, this produces the required crushing action. Stone is fed in at the top and crushed product falls out from the bottom of the cone. The mantle can be raised or lowered within the concave, allowing the gap, and therefore the size of the crushed product, to be varied to a limited degree. If the crusher is jammed by a stray bit of steel e.g., a digger bucket tooth, the mantle automatically moves down to clear the obstruction.

Each stage of crushing produces progressively smaller sized stones. In order to produce a usable end-product, the crushed rock has to be screened into various size categories. Some categories of aggregates, such as sand and gravel, undergo complementary processing including washing, cycloning and scrubbing, primarily to make them cleaner. Screening is carried out at various stages in the crushing process. Screens which are made to vibrate by a rotating transverse shaft are usually multi-deck i.e. two or more screen meshes are stacked vertically within the screen frame. The whole screen is coupled to its support frame by springs or resilient rubber mountings. Screen decks are mounted at an angle so that the aggregate moves them down. Aggregate is fed onto the high end of the top deck and the vibration causes the aggregate to jiggle down the screen until it either drops through a mesh aperture or falls off the end of a deck. The aggregate is then sorted or "screened" according to the mesh sizes fitted, from large aperture mesh at the top, to small aperture mesh at the bottom.

Final screens are typically mounted in a screen house over large bins or hoppers into which the different sizes or grades of aggregate are fed. The hoppers are roused on legs so that trucks can drive under them to be loaded. Material is continually drawn from the storage bins for immediate use (e.g. in a coating plant) or for transfer, either by dump truck or conveyor, to storage stockpiles in the quarry to different grading category.

Screen mesh sizes are chosen with regard to the nature of aggregate being crushed (e.g. shape – cubical, flaky, elongate, or any combination), and the characteristics of the screen (e.g. screen efficiency, throughput, and whether screen is over, under or correctly loaded).

3.1.4 Quarry products

A stone quarry typically produces the following products:

- Large size blocks blasted from the quarry face, from approximately $0.5m^3$ (approximately 0.36 tonne weight) to 1.25 m^3 (approximately 5-6 tonne weight) are called rip rap or rock armour and are used in coastal and river flood defense schemes to shore up sea fronts and river banks.
- Rubble drawn direct from the shot pile is called face fill and is used as large scale fill on construction sites.
- Material screened immediately prior to primary crushing is called scalping or grizzly which is again used as fill on construction sites.
- The direct unscreened output from a crusher contains a complete mix of sizes from dust up to the maximum size that the crusher can pass. Output from the primary and secondary crushers is fed, unscreened, to intermediate or separate stockpiles. Material drawn from these stockpiles is called crusher run and is used for construction fill.
- Screened out fine material from the secondary crusher is called blinding. Some screens have multiple decks and can screen out several grades of blinding. As with crusher run, blinding materials contain a mix of sizes, from the maximum size that the screen mesh can pass down to dust. Blinding, because it is finer than crusher run, is used for final shaping up of construction sub bases, particularly in road construction, where the sub base is the last unbound layer before coasted materials are laid.
- Screened aggregate (ballast) for concrete.
- Screened aggregate is heated and mixed with bitumen, according to certain recipe proportions to make different grades of bituminous mecadams or mixed with sand, ground limestone filler and bitumen to make hot rolled asphalt colloquially called bitmac or tarmac. The words tar or tarmac, though very frequently used, is incorrect as tar is no longer available. For coated materials, bitumen, derived from the distillation of

petroleum crudes has been in almost universal use as a binder for the last four to five decades.

