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Evaluation of Rocks Potentials for Aggregates Production from Sandstone Complex of Afikpo Basin, Southeastern Nigeria

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Abstract

Construction industries are faced with the challenges of transporting chippings from far distances due to the perceived unavailability of neighboring rock mass for aggregate processing. The consequence is not limited to road traffic, and accidents, even as rocks of competent aggregates could be nearby, nonetheless, unnoticed. This research explored and verified aggregate chips from simpler methods than customary direct (strength) analyses, using samples outside usual igneous and metamorphic products; particularly where sedimentary rocks were massively emplaced. The applicability was in Afikpo Basin, Nigeria, where consolidated sandstones were deposited in ridges and cuestas, mainly at Amasiri and Akpoha type localities, respectively, yet the region is developing, demanding certified aggregates for buildings/ roads constructions. Bulk samples of the sandstones from different parts of the basin were subjected to petrographic and grain size analyses. While quartz formed the modal mineralogy at 74–81% and feldspar less than 25%. The grains are poorly sorted and angular in convex/ concave contacts. These characteristics typified hard sandstone grouped, like greywacke. Thus, fragments of the rock mass can withstand stress relative to compression/ compaction associated with loads during and after building constructions. It is safe, therefore, to assert that the sandstones are useful as good chippings/ aggregates in infrastructural developments.

Keywords: *Aggregates, Construction, Sandstones, Stability, Afikpo Basin, Nigeria*

1. Introduction

Building collapse is often attributed to the nature of the construction materials used (Bamigboye et al., 2019). These materials involve rock aggregates (Shah et al., 2022) that usually make up over 90% of asphalt pavements and 80% of concrete used in buildings (Hussain, et al., 2022). In concretes, even though [Portland] cement is used as a binder (Ghrair et al, 2023), the strength depends on the grades of aggregates. The grades depend on the quality of the relevant mineralogical composition of parent rocks. It means that rocks may be everywhere around the earth, but the specified quality for engineering uses may not be available where needed at the neighborhood of construction sites. While lots of rocks are yet to be identified within the subsurface where hidden as bedrock around the needful sites, some have outcropped and adjoined the places were perceived as unsuitable because of inadequate verification, possibly by sticking to a particular method. Consequently, advanced but simple integrated analyses of rocks to justify their suitability have become requisite authentication techniques prior to their use in engineering constructions. The suitability of aggregate must reflect its ability to withstand limitations, such as abrasion, crushing, impacting, and disintegration when stored and processed under asphalt pavement being compacted with rollers and exposed to loading (Rehman et al., 2020). The ability depends on petrographic factors, such as mineral composition, the strength of the individual minerals, cohesion between grains, material size, and textural anisotropy (Maricic, 2014). Verification of these parameters is important in the selection of reliable rock materials for the construction of stable buildings, using the case of Afikpo Basin where massive outcrops of different rock formations exist as a group of consolidated sediments. Yet, there has been incessant failure of infrastructures in the basin, especially roads constructed with aggregates perceived to have been imported from other regions.

It was observed that the areas studied in the Afikpo Basin have been characterized by road pavement collapse after a short period of construction. The challenge created concerns between two opinions: the uncertainty over the qualities of rock materials used for the construction and questionable skills of contractor engineers who design without compliance to specifications. The uncertainty enmeshed in the first opinion has even caused negative aesthetic impacts, resulting in low demands of crushed stone [or chippings] produced within the region against the high potential supply that would have been available from active mechanized quarry industries deployed to the area. This uncertainty created a gap between supply and demand and a decline to a very low demand that has continued to affect the economy, hence, must be resolved with innovative investigations. Thus, investigation into the quality stance of the rock fabrics was the scope of the present research. The research commenced with combined petrographic and grain size analyses of sandstones adjudged as the

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most consolidated formation of the Ezeaku Group. These mechanical tests portrayed the major chemical contents relatively. It is a novelty fact that has not been identified hitherto in petrographic studies as a relevant geologic tool in the exploration of bulk/ industrial materials for engineering constructions. On this note, the research presents part of the roles needed in sourcing raw materials for indigenous buildings and construction industries in Nigeria, following Durotoye (2003) who earlier emphasized that geologists have very important roles to play for national development. The present study demonstrated the needed role, by introducing a simplified and low-cost approach to verifying aggregate quality. It shows its affordability to mechanized and artisan entrepreneurs, encouraging massive infrastructural development by the availability of the certified quantity of aggregate quality. This can create job opportunities for sustainable development and consolidation of the national economy.

According to Orife (2003), the production of construction materials constitutes a substantial part of the national economy that has not been properly harnessed. Therefore, the general aim of the present research was to establish baseline data that can be set into the quality assurance checklist of the construction industries in the selection of reliable primary [nonmetallic minerals] materials for construction of competent infrastructures, in terms of road pavements and buildings' foundations.

