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Petrographic and geotechnical evaluation of Ogwashi-Asaba ferruginised sandstone, Niger Delta, as aggregates for construction

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ABSTRACT

The need to reduce the high cost of long-distance haulage of aggregates has necessitated the search for suitable aggregates close to the construction site(s). The petrographic and geotechnical properties of Ogwashi-Asaba ferruginised sandstone were investigated to ascertain their utility potential. The petrographic, physical, and mechanical properties investigated include; the modal composition, texture, packing density, degree of interlocking of grains, specific gravity (SG), water absorption capacity (WAC), aggregate crushing, aggregate impact, and Los Angeles abrasion values. Which were determined according to BS and ASTM standards. The percentage of iron (Fe_2O_3) was determined by fusion inductively coupled plasma (FUS-ICP). The results show the mean value of quartz as 59.4%, sub-angular to angular shape, medium, medium-coarse, and coarse-grained with sutured, concavo-convex, and long contacts. The mean values for the S.G., WAC, ACU, AIV, and LAAV are 2.68, 4.80%, 53.76%, 41.99%, and 50.12% respectively, and 17.8% for Fe_2O_3. The medium-grained sandstone is preferred because of its relatively higher quartz percentage, more sutured contacts, and a greater degree of grains interlocking. Fe_2O_3 in sandstone has a strong negative correlation with AIV and ACV. This implies that Fe_2O_3 in sandstone will influence strength in sandstone thereby enhancing its utility potential. Though the ferruginised sandstone may be suitable as base course material in high-density traffic roads, it can be utilized as sub-grade and sub-base materials in low-density traffic roads.

1. Introduction

Sandstone occurs in abundance within the Asaba Capital Territory of Delta State in the Niger Delta region. Since Asaba assumed the status of State capital, massive infrastructural development has been going on within the Territory. This has led to a high demand for aggregates for various construction works. The huge cost of haulage of aggregates from other terrains has greatly increased the cost of construction hence the search for aggregates within the vicinity to reduce the cost of the construction material. Unfortunately, this vast resource has been neglected due to the unavailability of useful geotechnical information about them, when compared to granite, which is widely known and has been in use for a long period for various engineering construction projects within the area.

Rock aggregates are generally utilized based on their strength (Ugbe, 2020). Moving further away from the usual practice of investigating the geotechnical properties of only crystalline rocks, more research efforts have now been directed toward non-crystalline sedimentary rocks. By investigating the petrographic and geotechnical properties of non-crystalline rocks, rock quality can be determined, and this could suggest a possible deviation from the normal trend of utilizing only crystalline rocks.

Asif et al. (2022) investigated the geochemical, petrographical, and geotechnical properties of Carbonate rocks from Kohat Basin and reported them to be suitable as a potential source of aggregates for roads and other infrastructure. One such non-crystalline rock currently under investigation is sandstone which has been recommended for use as construction materials in different parts of the World (Shakoor and Bonelli, 1991; Ulusay et al., 1994). The research work of

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Chioma et al. (2021) on the quality of crushed Amasiri Sandstone suggests the possibility of using marginally suitable sandstone for construction purposes, provided that adequate design is made to compensate for their defects. Rakshit et al. (2021) while investigating the influence of micro-mechanical properties of sandstones of Western Indo-Burmese Ranges, Northeast India, opined their strength reduction to be a result of the presence of angular and semi-angular spherical grains. Similarly, Monsees et al. (2021) while investigating the relationship between diagenetic alteration and mechanical properties of Permian Siliciclastic sandstones suggested optical porosity which was linked to diagenetic alteration as a significant factor influencing its mechanical properties. Wang et al. (2019) who observed the failure modes for three types of sandstones noticed the destruction of the sandstone with the highest strength before the mudstone interface.

Edet (2018) while correlating the physico-mechanical parameters and geotechnical evaluations of some sandstones along the Calabar-Odukpani–Ikom–Ogoja highway transect, Southeastern Nigeria, reported that most of the sandstones are unsuitable for use as materials for building and foundation due to their low strength, high porosity, and water absorption. Sandstones interlayered with mudstone were also investigated by Wang et al. (2019) positing that the mudstone layer contributes significantly to the failure of the sandstone. Various researchers have suggested several parameters which influence their engineering properties such as grain size, packing density, modal mineralogical composition, degree of interlocking, type, and length of grain contact, and type and abundance of cement/matrix (Cantisani et al., 2013; Yar et al., 2017). In the face of rising calls encouraging the utilization of non-crystalline rocks which are close to the site of engineering construction, Buertey et al. (2016) and Van de Wall and Msc (1997) have however cautioned against their usage without prior investigation of possible variation in their physicomechanical properties which may exist on a site-to-site basis.

The sandstones in this current study are ferruginised, hard, and compact, unlike the sandstones in other parts of this terrain that are loose and friable. The aim of this study, therefore, is to evaluate the petrographic and geotechnical properties of these ferruginised sandstones. In addition, it also aimed at determining whether there is a correlation between modal composition, grain size, grain contact, and packing density with the physical and mechanical properties of the rock and to ascertain the possible utility potentials of the Ogwashi-Asaba ferruginised sandstone for construction purpose.

2. Location and geology of the study area

This study area is part of the Niger Delta Basin of Nigeria and is located between latitudes 6°11’24” to 6°11’29” N and longitudes 6°39’26” to 6°39’34” E (Fig. 1). The Ogwashi-Asaba Formation is generally composed of alternating bands of sandstone and shale (Ejeh et al., 2015a). The sandstone units exhibit a wide range of colors ranging from yellow, whitish, and red to dark reddish brown. It is sometimes friable, but mainly hard, indurated, and ferruginised (Ejeh et al., 2015b).

