ENGINEERING AND GEOLOGICAL EVALUATION OF ROCKS FOR CONCRETE PRODUCTION

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ABSTRACT
Engineering and geological properties of rocks from eight different quarries in Ibadan were evaluated to determine their suitability for concrete production. Samples from each quarry sites were subjected to grading, relative density, water absorption, bulk density, amount of materials finer than 75µm, flakiness and elongation Index, Aggregate Impact Value (AIV), Aggregate Crushing Value (ACV), Aggregate Abrasion Value (AAV), 10% fines value and petrographical analysis adopting BS testing methods. The relationship between engineering properties with one another and the petrographical characteristics were described by Pearson correlation coefficient and bar charts. The results of engineering analysis revealed that rocks from all the quarries are generally sound and good because of their possession of necessary characteristics for use in concrete production when compared with British (BS), Indian (IS) and American Society for Testing and Materials (ASTM) standards. Petrographical analyses revealed that samples which have performed better in all the engineering tests possess higher content of quartz mineral and finer texture. Statistically significant correlations were found among the tests performed.

Keywords: Aggregate, engineering analysis, petrographical characteristics, quartz and texture.

INTRODUCTION

Concrete is one of the versatile and widely used building materials in the construction industry. It is a composite material which consists of cement, fine aggregate (sand), coarse aggregate (gravel or crushed rock) and water in a certain prescribed proportion. In Nigeria, crushed rocks are most widely used as coarse aggregate material for concrete production because it is relatively in abundance. However, most of the stakeholders in the Nigerian concrete industry have little or no knowledge of the properties of crushed rocks they use for production of concrete. Knowing these properties will prevent making wrong choice of selecting unsuitable aggregate materials that may lead to concrete failure.

Neville (2011) noted that many properties of the aggregate such as, chemical and mineral composition, petrological characteristics, hardness, strength, specific gravity, physical and chemical stability, pore structure, and colour, depend entirely on properties of parent rock for the reason that all aggregate particles originally formed a part of a larger mass and may have been fragmented by natural process of weathering or artificially by crushing. Other properties possessed by aggregate such as particle shape and size, surface texture and absorption but not in parent rock also have considerable influence on the quality of the concrete product.

Selecting the right aggregate material for concrete production is vital to overcome the recurrent problem of concrete failure observed in collapsed buildings. The rock constituent must be able to maintain its properties when wet because water can pass through the open structure of concrete and affect the aggregate properties. Egesi and Tse (2012) stated that rocks are exposed to a variety of stresses in various ways they are used, and the response of the structure in which it is used will largely depend on the properties of the aggregate. The high variation in strength between concrete and mortar of the same cement/aggregate proportion, suggests the quintessence of coarse aggregates in the development of strength in concretes (Aginam et. al, 2013).

The quality of the coarse aggregates is essential when considering the quality of the concrete itself. Research indicates that changes in coarse aggregate can change the strength and fracture properties of concrete (Rozalija and David, 1997). Young and Sam (2008) concluded that smooth rounded aggregates was more workable but yielded a lesser compressive strength in the matrix than irregular aggregates with rough surface texture. They also stated that fine coating of impurities such as silt on the aggregate surface could hinder the development of a good bond and thus affects the strength of concrete produced with the aggregates. In addition, Neville (2011) stated that bond is affected by other physical and chemical properties of aggregate, related to its mineralogical and chemical composition, and to the electrostatic condition of the particle surface.

Wei et al. (2011) indicated that mechanical properties of coarse aggregate have varying degrees of influences on drying shrinkage, creep, and temperature crack of concrete. The study confirmed the possibility of cracking of concrete prepared by aggregate with low density is much bigger than concrete prepared by aggregate with high density.

The properties of coarse aggregates do grossly affect the durability and structural performance of concrete. Such properties of aggregates are considered alongside the mineral composition of the rock material from which the aggregate formed a part. Lindqvist et al. (2007) stated that the engineering properties of rocks can be assessed through their intrinsic properties, including texture and mineralogy. Raisanan (2004) reported that mechanical properties are significantly influenced by the abundance of fine-grained minerals, grain-size distribution, and degree of interlocking of grain boundaries of minerals.

Irfan (1996) noted that the properties of rock are influenced by the mineral composition, texture, fabric and the weathering state. Sajid and Arif (2014) concluded that variations in the mechanical properties of rocks are largely associated with differences in their textures and modal mineralogical compositions. These variations in the aggregate mechanical properties will in turn affect the performance of aggregate when used in concrete.

This study seeks to evaluate the engineering and geological properties of rock materials from some selected quarries in Ibadan that produce and supply coarse aggregates with a view to provide local concrete industry and practitioners necessary information regarding the application of coarse aggregates sourced from Ibadan for producing concrete. This will prevent them from making wrong choice of selecting unsuitable aggregate materials that may lead to concrete failure as well as collapse in buildings. Furthermore an investigation into the influence of mineral composition of rocks as an indicator of durability and strength of aggregate used in concrete production is undertaken. In addition the examined engineering properties are compared with the BS, IS, ASTM standards and other authorities for aggregates used for construction purposes.

METHODOLOGY

Rock samples were obtained from eight different quarry sites including Express (S1), Kopek (S2), Ratcon (S3), Platinum (S4), Wetipp (S5), Digital (S6), Lord Chosen (S7) and Spring (S8) in the study area (Fig. 1). The quarry sites were selected based on the result of questionnaire administered on consultants, contractors and marketers/suppliers of coarse aggregates to the University of Ibadan for concrete production. The questionnaire was designed to capture data on the sources/locations of coarse aggregates in the study area. The maximum size of aggregate collected for test from stockpiles in accordance with BS standard was 25 mm. Fresh, non-weathered crushed rock boulders were also collected from each site for petrographic analysis.