- 32/50 is used for railway ballast and as filter media in water treatment plants (if the rock type is tough enough).
- Most category GC aggregates can be used as a trench fill drainage stone, as the void space between aggregate particles allows water to flow through.
- It the rock quarried is resistant to the polishing action of vehicle tyres, aggregate of size 14/20 GC 85/20, when coated with $1^1/_2$% bitumen, is called pre-coated chippings or pre-coats. Such chippings go on the surface of the hot rolled asphalt which surfaces many roads in the British Isles. The chippings are distributed in a single layer direct onto the laid asphalt and rolled into it while it is still hot. The chippings help give the asphalt a rough surface texture which together with the stone's resistance to polishing, provides grip to the surface which allows vehicles to brake and stop safely.
- Every summer, large quantities of 2.8/6, 6.3/10 and 8/14 category GC aggregates are used to surface dress many roads in Minnesota, United States. Surface dressing is a cost-effective remedial process which seals, restores grip and prolongs the life of the road treated. Surface dressing is carried out by a large squad of men in a military-like operation. The road is first swept by a suction sweeper. The bitumen sprayer then sprays half the road width with a bitumen emulsion or a cutback (fluxed) binder. The sprayer is then followed by one or more gritters, which lay down a layer of chippings ahead of themselves onto sprayed binder. Gritters have a rear hopper which receives aggregate from the delivery lorries. Aggregate tripped into the gritter is transferred by conveyor to the front driving end and distributed across the width of the gritter by auger screws and a fluted distribution drum. Finally, rubber tyre rollers follow up, rolling the chippings firmly into the binder.

Surface dressing is universally by motorists due to the risk of broken windscreens or chipped paint from loose chippings. This usually happens when vehicles are driven too fast on freshly dressed roads. As with all road construction sites, drivers and their vehicles will be safe from accidents if all the traffic signs posted are obeyed. The treated road will be finally suction swept after the chippings have firmly bedded into the binder. Bedding-in usually takes a day or two.

This is used for stone or rock to make buildings. The quarry is an open pit mine and it's less deep than other mines. The way that quarrying is done depends on the rock that the miners are trying to get out of the ground and what the rock will be used for after it's mined. For example, if they want to get an ingredient of cement, they will use explosives to break the rock into small bits. This is alright because cement needs to be in small pieces when it is sold. If they want larger pieces of granite for kitchen countertops, the miners will drill holes in the rock, long distances apart. Dynamite will be packed into these and the blast will separate large slabs of granite that will be sliced with wire saws. There are other ways to quarry such as drilling holes, blasting dynamite to make an opening and then blowing in compressed air (or water) that splits the rock. One of the biggest problems for quarries is drainage. Many quarries are dug in hillsides so that water can drain better. Water flows into the quarry from the ground.

The quarry needs to be pumped out to get rid of it. This adds to the costs of quarrying the rock. When the mining is over, the area can become a landfill that is filled with refuse and garbage until it fills the pit and is covered over with layers of drift. This is called reclamation. In our area, most quarries are abandoned and left as a giant pit. Then they refill with water and become a small pond or lake. This may sound nice but most of our quarries are considered to be unsafe, unstable and a safety problem.

3.1.5 Types of machinery used in quarries:

- Pneumatically operated channelers
- Gadding machines
- Wire saws
- Dump trucks
- Surface mining vehicles

3.2 Production of crushed- rock aggregates

Crushed rock aggregate is produced from quarries that are much larger and deeper than sand and gravel pits. Crushed rock aggregate is normally extracted using blasting. The excavated material is delivered it to a production plant in a form suitable for processing (Mitchell,2001).

Fig. 2: Gyratory crusher, Leicestershire, UK (Mitchell, 2018)

Production of crushed rock aggregate involves screening (Scalping) to remove fines and wastes material followed by crushing and screening to produce material with specified site grades. Crushing is carried out to reduce the size of the excavated material from large blocks (up to a metre across) to a size finer than 20 to 50mm (Fig. 2).

The stone and aggregate industry creates crushed aggregate using a lengthy process. The stone must be mined in a quarry and then transported to the rock crusher which begins the process of crushing the larger stones into more manageable pieces. As the stones leave the rock crusher, they are sent to a rock conveyor for transport to the impact crusher, where they will be broken down further. After being processed in the impact crusher, the aggregate is screen for sizing. This process might be handled in a screen shaker or during the washing process in an aggregate washer. If the aggregate is sufficiently crushed, it is transported to the storage area. If the stone is not crushed to the desired size and type, the process is repeated or the stone is transported to other equipment for further processing. So much machinery, time and labour are involved in the creation of crushed aggregate that it can become a very expensive product. Despite the cost, aggregate products are the main component of concrete construction. In the majority of cases, crushed aggregate is used locally to prevent further costs being incurred in transporting the material.