Three formations, namely, from the oldest to the youngest, the Akata, Agbada, and Benin Formations make up the subsurface Geology of the Niger Delta Basin of which the Asaba Capital Territory is part. The lateral equivalents of the Agbada Formation at the surface are the Ogwashi-Asaba and the Ameki Formations of the Eocene-Oligocene age. The Ogwashi-Asaba Formation is the main outcrop in the Asaba capital Territory (Short and Stäuble, 1967).

3. Materials and methods

Ten bulk rock samples were collected from the study location. The rockslides were prepared in the Thin Section Laboratory of the Earth Science Department at the University of Lagos, Nigeria using the Logitech thin section rock cutting machine (Model GT51). The rocks' slides were later viewed under the Olympus Trinocular Polarizing microscope. Photomicrographs of the rocks were obtained under cross- and plane-polarized light with the aid of a camera attached to the microscope. The modal composition of the sandstone was determined using the point count method (Chayes, 1949), while textural parameters including grain size, grain shape, packing density, and the degree of interlocking of grains were determined by visual inspection of thin sections observed under the microscope.

Major oxides geochemistry was determined by fusion inductively coupled plasma (FUS-ICP) with a detection limit of 0.001–0.1%. The analysis was conducted at Activation Laboratories Limited, Ontario Canada. This test was done to ascertain the percentage of Fe_2O_3 in the sandstones.

The bulk samples were crushed into suitable aggregates which were subjected to physical and mechanical analyses for parameters such as aggregate crushing value (ACV), Los Angeles abrasion value (LAAV), specific gravity (SG) and water absorption using applicable British Standard tests procedures such as BSI (2000) and BSI (2020). The ACV indicates the ability of the aggregates to resist crushing. It is largely controlled by texture, mineralogy, and degree of soundness of the aggregate (Waltham, 1994). The LAAV indicates the strength or wearing capacity of steel balls due to rubbing action with aggregates (Khanna and Justo, 1990). The aggregate impact value (AIV) is an estimate of its resistance to sudden impact or shock. SG is the ratio of the mass (or weight) in the air of a unit volume of a material to the mass of the same volume of water. Water absorption capacity (WAC) is the ratio of the weight of water absorbed by a material in the saturated state over the weight of the dry material.

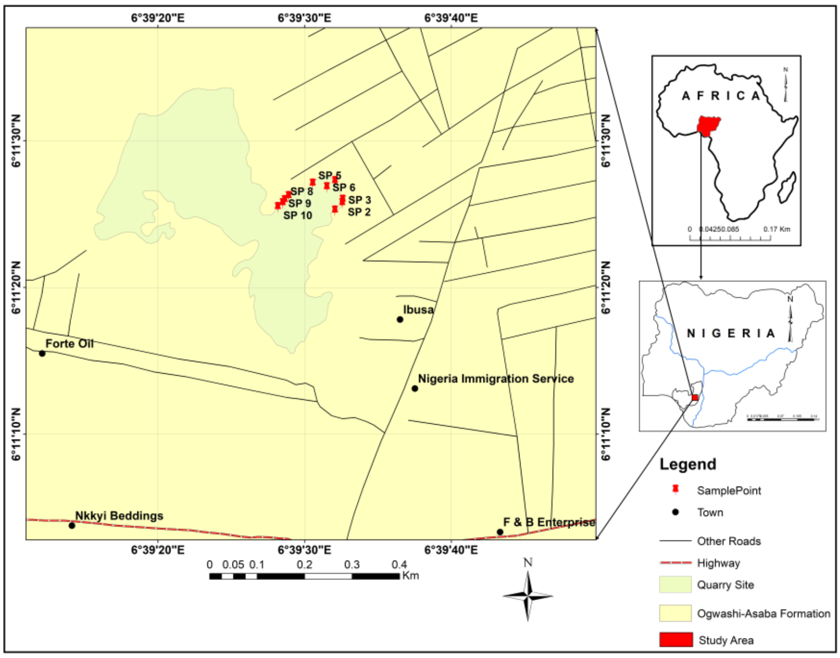

Fig. 1: Geological map of the study area

The statistical method involving the determination of the mean, standard deviation (Std), and coefficient of variation (COV) were used to determine the homogeneity of the data set for the different parameters investigated. Bar charts were also employed in the comparison of petrographic and mechanical properties together with regression analysis and t- and p-tests which were carried out to evaluate the correlation between petrographic and mechanical properties of the sandstone and to obtain t- and p-values for various parameters.

The Std for a given set of data is suggestive of the measure of spread within that data set, while the coefficient variation provides a standard measure of the dispersion of frequency distribution. The t- and p-values on the other hand reveal the statistical significance that may exist between group mean and the existence or non-existence of a statistical relationship between the two variables being studied.

4. Results and discussion

4.1. Physical, mechanical, mineralogical, and chemical composition of the ferruginous sandstone of the Ogwashi-Asaba formation

Results of the physical, mechanical, and chemical (Fe_2O_3) contents of the ferruginous sandstones are presented in Table 1. From Table 1, there is a clear indication that locations B and H have the highest percentage of quartz and lowest percentage of matrix and the highest percentage of the matrix is in the medium to coarse (A, C, F, G, and I) and coarse-grained sandstone (D, E, and J). The sandstone strength decreases when the matrix portion dominates because they are weak elements as postulated by Bell and Culshaw (1998). