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Production and Uses of Crushed Rock Aggregate from Intrusive Igneous Rocks: A Review

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ABSTRACT
Aggregate is a broad category of coarse to medium grained particulate material used in construction, including sand, gravel, crushed stone, slag, recycled concrete and geosynthetic aggregates. Aggregates are the most mined materials in the world. Commonly used aggregates include sand, crushed or broken stone, gravel (pebbles), broken blast-furnace slag, boiler ashes (clinkers), burned shale, and burned clay. Crushed aggregate in its own class, refers to a crushed stone product in quarries. In areas where natural sand and gravel aggregate deposits are insufficient to handle local demand, larger stones are processed in an impact crusher to create crushed rock aggregate. It is distinct from gravel which is produced by natural processes of weathering and erosion, and typically has a more rounded shape. The absence of natural aggregate at cost-effective transportation distances has prompted extensive use of manufactured aggregates. Aggregates are widely used in drainage applications such as foundation and French drains, septic drain fields, retaining wall drains, and road side edge drains. Aggregates are also used as base material under foundations, roads, and rail road or as a low-cost extender that binds with more expensive cement or asphalt to form concrete. Despite the low value of its basic products, the crushed stone industry is a major contributor to and an indicator of the economic well-being of a nation. The demand for crushed stone is determined mostly by the level of construction activity, and, therefore, the demand for construction materials. The production of crushed rock aggregate involves the process of mining known as quarrying and it also has some environmental impacts such as noise pollution as a result of explosives and heavy machineries, the production of fines which pollutes the air and causes several other problems to man and his environment.
Keywords: Crushrock, aggregates, quarry, construction, environment

INTRODUCTION
Aggregate is a granular material, such as sand, gravel, crushed stone, crushed hydraulic-cement concrete, or iron blast-furnace slag, used with a hydraulic cementing medium to produce either concrete or mortar (Hardin, 1985).
Aggregate, in building and construction, material are used for mixing with cement, bitumen, lime, gypsum, or other adhesive to form concrete or mortar. The aggregate gives volume, stability, resistance to wear or erosion, and other desired physical properties to the finished product. Commonly used aggregates include sand, crushed or broken stone, gravel (pebbles), broken blast-furnace slag, boiler ashes (clinkers), burned shale, and burned clay. Fine aggregate usually consists of sand, crushed stone, or crushed slag screenings; coarse aggregate consists of gravel (pebbles), fragments of broken stone, slag, and other coarse substances. Fine aggregate is used in making thin concrete slabs or other structural members and where a smooth surface is desired; coarse aggregate is used for more massive members (Collins, et al 1997., McDowell et al, 1998).
Aggregate is one of the most frequently mined materials in the world and is used for a wide variety of construction based purposes. It is composed of granular materials such as sand, gravel, or crushed stone and it is most commonly used as an accompaniment to add strength to other composite materials

such as concrete, but it can also be found in roads and railroads. By using aggregate, foundations are reinforced and they provide a stable basis because of their reliable, highly adaptable qualities. Without aggregate, modern infrastructure would be built very differently and is a cornerstone of the construction industry. One of the earliest examples of aggregate being used is in the Roman Empire. The Romans are famed for their vast and complex road system, the foundations of which are still used across Europe today. Aggregate was refined by the Romans to reduce any impurities in the material, which is one of the first occurrences of this process throughout history. The Romans also used aggregate to build aqueducts, which was the infrastructure put in place to supply water to their cities. The aqueducts required robust and durable materials to be used in their construction. Aggregate was used to create underground conduits of stone or concrete which helped to move the water from distant locations toward the city. Roman aqueducts proved to be extremely hard-waring, with many still being used hundreds of later and even partially being used today.