2. Geology of the Area

Some previous literature recently updated by Ukpai (2020) buttressed facts that an undeveloped rift arm was formed from the break-up of the Gondwana super continent in the Jurassic era. Following the end of the rift stage, this particular arm traversed West Africa and crossed Nigeria as a trough. The trough was reaffirmed in Nigeria as Benue Trough by Hoque and Nwajide (2002) with a length and width of about 800 km and 150 km, respectively in the Northeast direction from the present Niger Delta to Lake Chad (Obaje, 2009). There was a sea level rise that affected the South Atlantic Ocean in Albian time and created a hydrologic slope towards the Benue Trough (Ukpai, 2021), resulting in a series of transgressions and regressions. A succession of these alternating hydro-geological processes culminated in sedimentary deposits. The first set was at the commencement of the transgressive episodes that produced marine sediments. Nwajide (2013) buttressed that these marine sediments, named Asu River Group, belong to the Albian age of the Lower Cretaceous Era. The second transgression of the marine sediments took place in the Cenomanian Age but was characterized by a current lower than in the former episode, hence, could not advance further than the Odukpani area; otherwise, the Odukpani Formation [mainly limestone] that formed lower limit of Upper Cretaceous era around Calabar flank. However, the absence of the Cenomanian sediments across a wider spectrum of the Benue Trough created an unconformity between the lower and upper Cretaceous eras. Subsequently, the Mamfe Formation was deposited in the Turonian Age through the Bakassi peninsula and spread via a high current to the extreme south of the trough around Afikpo Area where the sediment was originally identified near the Ezeaku River as Ezeaku shale. The thickness of sediments in the Turonian Age increased during the recession of the current [regressive episode] with continental swabs which produced sandstones, in addition to the shales constituted Ezeaku Group. Other sediments of the Upper Cretaceous era within the Benue Trough spanned from those of Coniacian age, dominated by the Awgu Formation to the Nsukka Formation of the uppermost Maastrichtian Age.

The tectonic process affected the entire Benue Trough in the Santonian time, particularly deformed sediments from the Albian to Coniacian ages; consequent upon which a regional uplift was formed. The most prominent of the deformation features was an Anticlinorium formed around the Abakaliki region at the southern part of the trough. The anticlinorium separated Afikpo and Anambra Basins, even as sediments of post-Santonian ages were later deposited across the two depocenters, with increased thickness towards Anambra Basin. This is because, the Nkporo Group, being the basal thick sediments of Anambra Basin is less thick at the southern flank of Afikpo Basin around the Edda Area, followed by negligible thickness of Mamu Formation near the confluence of Cross River and Ebonyi River around Ehugbo area, southeast flank of Afikpo Basin. However, the presence of Ajali and Nsukka Formations belonging to the uppermost Maastritchtian age is scarce in Afikpo Basin. According to Nwajide (2013), the Afikpo Basin is dominated by the Ezeaku Group, comprising shales and sandstones, as well as a minor spread of siltstones.

3. Materials and Methods

The sampled rocks were located by means of Global Positioning System (GPS) of e-Trex model following Okogbue and Ukpai (2013) who used same application and identified sampled locations. In this study, identification of the samples was systematic as it covered the rock type descriptions and associated structures, delineation, and demarcations of litho contacts, as well as measuring the attitudes of bedding planes. In the study, it is believed that rock quality for aggregates as construction material depends on the mineralogy and textural features, so some sandstone samples were collected for petrographic analysis. The petrographic analysis was carried out on samples, collected from Reynolds Construction Company (RCC) abandoned mines (NC05), Ndukwe-Amuro Setraco quarry site (NC07a), Ezeke Amuro NC10a, local quarry sites (NC12), Ezeke local quarry site (NC15), Amasiri, precious foundation school (NC14). These sandstone samples were cut into thin sections at the Department of Earth sciences (Geology), Kogi State University, Anyigba, Nigeria. The thin sections were viewed under petrographic microscope (Meiji monocular series) and photomicrography, using a compact digital camera [fixed with zoom lens] at the department of Geology, Ebonyi State University, Abakaliki, Nigeria. The petrographic analysis was intended to investigate mineral compositions of the sandstones samples and ascertain if the modal mineralogy is of such quality that can be used as aggregates. Accuracy was ensured as the analyzer and polarizer lenses of the microscope were properly adjusted to determine change in properties of the minerals under both plane (PPL) and cross polarized lights (XPL). Interpretation of the mineralogical details was facilitated through photomicrographs following Mohamed and Abdulkader (2010). However, fossil assemblages were not analyzed because they are not within the scope of the study.

The level of textural cohesion was verified via sieve analysis, performed on selected few samples, mainly where the friable sandstones were easily accessed to determine the typical grain size distribution. About three samples, each weighing 50g, were randomly collected and labeled according to the location codes. Each sample was sieved through sieves stacked in a row of sieve openings. Slot sizes of the openings decreased downwards from the topmost largest to the least screen opening which hangs on a receiver pan at the base. The stack of sieves was placed on a mechanical shaker connected to power source, switched on and shook for 10 minutes. At switching the shaker off, the material retained on each sieve was weighed, and the results were recorded on a specially designed sieve report sheet. Sieve loss was noted and recalculated to correct the weights, and the corrected weights converted to weight percent and cumulative weight percent. The cumulative percent (%) was plotted against phi (Φ) to graphically obtain cumulative frequency curves for analyses of relevant parameters as follows:

$$\text{Mean } (\overline{X}) = \frac{\Phi 16 + \Phi 50 + \Phi 84}{3} \quad (1)$$

$$\text{Standard deviation (Sd)} = \frac{\Phi\, 84 + \theta 16}{4} + \frac{\Phi\, 95 + \theta 5}{6.6} \quad (2)$$

$$\text{Kurtosis} = \frac{\Phi 95 \quad - \Phi 5}{2.44\,(\Phi 75 - \Phi 25)} \quad (3)$$

4. Results and Interpretation

4.1 Litho-facies analysis

Alternating sandstones were observably overlying black shales (Figs.1 [A and C]). The shale facies change to argillaceous (silty) materials towards contact with the sandstones. While the silty nature decreased away from flanks of the [Afikpo] synclinorium, the shale turned blocky outwards from the center where the sandstones dominated with sharp contacts around Amasiri area (Figures 1A and 1B) and irregular contacts at Akpoha area (Figure1C). Most of the contacts are characterized by seepages which exposed the shales to weathering due to moisture saturation. Visual inspection of the rock units showed that the sandstones are calcareous, particularly seen from inherent debris of shelly materials that easily break into powdered form when the specimen at fresh road-cut is pressed with fingers. This biological fabric may have been affected by diagenetic and depositional conditions. For this reason, bedding plane dispositions were verified to probe into paleo-geological processes associated with the rock origins and depositional environment.