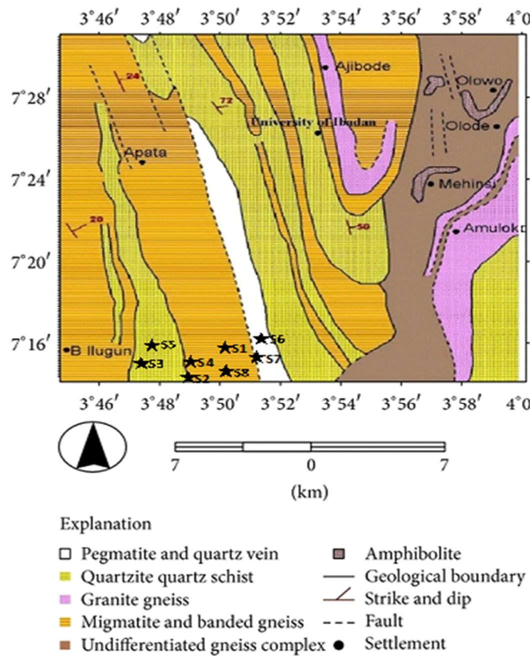


Fig. 1. Geological map of Ibadan (after Okunlola *et al.,* 2009). The bold stars show the locations at which samples were collected

Rock samples from each of the quarry sites were subjected to engineering analysis adopting British Standard methods for testing aggregates {BS812:101 (1995), BS812:2 (1995), BS812:105.1 (1990), BS812:105.2 (1990), BS812:110 (1990), BS812:111 (1990), BS812:112 (1990), BS812:113 (1990), BS812:103.1 (1985)}. The engineering properties tested include grading, relative density, water absorption, bulk density, amount of materials finer than 75microns, flakiness and elongation index, Aggregate Impact Value (AIV), Aggregate Crushing Value (ACV), Aggregate Abrasion Value (AAV), and 10% fines value.

The results of the tests were compared with BS, IS and ASTM standards. Petrographic analysis, which is the systematic description of rocks based on observations in the field, hand specimen, and in thin sections, was employed during the study for identifying the mineral composition and texture of the rocks. Pearson correlation coefficient and bar charts are used to show relationships between the engineering properties and petrographic characteristics.

RESULTS AND DISCUSSION

Engineering analysis

The engineering analyses, entails the physical and mechanical characteristics of the aggregates used in the study. Figure 2 presents the particle size distribution for graded aggregates (20mm-5mm) used in this study and compare them with the upper and lower limits stipulated by BS882 (1992). The shape of the curves obtained after plotting indicate most of the aggregates complied with the code apart from S6 and S8 which fall slightly out of the limit. Nevertheless, according to the Unified Soil Classification System (USCS) (ASTM, 2011) in Table 1, all aggregates can be classified as poorly graded gravels.

Results of the physical and mechanical tests are shown in Table 2. The specific gravity of all the samples tested is within the standard range. The result ranges from 2.44 for S2 to 2.88 for S4. A rock of high quality often poses good specific properties. Low specific gravity value for S2 was as a result of fracture that might contain water and alteration of feldspar. S4 has the highest specific gravity of 2.88 due to the fine texture and closely packed minerals. However most of them still fall within normal weight aggregate as average specific gravity of rocks vary from 2.6 to 2.8 (Shetty, 2005). According to Neville (2011), the specific gravity ranges from 2.5 – 3.0 for natural aggregates. Kosmatka et. al. (2003), agreed that most natural aggregates have relative densities between 2.4 and 2.9 with corresponding particle (mass) densities of 2400 and 2900 kg/m^3.

The significance of water absorption is control of concrete quality (water-cement ratio). Generally the water absorption rates for all the samples are below 3% specified in BS5337. S7 shows the lowest water absorption value 0.44%, and S2 shows the highest value 1.01% due to presence of micro cracks. It cannot be excluded that a slight weathering of the top surface may affect the water absorption values.

Weight of the aggregate required to fill a container of unit volume called bulk density is used in mix design calculations. A good result was recorded for the samples tested. It ranges from 1470kg/m^3 to 1663kg/m^3. The approximate bulk density of aggregate commonly used in normal-weight concrete ranges from about 1200kg/m^3 to 1750kg/m^3 (Kosmatka et. al., 2003).

The void content between particles affect paste requirements in mix design. Results were between 36.65% for S8 and 45.25% for S5. Void contents range from about 30% to 45% for coarse aggregates to about 40% to 50% for fine aggregate. (Kosmatka et. al., 2003).

The materials finer than 75micrometres sieve range from 0.1% for S4 to 0.4% for S6. This shows that all the samples tested are below the maximum value specified in the codes. BS 882, 1992 specified maximum value of 2% for crushed gravel coarse aggregate and 4% for crushed rock aggregate. The results show that the maximum value for the flakiness and elongation index does not exceed stipulated limits in the codes. S3 had the lowest value of flakiness index 16.03% while S7 had the highest flakiness index 20.32%. S8 had the lowest elongation index of 18.98% while S3 had the highest value of elongation index of 27.87%.

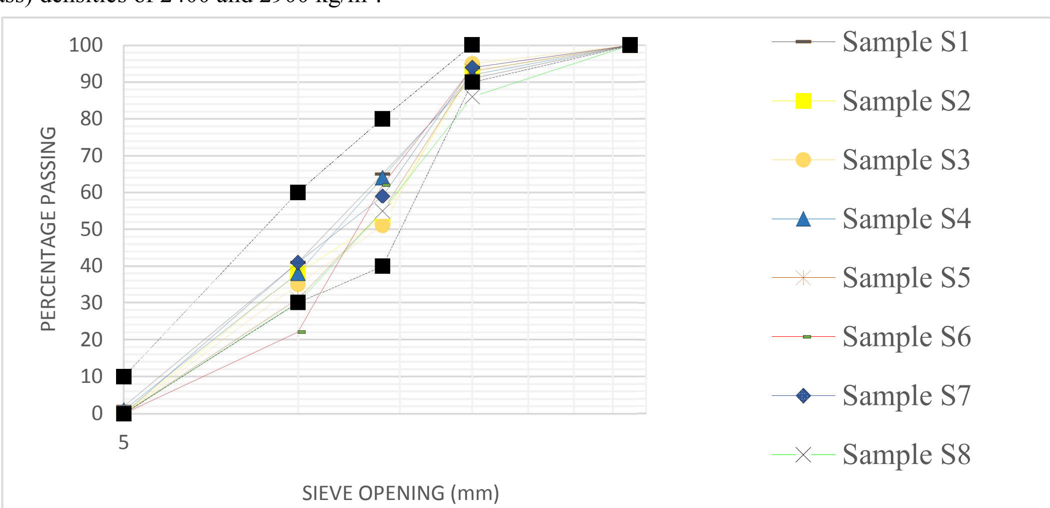


Fig. 2. Particle size distribution for aggregates used in this study

Federal Ministry of Works in the specification limits for materials and workmanship, for concrete works (revised 1997) specified flakiness and elongation index of ≤ 30% while BS 882, 1992 specified maximum value of 40% for aggregate used in concrete works.