Sources of Aggregates

Broadly, there are basically two sources of aggregates based on origin:

Natural Aggregates:

- ***Sand and Gravel Mine (Pit):*** These are aggregates that come from unconsolidated sand and gravel deposits. Typically deposited by streams (alluvium) or glaciers (fig 1). Gravel consists predominantly of particles larger than sand, such as boulders, cobbles, pebbles or granules. Building sands occurs in limitlessly large quantities all over Nigeria. The river beds furnish sharp sands as well as gravel. Gravel is of widespread occurrence in the country. In many cases, the gravel occurs in clay beds with an overburden of soil and laterite.
- ***Quarry:*** These are aggregates that come from bedrock deposits. Bedrock, which is consolidated rock includes: granite (fig 2), basalt, quartzite, gabbro etc. This is obtained generally from areas of the country underlain by the basement complex and in those areas where basalt or limestones occur. Crushed aggregate, also known as rock aggregate, refers to a crushed stone product produced in quarries. In areas where natural sand and gravel aggregate deposits are insufficient to handle local demand, larger stones are processed in an impact crusher to create crushed rock aggregate.

Contrived Aggregates:

- ***Recycled Aggregates:*** These are aggregate products that include crushed concrete, bituminous or demolition debris (fig 3) and in some instances taconite tailings

Fig 1: Gravel/Sand deposit (Benin Formation, Ikot Amama Akwa Ibom State)

Fig 2: Diorite quarry (Lokpaukwu)

Fig 3: Demolition Rubble

Production of Crushed Rock Aggregate

Today, if there is a vast deposit of aggregate material then quarries are used in order to extract this material. Modern blasting methods allow this to be possible in a quarry and aggregate is able to be separated out more efficiently.

The stone and aggregate industry creates crushed aggregate using a lengthy process. The stone must be mined in a quarry, this stage involves drilling to make holes and develop access to the rock. When the rock material is now exposed by the removal of the overburden material, because the rocks are massive and buried deep inside the ground it cannot be easily removed by shovels and other equipment. To break the rocks into smaller fragments that can be easily moved, explosives are used to blast the rock and this process is called blasting. Blasting the rock with explosives reduces the rock to smaller fragments that can be easily loaded with power shovels and or other equipment into the vehicle that will transport the rocks to where it will be further processed; this process is known as loading and transportation.

The rocks will then be 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 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 passes through the screening process 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.

Screening of crushed stone is necessary in order to separate the aggregate by size ranges. Most specifications covering the use of aggregate stipulate that the different sizes shall be combined to produce a blend having a given size distribution. Persons who are responsible for preparing the specifications for the use of aggregate realize that crushing and screening cannot be done with complete precision, and accordingly they allow some tolerance in the size distribution (McDowell and Bolton, 1998).

Stages/Procedure of Production

The process begins with a detailed three-dimensional survey of the quarry face. This allows the explosives engineer 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. The survey will show if there are any bulges or hollows in the face. A bulge will need more explosive than normal to ensure that it is completely fragmented and not left in place in the face. Hollow areas require less explosive than normal. The placement of explosives is professionally planned to ensure that the required fragmentation of the rock is achieved with the minimum environmental impact.

After the face profiling survey, the drilling contractor arrives. Using an air operated drilling rig, he drills 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. Fig 4 is a schematic description of the procedures. After the shot holes have been drilled, they are surveyed to check that they 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. On the day of the blast, the explosives are delivered and taken to the site of the blast. Detonator cord is placed in each hole and the holes are then loaded with high explosives to within a few metres of the top. The remaining depth is "stemmed" with quarry dust or fine aggregate. The site is cleared. Sirens are sounded to make sure that everyone nearby is warned. The detonators are connected to the electric trigger wire and the circuit is checked. A final safety check is carried out and only when the final all clear is given does the shot firer set off the explosives. A single blast can fragment up to 20,000 tonnes of rock. After the blast, the face and shot pile (sometimes called the muck-heap) are inspected to check that all the shot holes have 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 to one side for secondary breaking at a later date. Secondary breaking is typically done using a hydraulic digger fitted with a rock hammer, though crawler cranes with steel drop-balls may be used in some quarries.

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.