Figure 1. Photographs showing the rocks units of the area (**A**) Sandstones quarried to the groundmass shale base contact (**B**) Massive sandstones ridge showing the typical alignment before the quarry process (**C**) Blocky nature of the sandstone hill flanks (**D**) Dolerite intrusion localized at few places

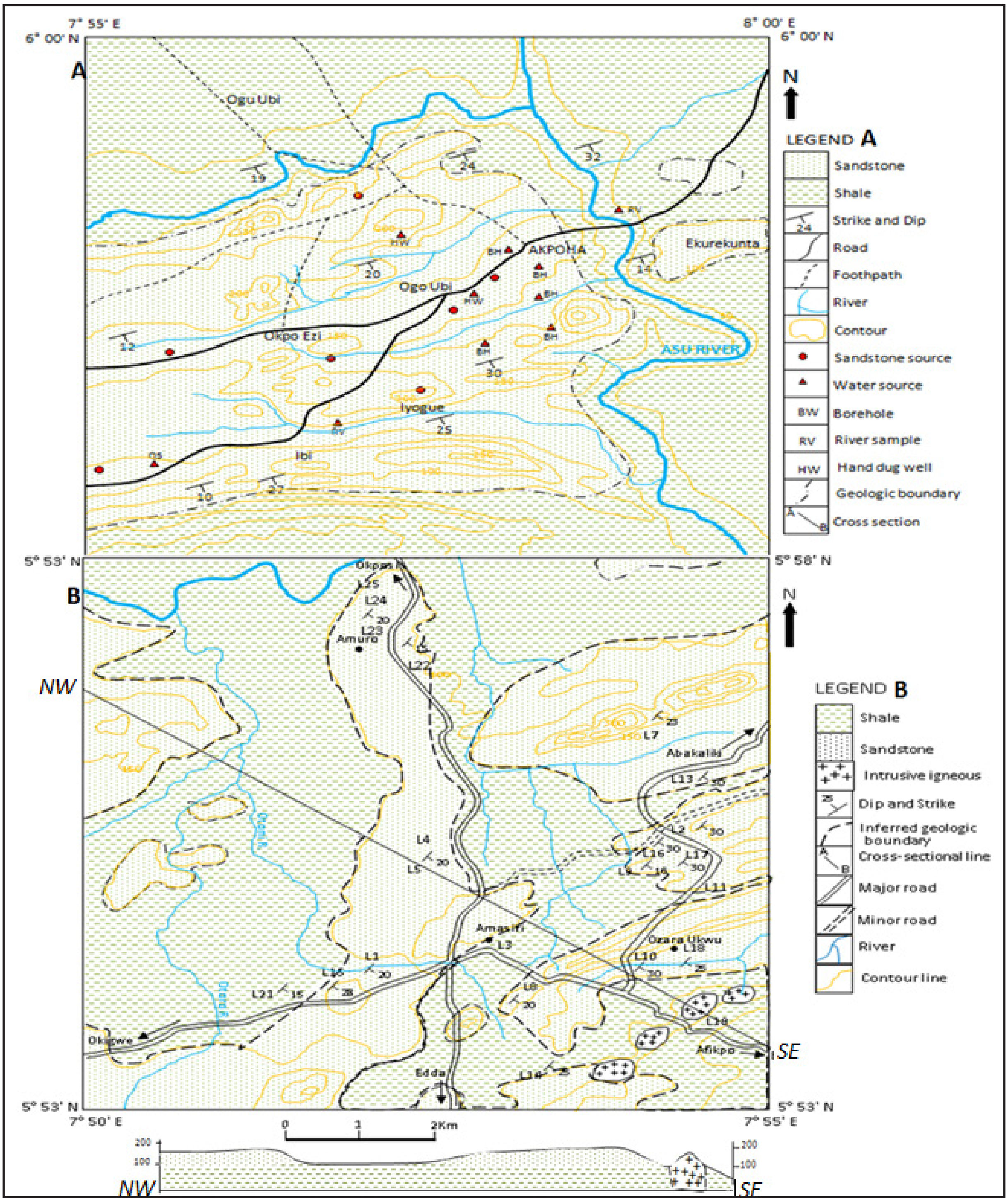

Figure 2. Geological Maps (**A**) Akpoha area (**B**) Amasiri area; and showing the typical alignment of the Ezeaku shale overlain by Amasiri-Akpoha sandstones in a section that crossed part of Amasiri area.

Attitudes of the sandstones at the natural beddings (Figure 1C) showed amount between 17^0 and 40^0; dipping southeast (Figure 2) as confirmed in planar cross beds (Tables 1A and 1B) and trough-cross bedding (Tables 2A and 2B). Both cross beds showed unimodal patterns indicating past fluvial environment that was dominated by regressive-transgressive cycles, influenced NE-SW paleo currents (Figures 3A and 3C). Based on this information, the present study affirms two major provenances. The first was controlled by the transgressive episode from the South Atlantic Ocean at the southwest from Afikpo Basin, and the second was by regression from eastern highlands at the northeast from the Basin (Figure 3B). The transgressive and regressive cycles streamlined depositions of the respective shales of marine source and sandstones of continental origin.