Table 1. Soil Classification According to USCS

Tests/Samples	S1	S2	S3	S4	S5	S6	S7	S8
Coefficient of uniformity (Cu)	2.2	2.5	2.3	2.3	2.2	2.0	2.3	2.2
coefficient of curvature (Cc)	0.9	1.0	1.0	1.0	1.0	1.2	0.9	1.0
Fineness modulus (FM)	2.01	2.16	2.19	2.05	2.21	2.22	2.16	2.30
Classification according to USCS	Poorly graded gravels, gravel-sand mixtures, little or no fines.							

Table 2: Tests and permissible limits for engineering properties of coarse aggregates for concrete as stipulated by BS, IS and other authorities

Test/Sample		S1	S2	S3	S4	S5	S6	S7	S8	Permissible Limits	Authority
Physical properties											
Relative Density	Oven-dry	2.76	2.44	2.82	2.88	2.74	2.77	2.61	2.51	-	-
	SSD	2.78	2.47	2.84	2.90	2.77	2.79	2.62	2.53	-	-
	Apparent	2.81	2.50	2.88	2.93	2.80	2.81	2.64	2.57	-	-
Water Absorption (%)		0.67	1.01	0.69	0.59	0.79	0.49	0.44	0.90	Max. 3%	BS5337:1976
Bulk Density (Kg/m^3)		1530	1541	1622	1663	1500	1605	1470	1591	-	-
Voids (%)		44.56	36.89	42.55	42.36	45.25	42.24	43.68	36.65	-	-
Materials Finer than 75micrometres (%)		0.3	0.2	0.3	0.1	0.2	0.4	0.3	0.2	Max. 4%	BS882:1992
Flakiness Index (%)		16.70	18.24	16.03	20.97	18.04	16.11	20.32	14.57	Max. 30%	FMW, 1997
										Max. 40%	BS882:1992
Elongation Index (%)		23.96	25.44	27.87	22.90	24.05	19.63	23.19	18.98	Max. 30%	FMW, 1997
										Max. 40%	BS882:1992
Mechanical Properties											
Aggregate Impact Value (%)		9.12	12.46	10.09	9.14	11.04	8.83	8.52	12.16	Max. 25%	BS882:1992
										Max. 30%	IS383-1970
Los Angeles Abrasion Value (%)		18.32	21.26	18.68	18.14	19.72	17.30	16.10	20.40	Max. 30%	BS882:1992
										Max. 30%	IS383-1970
Aggregate Crushing Value (%)		19.7	21.9	20.3	19.9	20.8	19.4	18.4	21.7	Max. 45%	FMW, 1997
										Max. 30%	IS383-1970
10% Fines (Dry) KN		286	246	273	279	269	291	300	261	Min.100KN	BS882:1992

Note: SSD = Saturated surface dry

The Aggregate Impact Value of all the samples tested is below the maximum value specified in the codes. S2 had the lowest impact value of 12.46% and followed by 12.16% for S8. The best AIV is from S7 with 8.52% followed by S6 with 8.83%. Comparing the results to the permissible AIV in the codes, it indicates that the aggregate are strong enough and has good abrading properties. The BS 882-1992 specified maximum values 25% for heavy concrete floor finishes, 30% for concrete used in pavement wearing surfaces and 45% for others. The IS 383-1970 code specifies that aggregate impact value shall not exceed 45% by weight for aggregate used for concrete other than wearing surface and 30% by weight for concrete used for wearing surfaces, such as runways roads and pavement.

The Los Angeles abrasion value ranges from 16.10% to 21.26%. S7 has the best LAAV of 16.10% followed by S6 while the lowest LAAV value is 21.26% (S2). All the values are within safe limits for concrete works. According to IS 383-1970 the abrasion value should not be more than 30% for wearing surface and not more than 50% for concrete other than wearing surface.

The values of relative measure of resistance of an aggregate to crushing when it is subjected to compressive forces of aggregate took the same trend as aggregate impact value; there will be a positive correlation between these two characteristics. The laboratory test results obtained range from 18.4% to 21.9%. Comparing these with the permissible ACV (≤ 45% for concrete works as given in the specification limits for materials and workmanship, 1997 by Federal Ministry of Works, Nigeria) shows that the aggregate are good enough in resisting applied loading and can give optimum performance when used in concrete construction. The IS 383-1970 code specifies that aggregate crushing value shall not exceed 45% for aggregate used for concrete other than wearing surface and 30% by weight for concrete used for wearing surfaces, such as runways roads and pavement.

Generally the 10% fines value for all the samples are above the minimum value specified in the codes. The value ranges from 246KN to 300KN with S2 possessing the lowest value and S7having the highest value. BS 882, 1992 specified minimum values of 150KN for heavy concrete floor finishes, 100KN for concrete used in pavement wearing surfaces and 50KN for others.

Petrography analyses

Petrographic studies of rocks in the study area revealed the abundance of quartz, feldspar, amphibole and mica (Table 3). Sample S1 was observed to be medium-grained migmatite with thin section analyses showing unequal grain size (inequigranular) and a weakly developed porphyritic texture. The grain boundaries are principally irregular. In some parts, the grain boundaries have a regular character. In terms of modal composition (Figure 3a), the rock is made up of 40% feldspar, 36% quartz and 19% mica (biotite and muscovite). Large crystal grain of amphibole was also observed. The rock contains traces of opaque ore as accessory minerals.