3.2.1 Procedure for producing crushed rock aggregates

Aggregates are indispensable raw materials used in the manufacturing of concrete and building materials. The processes involved in the production of crushed rock aggregate include;

i. Drilling
ii. Blasting
iii. Loading
iv. Transporting
v. Crushing
vi. Screening
vii. Product handling and storage

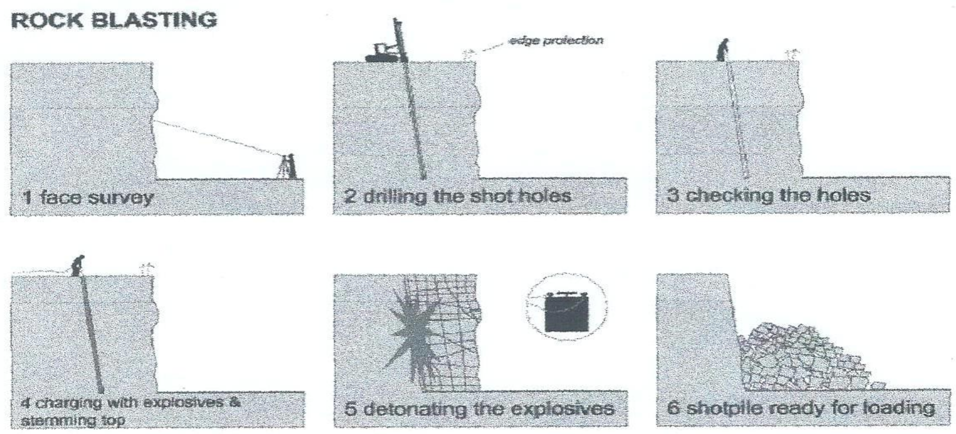

Fig.3: Rock blasting (Northstone, 2018)

Outlined below is detailed procedure:

Step 1: Extraction

The extraction of alluvial materials can be carried out with the help of a loader or excavator, if the area is dry, if the area contains water, a dredge connected to floating conveyors. From a bench or massive rocks, extraction requires the use of explosives. Blasting breaks down the materials which are then brought to a handling facility.

Step 2: Transfer

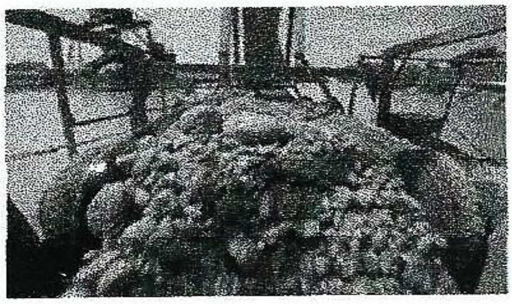

Fig. 4: Transport of aggregates on a conveyor belt

Transferring aggregates to handling facilities is generally carried out by means of belt conveyors. This reduces the cost of transportation.

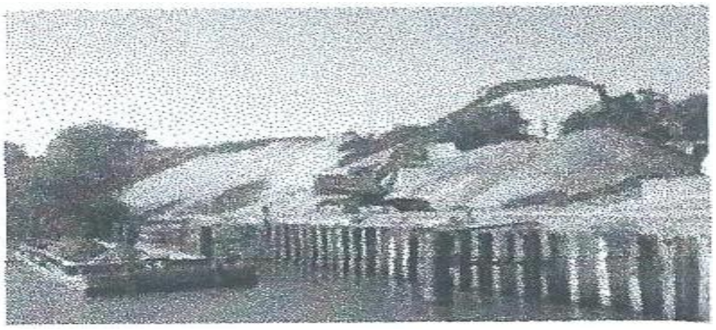

Fig. 5: Unloading a barge

When belt conveyors are not feasible, the transfers are carried out by haul trucks or barges if waterway is available.

Step 3: Handling

Fig. 6: Aggregates

Aggregates are reduced in size by crushing. Then they are sorted using wire mesh screens. Afterwards the aggregates are often washed, as some uses require the material to be perfectly clean.

Step 4: Storage

The materials are stored in piles, in bins or silos where they are sorted according to different categories. There are sands, gravel and rocks of various sizes. Each category of aggregate meets specific criteria based on its intended uses.

Step 5: loading and weighing
All materials that leave the quarry are weighed with truck scales

Step 6: Transport

Fig.7: Barge loading with overhead conveyor

Delivery is performed by trucks, barges and trains. If concrete or asphalt is produced at the quarry site, the materials can be processed on place.