Table 1A. Trends of the planar cross beds of the study area.

S/No	Trend of cross-beds
1	N55^0 – N235^0
2	N52^0 – N232^0
3	N45^0 – N225^0
4	N55^0 – N235^0
5	N60^0 – N240^0
6	N55^0 – N235^0
7	N65^0 – N245^0
8	N52^0 – N232^0
9	N48^0 – N228^0
10	N80^0 – N260^0
11	N70^0 – N250^0
12	N70^0 – N250^0
13	N65^0 – N245^0
14	N55^0 – N235^0
15	N50^0 – N230^0
16	N45^0 – N225^0
17	N50^0 – N230^0
18	N45^0 – N225^0
19	N35^0 – N115^0
20	N40^0 – N220^0

Table 1B. Planar cross beds analysis using front Azimuth and its back equivalence and class interval of 30^0

S/No	Class interval	Equivalent	Frequency
1	0 – 30	181 – 210	
2	31 – 60	211 – 240	15
3	61 – 90	241 – 270	5
4	91 – 120	271 – 300	
5	121 – 150	301 – 330	
6	151 – 180	331 – 360	
			Ef = 20

Table 2A. Trends of trough cross beds

S/No	Trend of cross-beds
1	N75^0 – N255^0
2	N85^0 – N265^0
3	N94^0 – N274^0
4	N96^0 – N276^0
5	N105^0 – N285^0
6	N82^0 – N262^0
7	N90^0 – N270^0
8	N108^0 – N288^0
9	N65^0 – N245^0
10	N90^0 – N270^0
11	N110^0 – N290^0
12	N100^0 – N280^0
13	N85^0 – N280^0
14	N90^0 – N270^0
15	N75^0 – N255^0
16	N70^0 – N250^0
17	N98^0 – N278^0
18	N90^0 – N270^0
19	N95^0 – N275^0
20	N82^0 – N262^0

Table 2B. Trough cross beds analysis using front Azimuth and its back equivalence and class interval of 30^0

S/No	Class interval	Equivalent	Frequency
1	0 – 30	181 – 210	
2	31 – 60	211 – 240	
3	61 – 90	241 – 270	12
4	91 – 120	271 – 300	8
5	121 – 150	301 – 330	
6	151 – 180	331 – 360	
			Ef = 20

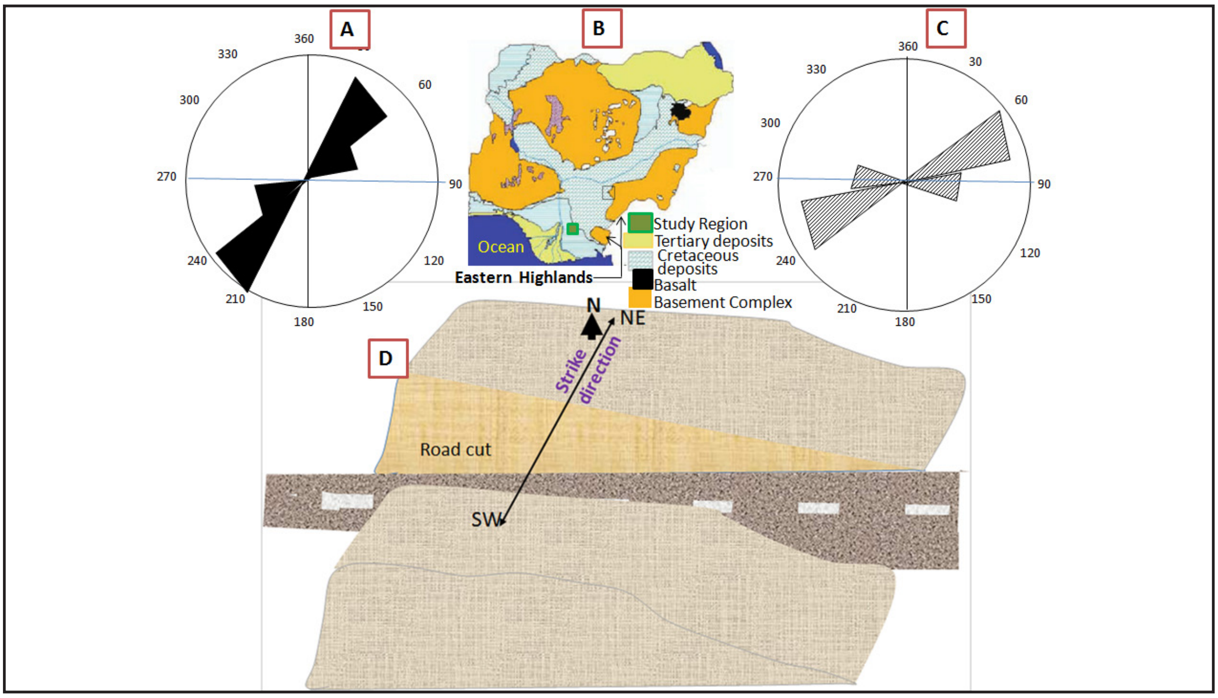

Figure 3. (**A**) Rosette diagram of the planar cross bed Azimuths (**B**) Map of Nigeria showing the generalized geology from Obaje, (2009), and (**C**) Rosette diagram of trough-cross beds (**D**) Schematic representation of the asymmetric form of the Amasiri sandstone ridge showing eastward gentler flank and westward face of steep flank