Table 3. Average Modal Composition of Rocks from Studied Quarries

Minerals	S1	S2	S3	S4	S5	S6	S7	S8
Quartz	36	30	47	50	38	51	53	33
Feldspar	40	10	23	30	42	27	32	12
Amphibole	5	35	5	-	4	-	-	40
Biotite	15	25	20	15	10	17	15	10
Muscovite	4	-	5	5	5	5	-	5
Sphene	-	-	-	-	1	-	-	-
Opaque minerals	Trace	Trace	Trace	-	-	-	-	-

On the other hand, Sample S2 is a strongly foliated medium to coarse-grained banded gneiss with light (quartz and feldspar) and dark (biotite and amphibole) bands. The amphiboles show characteristic green colour and they are pleochroic from pale yellow to dark green. They have high relief and their long axes are parallel to each other. These minerals are the most abundant (35 %) with Biotite being just about 25 % in abundance. Quartz (30 %) which is medium grained in texture, shows wavy extinction and are drawn into ribbons in some parts of the rock (Figure 3b). They are also found as inclusion in biotite and amphibole. The smaller grains of Quartz are likely to be product of recrystallization. K-feldspar occur as medium grained and in some parts coarse texture. They are characterised by their cross hatch twinning and are anhedral in shape and are about 7% in abundance. Plagioclase feldspar are observed as colourless minerals under plane polarized light. They show polysynthetic twinning and are about 3% in abundance. The rock contains trace of opaque ore as accessory minerals. Furthermore, Sample S3 is a medium to coarse-grained migmatite with mineralogical composition showing quartz, biotite, muscovite, amphibole, microcline and plagioclase. Quartz which occurs as fine to coarse-grained xenomorphic grains with irregular grain boundaries(Figure 3c) is the dominant mineral (about 47 %), while microcline and plagioclase make up about 23 %, biotite 20 %, muscovite 5 % and amphibole 5%. The rock contains trace of opaque ore as accessory minerals.

Sample S4 is a fine to medium grained granite gneiss. The grain boundaries are principally irregular. The rock consists of 50 % quartz and fine grained in texture and the fine grain are slightly inequigranular. In some places the quartz are drawn into ribbon shape (Figure 3d). Feldspar occupy 30 % while mica (biotite and muscovite) is 20% with biotite predominant.

The sample S5 is a medium to coarse-grained Banded gneiss. It has a uniformly wide grain size distribution (equigranular). The grain boundaries are irregular (Figure 4a). In some parts, the grain boundaries have a regular character. The rock contains feldspars (plagioclase and microcline), about 42 %, quartz (38 %), Biotite (15 %) with amphibole being just about 4 %. Sphene (1%) occurs as accessory minerals and is subhedral in texture. The texture of the sample varies from medium-grained to very coarse grained and is foliated which is defined by mafic (biotite) and felsic (quartz and feldspar) mineral bands.

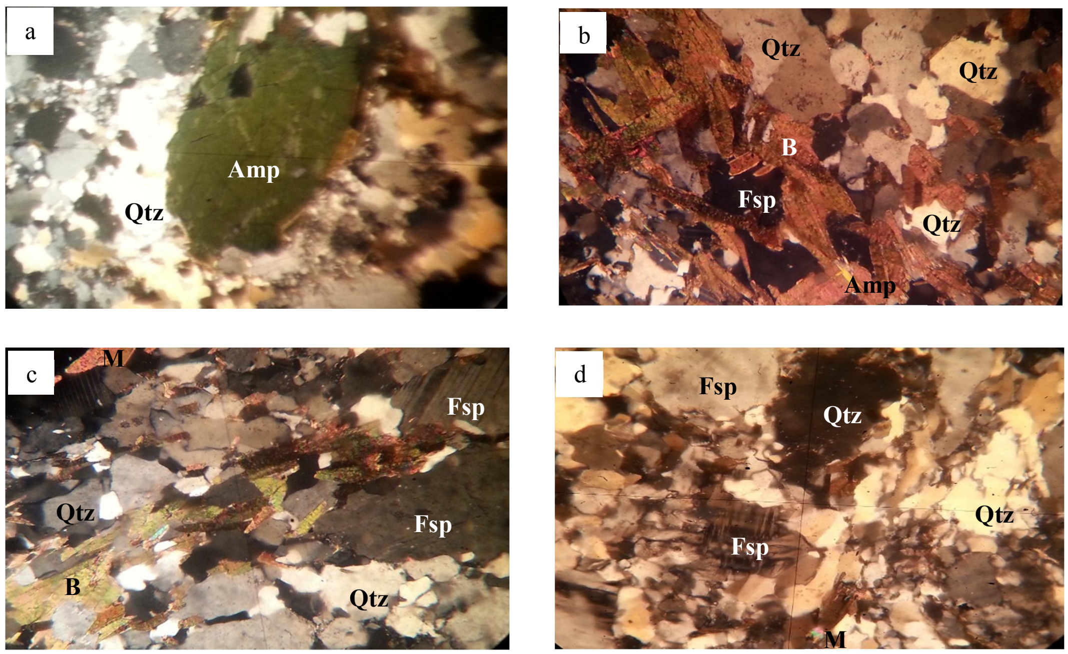
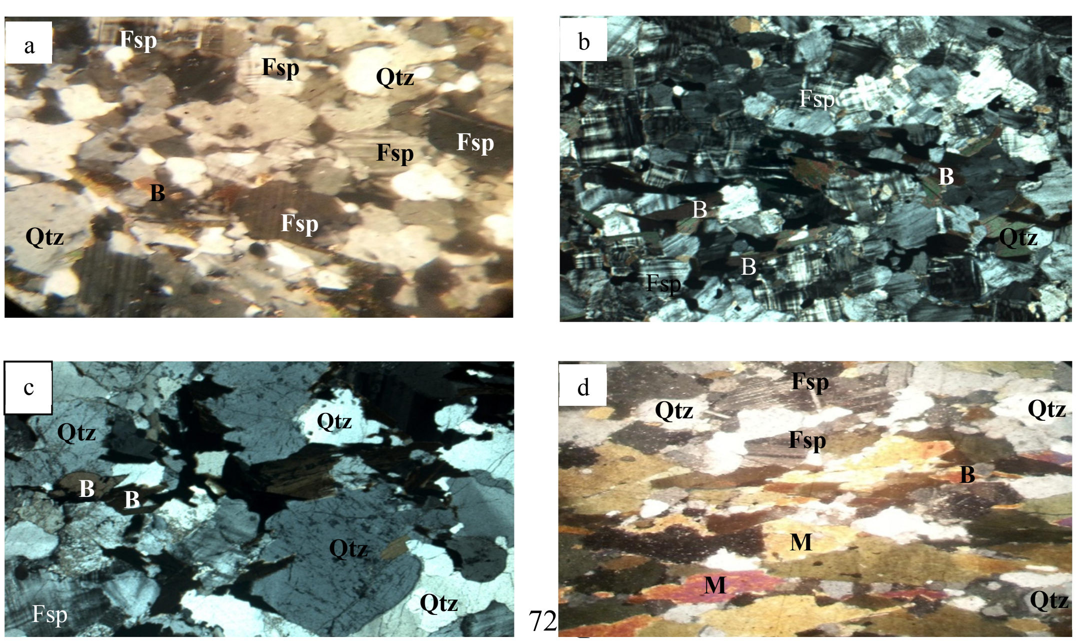