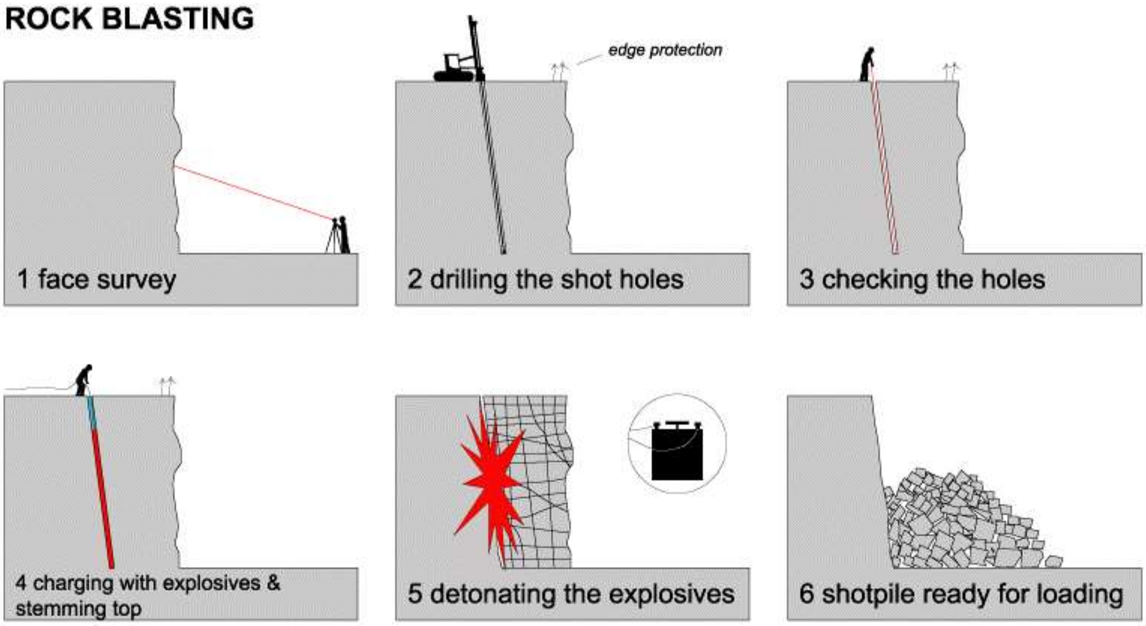
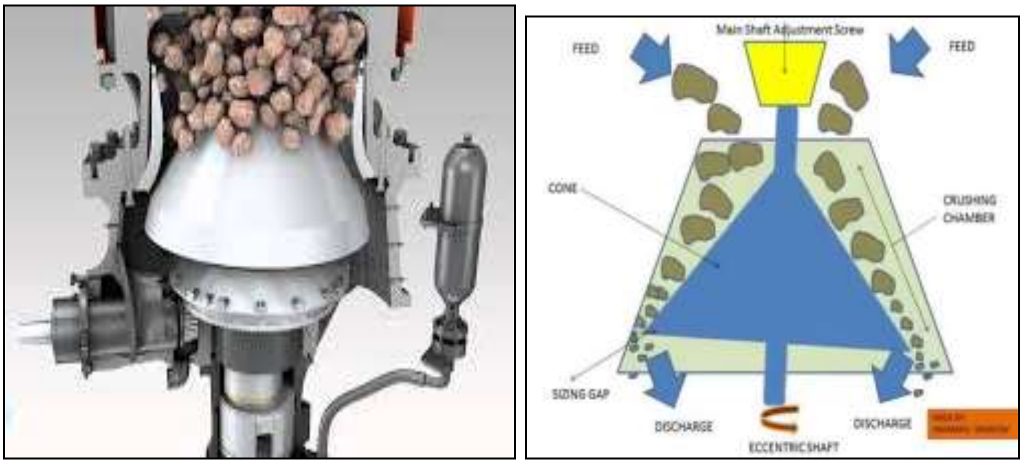


Fig 4: Schematic description of the blasting process

The primary crusher is fed via a chute and vibrating feeder (fig 5). 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 sand is used as rock fill.
Primary crushing is usually by a jaw crusher consisting of a heavy metal plate which moves backwards and forwards against a fixed plate (these are the "jaws"). The moving plate is kept in motion and given its crushing energy by a large flywheel. The crusher is wider at the top than at the bottom. Rock from the quarry face is fed into the top of the crusher and crushed rock falls out of the bottom of the jaws.



A B

Fig 5: A Cone Crusher (A) and schematic diagram of a cone crusher (B) (After Thangevelu and Adhikari, 2017)

Screening of Aggregates

Screening is carried out at various stages in the crushing process. Screens are basically box frames into which sheets of screen meshes of the required apertures are inserted, clamped and tensioned. Screens 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. Screens are made to vibrate by a rotating transverse shaft.

Fig 6: (A) Triple deck screen. (B) Woven wire screen mesh (www.vibratorscreenmesh.com)

The shaft is machined to be unbalanced, and when driven by an electric motor by v-belts, the required vibratory motion to agitate the aggregate is imparted. Screen decks are mounted at an angle so that the aggregate moves down them. 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 raised 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.

Typical screened aggregate sizes are 20/40 (formerly 40mm), 20/32 (nearest fit to former28mm), 10/20 or 14/20 (formerly 20mm), 6.3/14 or 8/14 (formerly 14mm), 4/10 or 6.3/10(formerly 10mm), 2/6.3 or 2.8/6.3 (formerly 6mm), and 0/4, 0/5 or 0/6 (depending on top size) (formerly quarry dust).

Fig 7: Screening sizes (A)14/20 screenings (B)6.3/10 screenings (ASTM, 2000)

Uses Of Crushed Rock

Our modern society needs aggregates for building roads, bridges and houses and for making concrete etc. Sand and gravel used to be the main aggregate material, but it is a finite natural resource that is running out in many areas. Crushed rock is the main substitute for sand and gravel.

Crushed stone is one of the most accessible natural resources, and is a major basic raw material used by construction, agriculture, and other industries. Despite the low value of its basic products, the crushed stone industry is a major contributor to the nation's economy. The demand for crushed stone is determined mostly by the level of construction activity, and, therefore, the demand for construction materials.

Stone resources of the world are very large. High-purity limestone and dolomite suitable for specialty uses are limited in many geographic areas. Crushed stone substitutes for road building include sand and gravel, and slag. Substitutes for crushed stone used as construction aggregates include sand and gravel, iron and steel slag, sintered or expanded clay or shale, and perlite or vermiculite.

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 road side edge drains. Aggregates are also used as base material under foundations, roads, and railroads. In other words, aggregates are used as a stable foundation or road/rail base with predictable, uniform properties (e.g. to help prevent differential settling under the road or building), or as a low-cost extender that binds with more expensive cement or asphalt to form concrete (Wood and Marek, 1996, Coop et al, 1997).

Preferred bitumenous aggregate sizes for road construction are given in EN 13043 as d/D (where the range shows the smallest and largest square mesh grating that the particles can pass). The same classification sizing is used for larger armour stone sizes in EN 13383, EN 12620 for concrete aggregate, EN 13242 for base layers of road construction and EN 13450 for railway ballast.

The American Society for Testing and Materials (2000) publishes an exhaustive listing of specifications for various construction aggregate products, which, by their individual design, are suitable for specific construction purposes. These products include specific types of coarse and fine aggregate designed for such uses as additives to asphalt and concrete mixes, as well as other construction uses. State transportation departments further refine aggregate material specifications in order to tailor aggregate use to the needs and available supply in their particular locations.


(a)


(b)


(c)

Fig 3.1: Some modern application of aggregates (a) Base for Road construction (b)foundation reinforcement (c) Bridges

Environmental Implication of Quarry Activities

Many people and municipalities consider quarries to be eyesores and require various abatement methods to address problems with noise, dust, and appearance (Tanko, 2007., Okafor, 2006). 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 (18 m) 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.

Dust from quarry sites is a major source of air pollution, 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. 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. 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.

CONCLUSION

This review has discussed production of crushed rock aggregates from igneous intrusive. The work also discussed the uses of crushed rock aggregates in many aspects and in various sectors. It also reviewed the environmental implication of crush rock activities. Crushed-rock aggregates have found use in everyday life in Nigeria for various constructional works including building stones, embarkment materials for highways, dams and concrete.

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