Locally, thickness of the shales was measured to a mean elevation of about 70 m above sea level at plain/ lowlands. For the sandstone cuestas, the mean thickness is about 100 m (0.1 km) where it usually occurs in ridges, mainly at the type locality around Amasiri area (Figures 1B and 2B), and up to 200 m (0.2 km), mostly at Akpoha area (Figure 2A) where it occurred in isolated hills (Figure 1C). Lengths and widths of the sandstones ridge are greater than 10 km and 0.2 km, respectively at Amasiri area, and at an average of 5 km and 0.25 km for the respective length and width of the cuestas at Akpoha area, hence, amounted to local volume of the resources from a range of 0.2 to 0.25 km³, equivalent to ton register from 70, 600,000 to 88, 300, 000 tons at Amasiri and Akpoha areas, respectively. While bioturbation is prominent on the sandstones around the hills, it is very scanty on the ridges, indicating that the Akpoha sandstones, north of Amasiri sandstone ridge (Figure 2) may have been formed under more anoxic, low energy conditions after high storms under which the ridges were formed had subsided. The ridges are asymmetrical in agreement with Nwajide (2013) who also noted west-facing steeper flank as represented in Figure 3D. The steeper side was possibly created by hitting paleo ripples from the sea, while gentler flank that faces the east showed evidence of the regressive influenced stacking of the sandstones from the eastern highlands. It is noteworthy that the first set of sandstones, deposited at the onset of the regression, that is, the Amasiri sandstones vary slightly in texture from those deposited at the later stage, like the Akpoha sandstones. Table 3 shows a higher percentage of quartz contents ranging from 75 to 81% [across samples NC 12, NC 13, NC 15, NC 16, NC 17 and NC 23] of Akpoha sandstones, than those in NC 05, NC 11, and NC 14 which range from 73 to 75% of Amasiri sandstones. However, based on the smaller number of samples analyzed from the later sandstone units, the quartz content cannot be discriminated as less than the Akpoha sandstones.

Moreover, cementation by quartz at a level greater than 75% is safe to certify the hardness of both sandstone formations. This level of hardness can be attributed to the reason why the sandstones could not be excavated mechanically during road cutting and quarry operations, but rather by blasting via detonation process. On this note, later research can focus on the investigation of the sandstone hardness via P-waves seismic survey to further decipher the rippability, following Kearey et al (2002) who had earlier reported a standard P-wave velocity 2000 ms^{-1} in sandstones rippable by mechanical excavations. It was further explained in the review that sandstones with a velocity greater than the specification require detonation with explosives. Confirmation of the hardness based on seismic velocity will not only certify the engineering application of the sandstones but also determine subsurface depth interfaces with the shales; a relevant condition for foundations/in-situ constructions.

4.2 Petrographic Analysis

Results presented in Figures 4A and 4B and a summary interpretation in Table 3 pointed out that quartz and feldspar comprise the modal mineralogy of the studied sandstones. According to Montgomery (2011), quartz-rich sand is used very largely in engineering construction. The engineering significance of the sandstones was verified based on framework composition, and in particular, the mineral types and shapes via petrographic analysis. This analysis is the best option to investigate the percentage (%) of the mineral contents. The major rock minerals like quartz, feldspars, and calcites have various ranges of resistance to weathering. But then, while quartz is the most resistant, calcite is the least. Thus, the level of aggregation [in percent] of quartz minerals in soils and rocks determines the degree of hardness as a baseline criterion selected for aggregates, chippings, and related building materials.

Discerning that the high quartz content, with the significant presence of feldspars and rock fragments in cleavage association, suspected as rhombohedral (Figures 4A and 4B), as well as the irregular grain shapes, observed under XPL view (Figure 5A), showing intact concave/ convex contacts (Figure 5B), the sandstones can be safely used as aggregates for construction materials. The relevance as aggregates was further verified through the analysis of textural character.y

Table 3. Summary interpretation of the framework composition

Sample code	Quartz %	Feldspar %	RF %	Total %	Interpreted from:
NC 05	73	13	15	100	Fig.4a
NC 11	74	16	10	100	Fig.4a
NC 14	75	15	10	100	Fig.4a
NC 23	78	13	9	100	Fig.4b
NC15	81	12	7	100	Fig.4b
NC13	79	13	8	100	Fig.4b
NC16	81	11	8	100	Fig.4b
NC17	75	14	11	100	Fig.4b
NC12	81	12	7	100	Fig.4b