Fig. 3. Microscopic image of thin-section of (a) Sample S1 showing a large crystal of amphibole. (b) Sample S2. (c) Sample S3. (d) Sample S4. Amp = Amphibole, B = Biotite, Qtz = Quartz, Fsp = Feldspar, M = Muscovite

S6 is a fine-grained granite gneiss whose fine grain crystals are mainly quartz and biotite. The thin section analyses shows large variation in the grain sizes of constituent minerals (inequigranular) and the grain boundaries are principally irregular (Figure 4b). The rock is composed of quartz (51 %), feldspar (27 %), biotite (17 %) and muscovite (5 %).



In addition, S7 is a fine-grained granite gneiss with porhyroblastic texture and the porphyroblast is composed of quartz. The rock is mainly composed of minerals of unequal sizes (inequigranular) with the grain boundaries highly interlocked (Figure 4c). The mineral composition of the granite is dominated by 53 % quartz, 32 % feldspar and 15 % biotite. The matrix is composed of fine grained quartz and biotite. The quartz are dominantly made of tightly interlocking grains.

Finally, S8 is a fine to medium-grained banded gneiss with observed slightly inequalgranular grain of major minerals (Figure 4d). The major mineral is amphibole (hornblende) about 40% and are elongated in specific orientation parallel to quartz ribbon. Other minerals include quartz (33 %), feldspar (12 %) and mica (15 %). The rock is essentially foliated with light and dark bands.

Relationships between the petrograhical characteristics and engineering properties

The physical and mechanical properties of rocks determine their strength and durability and hence their utility for different engineering purposes. These properties depend on petrographic characteristics, including both modal composition and texture. It could be observed from microscopic analysis that rocks with more fine-grained texture such as rocks from S7, S6, S4 and S1 tend to have low aggregate impact values, Los Angeles abrasion value and aggregate crushing values. This indicates that more fine-grained rock tend to yield better technical properties than more coarse-grained rock with similar mineralogy. This is consistent with previous studies such as Tugrul and Zarif (1999), Lundqvist and Göransson (2001), Raisanan (2004), and Bell (2007).

The relationship between mechanical strength of aggregate (AIV, LAAV, ACV) and water absorption (Figure 5) shows that low water absorption rate gave low values of AIV, ACV and LAAV which is an indication of higher strength. Sajid and Arif (2014) concluded in their work that rocks with greater strength possess lower water absorption values. Similar relationship was also observed from the work of Egesi and Tse (2012).

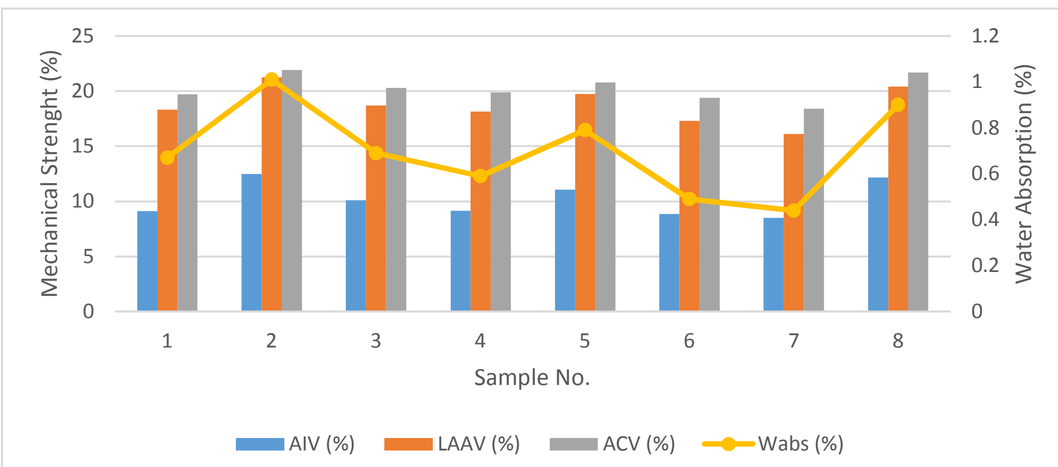


Fig. 5. Relationship between the mechanical strength (AIV, LAAV, ACV) and Water Absorption

A high concentration of physically strong minerals (i.e quartz) adds strength to rocks, as observed in Figures 6 – 8. The higher the percentage of quartz the lower the AIV, ACV and LAAV. Likewise in Figure 9, the higher the percentage of quartz the higher the 10% fines value. A similar relationship was also observed by previous researchers (Tugrul and Zarif, 1999; Sajid and Arif, 2014) who opined that quartz content has a primary effect on strength.