Physical properties:
The commonly measured physical aggregate properties include;
- Gradation and size
- Toughness and abrasion resistance
- Durability and soundness
- Particle shape and surface texture
- Specific gravity

These are not the only physical properties of aggregates but rather the most commonly measured. Tests used to quantify these properties are largely empirical. The physical properties of an aggregate can change over time. For instance, a newly crushed aggregate may contain more dust and thus be less receptive to binding with an asphalt binder than one that has been crushed and stored in a stockpile for a year.

4.0 Problems associated with production of crushed- rock aggregates

Several wastes are generated when rocks are extracted from the earth. Environmental disturbance as a result of mining and processing activities constitute a major threat to public health and environment (Adepoju, 2008).

Severity of the environmental problem depends on the characteristics of the mineral being extracted, the methods of mining, waste materials generated and the site characteristic. The effect is manifested in air, land, plants and water associated with mining process (Ukpong, 2012).

Quarries in level areas with shallow groundwater or which are located close to surface water often have engineering problems with drainage. Generally, the water is removed by pumping while the quarry is operational but for high inflows more complex approaches may be required. For example, the Coquina quarry is excavated to more than 60 feet (18mm) below sea level. To reduce surface leakage, a moat lined with clay was constructed around the entire quarry. Ground water entering the pit is pumped up into the moat. As a quarry becomes deeper water inflows generally increase and it also becomes more expensive to lift the water higher during removal, this can become the limiting factor in quarry depth. Some water-filled quarries are worked from beneath the water by dredging.

Many people and municipalities consider quarries to be eyesores and require various abatement methods to address problems with noise, dust and appearance. One of the more effective and famous examples of successful quarry restoration is Butchart Gardens in Victoria, BC, Canada.

A further problem is the pollution of the road from trucks when they are leaving the quarries. To control and eliminate the pollution of public roads wheel washing systems are becoming more common.

Like many other man-made activities (anthropogenic factors), quarrying activities cause significant impact on the environment. Some of the issues of concern are: visual intrusion, damage to landscapes, traffic, smoke, noise, dust, damage to caves, loss of land and deterioration in water quality. In particular, it is often necessary to blast rocks with explosives in order to extract material for processing but this method of extraction gives rise to noise pollution, damage to biodiversity and habitat destruction.

Dust from quarry sites is a major source of air pollution, although the severity will depend on factors like the local microclimate conditions, the concentration of dust particles in the ambient air, the size of the dust particles and their chemistry, for example limestone quarries produce highly alkaline (and reactive) dusts, whereas coal mines produce acidic duct. The air pollution is hot only a mixture (in terms of deposition on surfaces) and possible effects on health, in particular for those with respiratory problems but dust can also have physical effects on the surrounding plants, such as blocking and damaging their internal structures and abrasion of leaves and cuticles, as well as chemical effects which may affect long-term survival. Unfortunately, quarrying involves several activities that generate significant amounts of noise. The excavation of the mineral itself involves considerable noise, particularly if blasting methods are used. Following this, the use of powered machinery to transport the material as well as possibly processing plants to crush and grade the minerals, all contribute even more noise to the environment. Such extraction of raw materials from their natural habitats by mining, drilling, harvesting and those that relate to large scale water resources development projects, construction, agriculture, energy, industry and development projects, considerably affect the natural environment.

While quarries can cause significant impact to the environment, with the right planning and management, many of the negative effects can be minimized or controlled and, in many cases, there is great opportunity to protect and enhance the environment, such as with the translocation of existing habitats or the creation of new ones. Therefore, to achieve the equilibrium between natural ecosystems, protect planning, formulation and implementation is needed. In this study, we assess the environmental impact of unexploited site meant for quarry activity.

5.0 Conclusion

This work has discussed the total process of aggregate production from extraction through processing. Also discussed is the handling, stockpiling and shipping of the product up to the point where the material leaves the producer's control. Processing influences mineral quality and integrity, aggregate physical properties and in particular, gradation (size control).

Crushed-rock aggregates are in everyday use in Nigeria for various constructional works including building stones, embarkment materials for highways, dams and concrete. It has been estimated that almost every state has about twelve quarries or more and there is no production statistics for crushed-rock aggregates, sand in Nigeria.

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