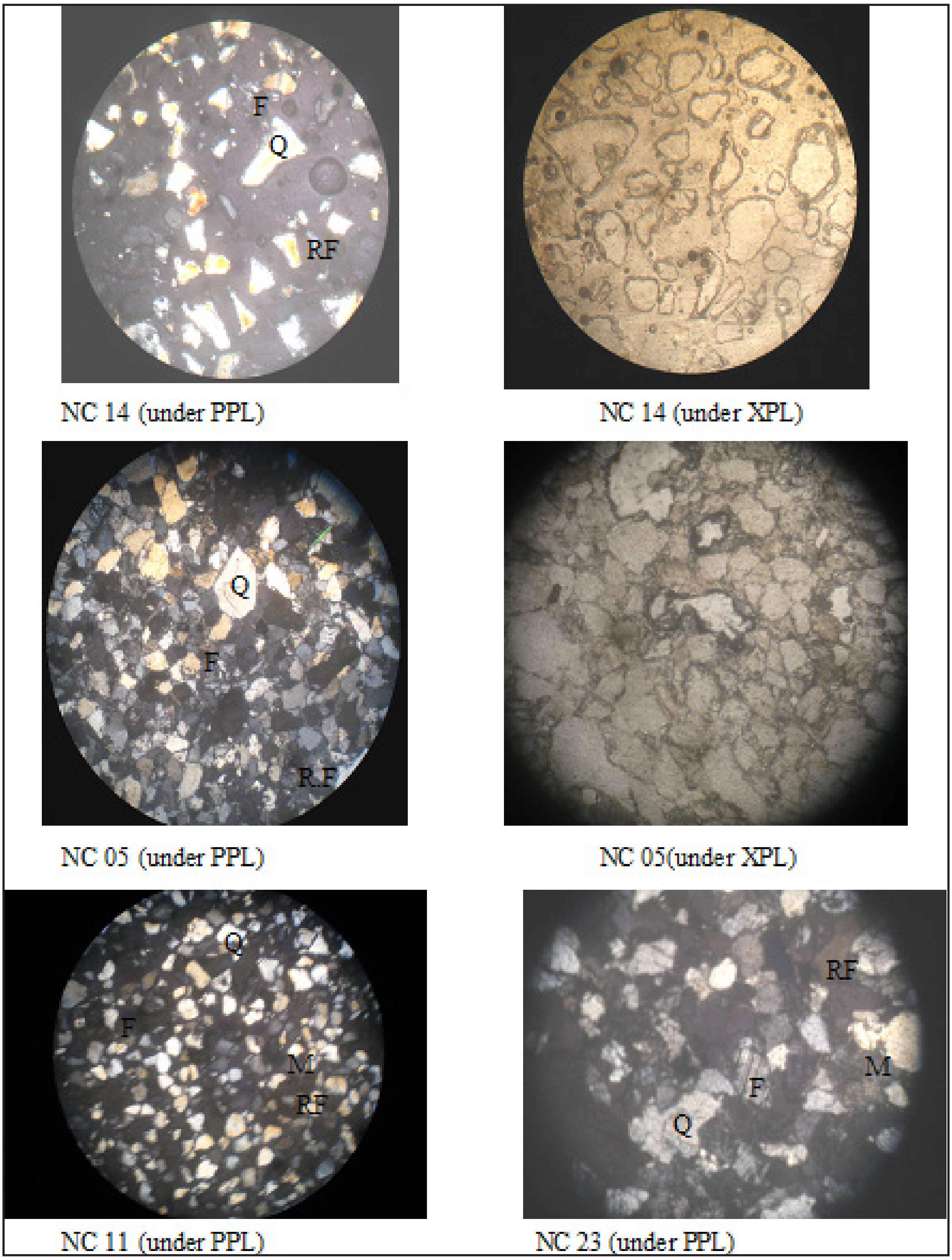

Figure 4A. Photomicrograph of Amasiri Sandstones, comprising mainly of convex to line contact, angular to sub angular grains of quartz [viewed under Meiji monocular microscope with magnification x 200].

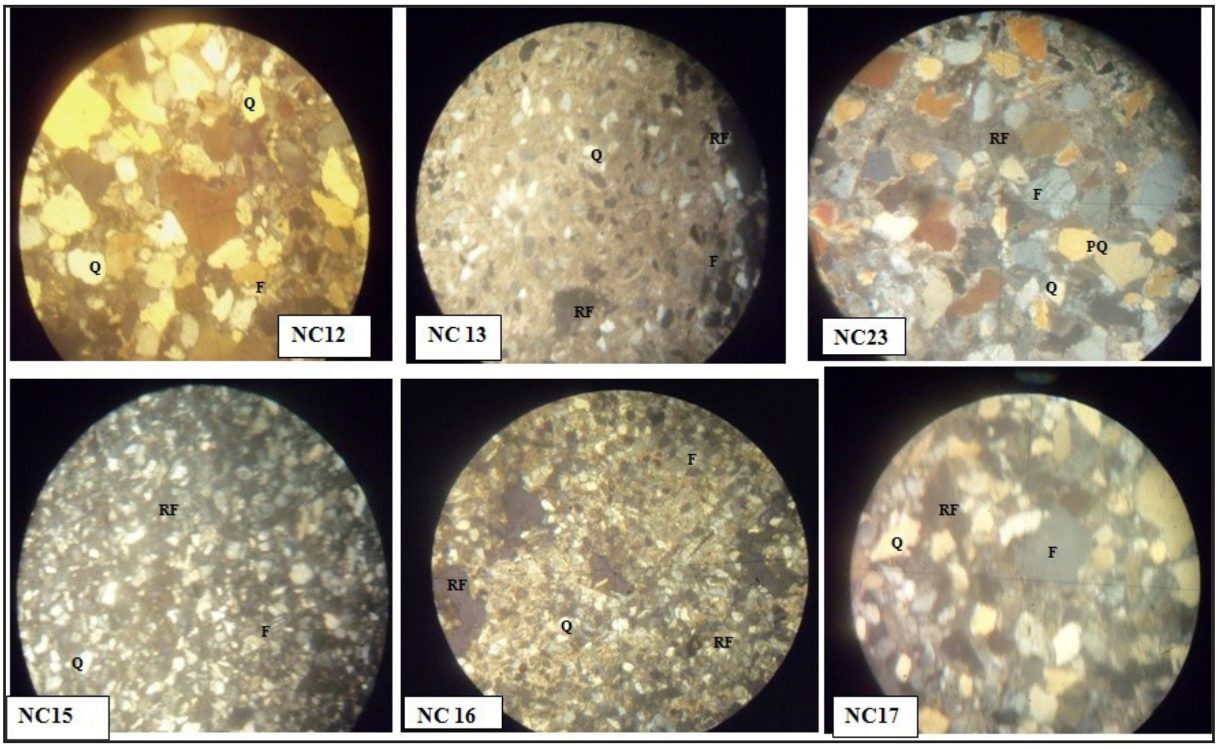

Figure 4B. Photomicrograph of Akpoha Sandstones, comprising mainly of concave-convex, angular to sub rounded grains of crystalline quartz [viewed under Meiji monocular microscope [magnification x 100].

RF= Rock Fragments suspected to constitute mainly of calcites and pyrites

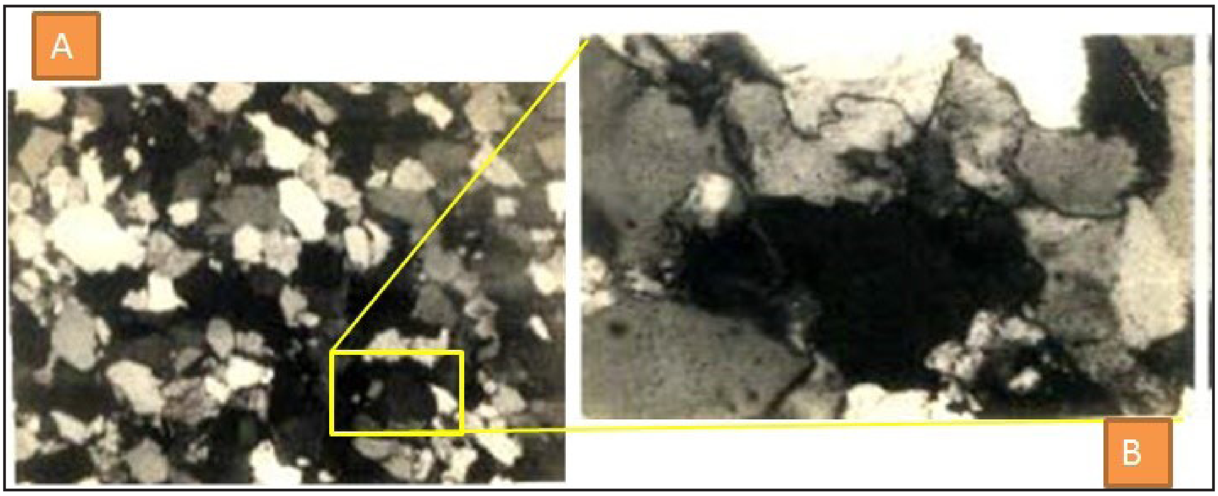

Figure 5. Photograph of the typical Sandstone sample [XPL]; (**A**) showing sub-angular to sub rounded grain shape [Magnification x 200], (**B**) a part visual enhancement showing [Magnification x 400].

4.3 Textural Analysis

The cumulative % and ϕ plotted to produce cumulative frequency curves (Figure 6-8) and the curve values extracted for analysis of the grain size parameters (Equations 1-3) produced the results in Table 5. As seen, the mean grain sizes ranged from 1.0 to 2.1 mm; the degree of sorting from 1.25 to 1.4 mm and peaked (Kurtosis) between 0.9 mm and 1.6 mm (Table 5). Interpretatively, the range of the standard deviation depicted poorly sorted rocks, indicating a mixture of different sizes of grains. Yet, the mean values pointed at the dominance of medium grains with shapes spanning from mesokurtic to leptokurtic curvatures.

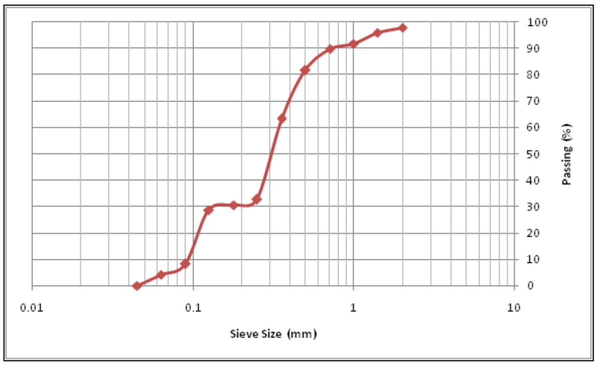

Figure 6. Grain size distribution curve for NC10a

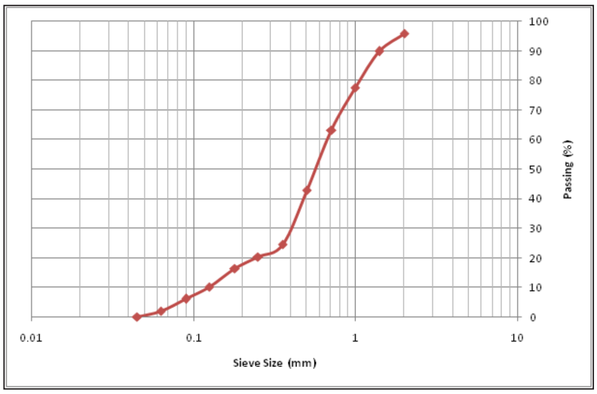

Figure 7. Grain size distribution curve for NC14

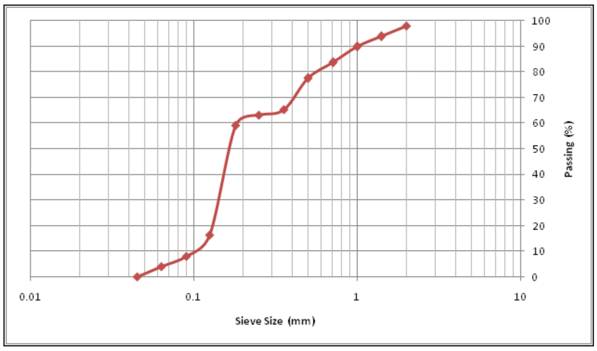

Figure 8. Grain size distribution curve for NC18

Table 4. Summary result of Textural analysis

Sample code	Mean (x)	Standard deviation (sorting)	Kurtosis
NC10a	2.0	1.25	0.953
NC14	1.0	1.4	1.640
NC18	2.1	1.35	1.077