In comparison, the fine-grained varieties of sample S8 have noticeably lower strengths than its coarser equivalents S1, S3 and S5 (Table 2). This diminution of strength can be explained by the water absorption values for fine-grained sample S8 that is 0.9%, which is much higher than that of its counterparts with water absorption values 0.67%, 0.69% and 0.79% for S1, S3 and S5 respectively. The increases in water absorption rates are due to extensive recrystallization, as observed during petrographic analysis. Sajid and Arif (2014) stated that the degree of recrystallization is an important factor that must be considered as it greatly influences the water absorption capacity of rock, which has a negative effect on its strength. However, the lower strength of fine-grained sample S8 could also be said to be due to lower amount of quartz mineral (averaging = 33%) compared to its coarser equivalents with values for S1, S3 and S5 (averaging 36%, 47% and 38% respectively). The quartz content has a primary effect on strength, the strength increases as the quartz content increases (Tugrul and Zarif, 1999).

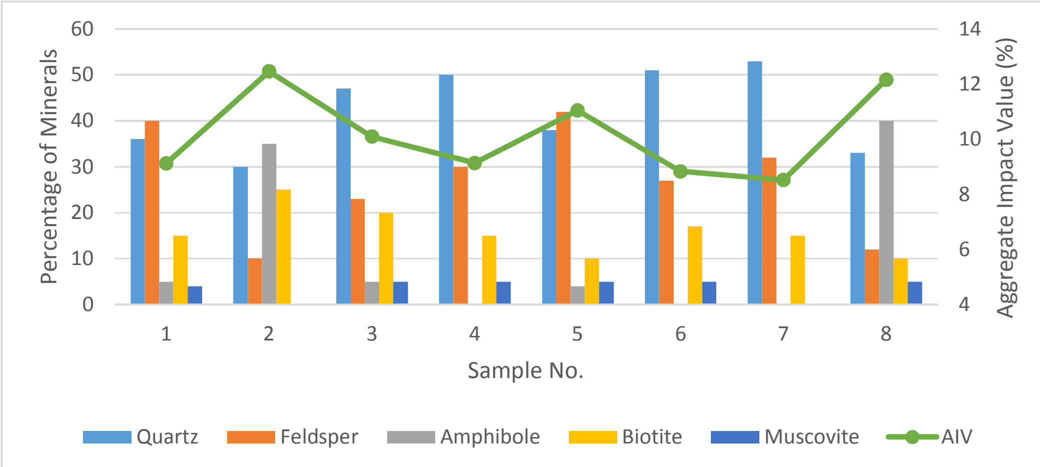


Fig. 6. Relationship between the percentage of minerals and Aggregate Impact Value

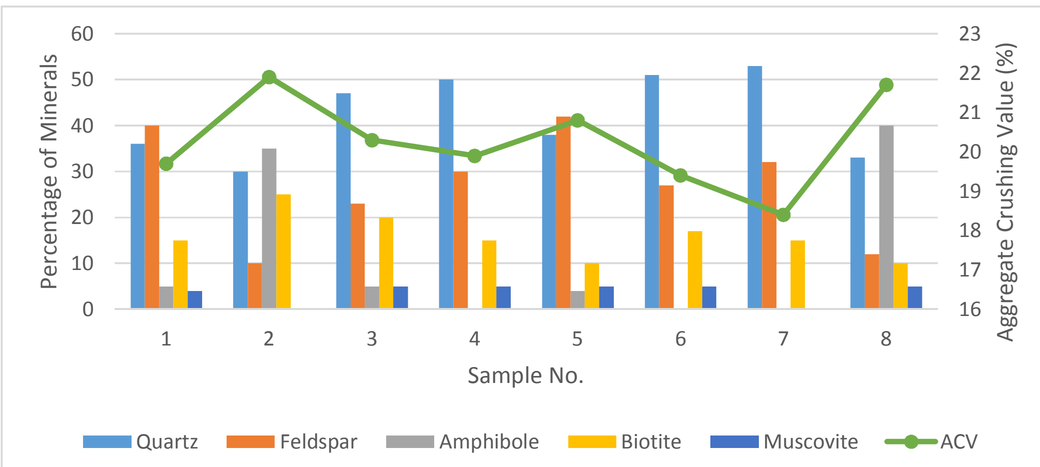


Fig. 7. Relationship between the percentage of minerals and Aggregate Crushing Value

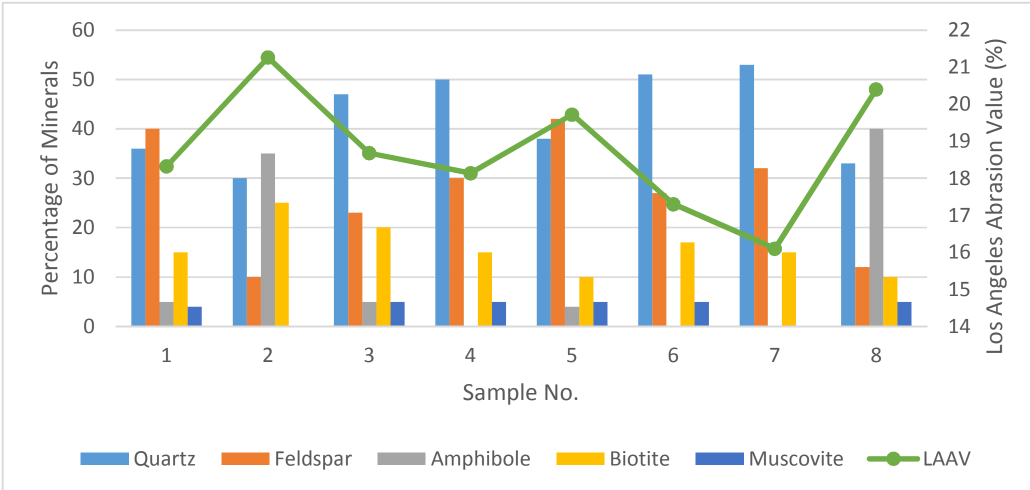


Fig. 8. Relationship between the percentage of minerals and Los Angeles Abrasion Value

S3 has a greater concentration of quartz (average = 47%) than S1 (average = 36%), although the strengths are greater in the latter than the former. The same scenario was observed between S5 with amount of quartz (averaging = 38 %) and S1 having quartz (averaging = 36 %), but the S5 sample is less strong. The reason for greater strength of each of the above mentioned samples could be attributed to their lower water absorption (S1 = 0.67%, S3 = 0.69%, and S5 = 0.79%) and finer texture. This is in consonance with Bell (2007), who concluded that rocks with fine-grained texture are generally stronger than their coarser equivalent. Also, Sajid and Arif (2014) reported that granites with greater strength possess lower water absorption values.

S7 possesses the highest strength amongst others due to its finest texture, lowest water absorption value (0.44%) and highest percentage of quartz (53%). Likewise, S2 has the lowest strength because of its possession of coarser texture than others, highest water absorption (1.01%) and lowest percentage of quartz (30%).

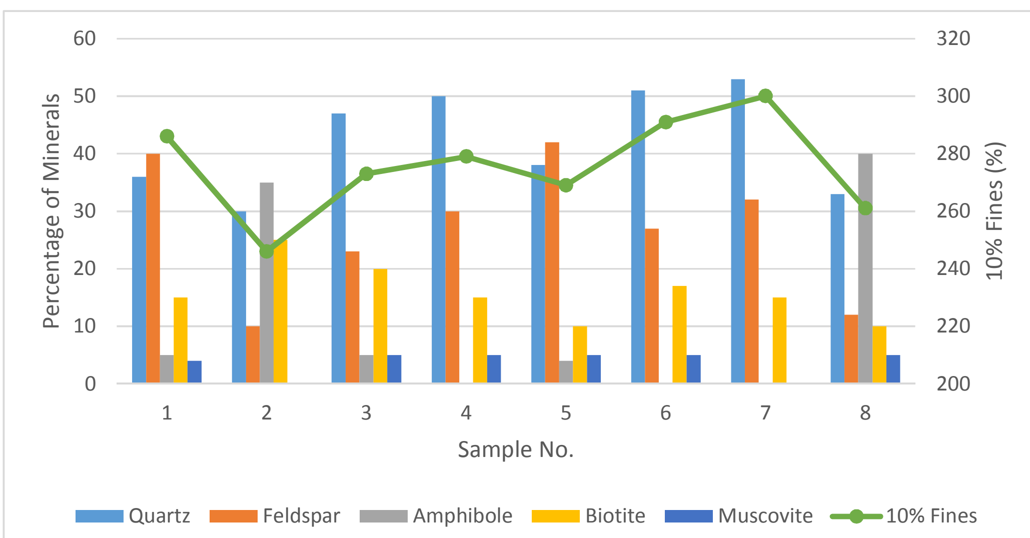


Fig. 9: Relationship between the percentage of minerals and 10% Fines Value

Correlations between the physical and mechanical properties

Pearson's correlation coefficient was used to measure the linear relationship between two tested properties of the rock samples. The value of the correlation coefficient, denoted as r, ranges from -1 to +1, which gives the strength of the relationship and whether the relationship is negative or positive. Figure 10 shows a negative correlation between aggregate specific gravity and water absorption rates which inferred low specific gravity value for rocks with high water content. Normally aggregate of high porosity exhibit high water absorption rate and low specific gravity while intact aggregate has low water absorption rate and high specific gravity (Amuda et. al., 2014). In Figure 11, 10% fines values and water absorption rates also gave a negative correlation. A similar relationship was also observed by a previous researcher (Jessica, 2014).

The 10% fines values and aggregate crushing value tend to have a strong negative correlation and are shown in Figure 12. The methodology of these tests is closely related and provides a good indication that the results for these engineering properties are correct. A good rock material is characterized by a high 10 % fines value and a low aggregate crushing value (Jessica, 2014).

The aggregate impact value and the aggregate crushing value show a positive correlation, as can be seen in Figure 13. Also, there is a positive correlation between aggregate impact value and Los Angeles value (Figure 14). Low aggregate impact value gives a low Los Angeles value. The 10 % fines and Los Angeles values are shown in Figure 15. A negative correlation was observed. The higher the 10 % fines values, the lower the Los Angeles values. 10 % fines values and aggregate impact values also show a negative correlation (Figure 16). Similar behaviors were also observed for rocks from Botswana (Jessica, 2014).
The Aggregate crushing value and Los Angeles value for all granite samples are shown in Figure 17. It shows a positive correlation, which also has been shown at the Road Research Laboratory (1959), who showed a 1:1 correlation between Aggregate crushing value and Los Angeles value.

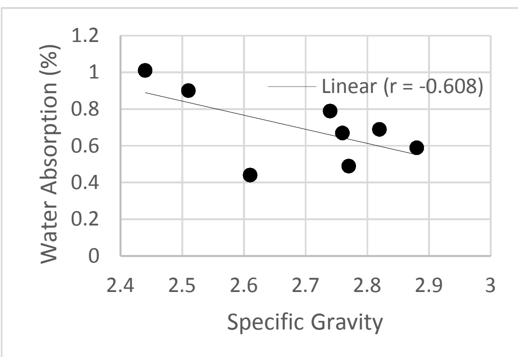


Fig. 10. Relationship between Specific Gravity and Water Absorption

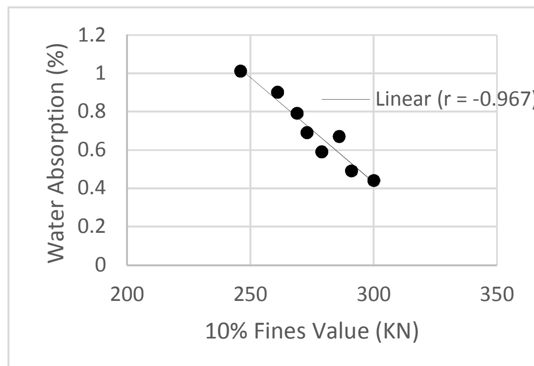


Fig. 11. Relationship between 10% Fines Value and Water Absorption

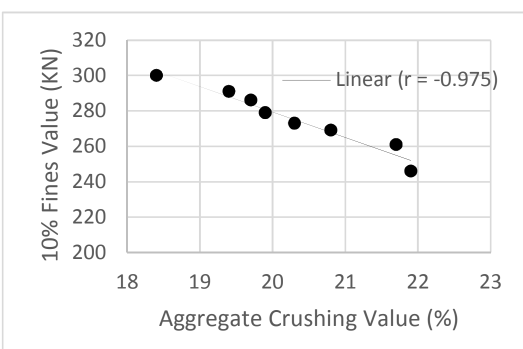


Fig. 12. Relation between Aggregate Crushing Value and 10% Fines Value

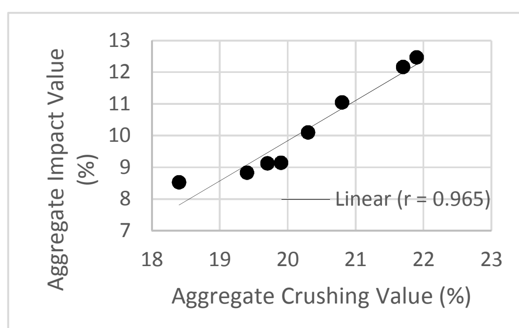


Fig. 13. Relationship between Aggregate Crushing Value and Aggregate Impact Value

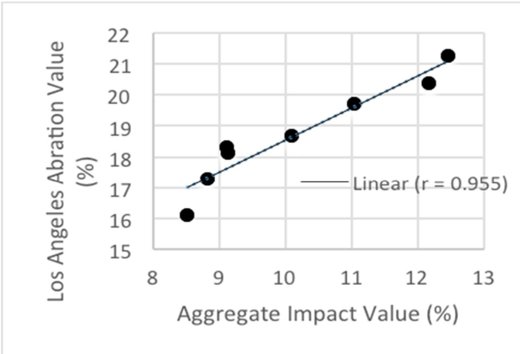


Fig. 14. Relationship between Aggregate Impact and Los Angeles Abrasion Value

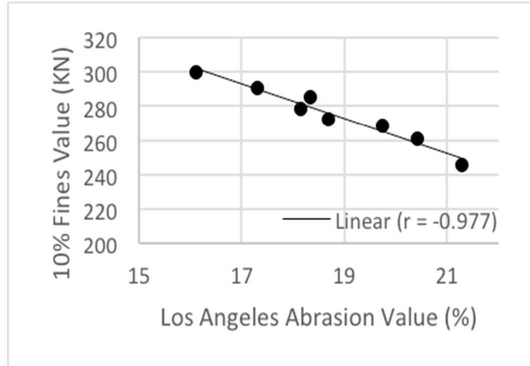


Fig. 15. Relationship between Los Angeles Abrasion and 10% Fines Value

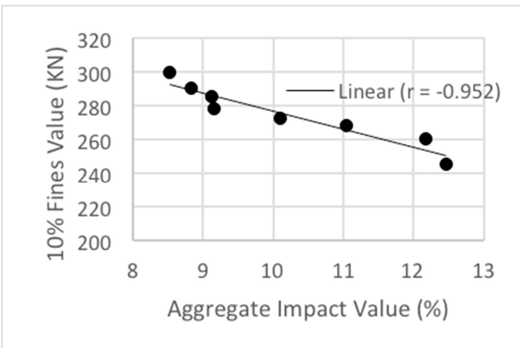


Fig. 16. Relationship between Aggregate Impact and 10% Fines Value

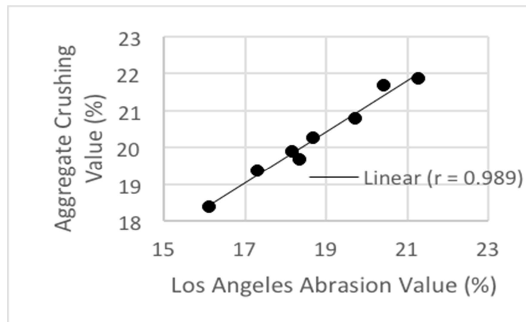


Fig. 17. Relationship between Los Angeles Abrasion and Aggregate Crushing Value

CONCLUSION

Aggregates are principal materials in concrete production and therefore knowledge of their properties is very crucial to designing an acceptable quality of concrete. A practical approach has been presented for the evaluation of rocks and aggregates from eight selected quarries that supplies coarse aggregate to the University of Ibadan for concrete production. The comprehensive evaluation used in this study revealed the link between physical, mechanical and geological properties of rock aggregates. Generally the rocks from all the quarries are regarded as strong and durable because of their possession of necessary characteristics for use in concrete works in accordance with BS, IS and ASTM standards.

The strength of the aggregates which were evaluated by a series of composite tests including Aggregate Impact Value (AIV), Los Aggregate Abrasion Value (LAAV), Aggregate Crushing Value (ACV) and 10% Fine Value revealed that samples which have performed better possess either lower water absorption capacity, finer texture or higher content of quartz mineral.

The water absorption rate for all the samples is very adequate except for Kopek samples which gave a slightly higher value due to microcrack/fracture observed during petrographic analysis. The specific gravity for most of the rock samples are greater than 2.6 which make them normal weight rock. Comparing the bulk density, percentage of voids, materials finer than 75microns sieve, flakiness and elongation index obtained from laboratory tests with standards, all the aggregate samples can be used for most construction works like concrete embankments, foundations and so on.

Among the engineering properties studied statistically significant correlations were found between specific gravity and water absorption, aggregate impact value and aggregate crushing value, Los Angeles abrasion and 10% fines value, aggregate impact and Los Angeles abrasion value, aggregate crushing and 10% fines value, 10% fines value and water absorption, aggregate impact and 10% fines value, Los Angeles abrasion and 10% fines value. It is concluded that aggregate samples tested have decreasing order of strength as follows: S7 → S6 → S4 → S1 → S3 → S5 → S8 → S2. The knowledge of this research work is recommended as a prospecting tool in selecting suitable rocks for the production of aggregate for optimum use in concrete.

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