5. Discussion

The percentage of silica-rich quartz in the sandstones certifies a high siliceous nature. According to Earle (2019), strong covalent and ionic bonding characteristics of silica tetrahedron generated hardness in quartz. The hard nature reflects compressive strength which varies in sandstones from 20 MPa to 170 MPa, depending on conditions due to digenesis and depositional environment, as well as the effect of weathering which depreciates the strength towards the lower limit. Having reviewed earlier that the studied sandstone belongs to the Ezeaku Group, the strength is therefore within the specified range; following Ukpai (2020) who studies the stability of the entire [Ezeaku] Group in the adjoining region and claimed that the bedrocks were slightly weathered, upon which the compressive strength was somewhat greater than 20 MPa. Grouping the sandstones at such a strength level of about 20 MPa reflects toughness:

Even as the sandstones sandwich shell hash debris in some places (Okoro et al., 2016), the macroscopic view was minimal during field inspection. It was observed in the present study that the calcareous portion behaves as diatomaceous earthen though it appeared insignificant, perhaps due to the minor alteration effect of the localized fossilized shells. This may subject the silica-rich quartz to possible alkali-silica reactivity. This reaction can be triggered if aggregates, processed from the rock mass, are exposed to agents of chemical activities, and moisture in particular. According to Yasir et al. (2018), damage due to the alkali (NaOH) reaction decreases the compressive strength. It means that the sandstone quality is certified for the production of aggregates used as construction materials should be supplemented by mixing concretes with adequate Portland cement [measured to compressive strength greater than 20MPa]. Furthermore, the aggregate product used in [walkway, runway, and driveway] pavements should be tarred at the surface to seal off moisture, as well as other chemical agents that may be aided by climatic conditions. These precautions will prevent sorts of degradations that can jeopardize the characteristic hardness found in the sandstones. The level of hardness and intact nature is relatively proved by the difficulty to breaking with sledge sledgehammer, coupled with the fact that the rock mass can only be extracted in-situ by blasting or detonation process. There is no doubt that the sandstones can withstand pressure when subjected to industrial crushing process to obtain desired aggregate sizes.

The reserve relevance is highly based on the proximity of the sandstone resources for marketing. Large areal extent of the outcrops, which can be suitable for budget friendly open blast mining via explosive devices, grade with respect to the local resource volume, as well as optimum quality in terms of efficient crushing strength which can raise social (enthusiastic) acceptability against the earlier negative perception. The reason for the acceptability is mainly because the aggregates cannot split into pieces when compressed into concretes, packed at pavement sub-base after rigorous exposures to loads of roller compaction which is a necessary process in road construction. This fact was supported by the modal mineralogy of the sandstones though usually controlled by quartz as also demonstrated in this study; yet quartz rich-rocks are vulnerable to thermal expansivity, but the considerable percentage of feldspar observed in the photomicrographs (Figs. 4a and b) is significant to balance the expansive characteristic because feldspar minerals are more resistant to the thermal effects. Based on this assertion, aggregates produced from the sandstone deposits can be resistant to chemical and thermal degradations.

Low water absorption of produced aggregates was suspected to enhance the mechanical property as the sandstones are devoid of coarse grain sizes that could have increased apparent porosity. Furthermore, as microstructures of coarse aggregates affect the strength of concretes (Petrounias et al., 2018), little or complete absence of the microstructures has been suspected because the studied sandstones are dominated by statistical [mean] values indicating medium grains (Table 4). Thus, finding the mineralogy has confirmed fabrics of aggregates produced from Amasiri sandstones as efficient construction materials in concretes and sub-base of road pavements. This study has, therefore, demonstrated that risk analysis of any rock potential for stable aggregates. Materials should begin with the identification of individual mineral components of aggregates used in the construction of the concerned infrastructure: an innovating efficacy just found in petrographic analysis when used for the verification of aggregate strength.

6. Conclusions

The engineering importance of consolidated sandstones was evaluated, to resolve probable perceptions that the quality is low for aggregate production. The study was applied in the Afikpo Basin where the sandstone deposit is massive in consolidated form by ridges along NE-SW trend and overlay shales, both constitute the Ezeaku Group of the Turonian age. Although, the sandstones are mainly distinguished in two litho-facies, the Akpoha and Amasiri Formations, the textures are similar with dominant medium grain sizes but slight variations in micro-facies. While concave-convex, angular to sub-rounded grains of crystalline quartz characterized the Akpoha sandstones, the micro-facies changed to convex-line contact, angular to sub-angular quartz grains in the Amasiri Formation. These textural and mineralogical characters resulted in hardness, such that the sandstones are relatively not rippable but still chippable via blasting/ detonation, hence, they can be mined by open pit method as aggregates of certified high quality, particularly for use in concretes and sub-base of roads pavements. The mineralogy also showed that the aggregate is not susceptible to thermal expansion.

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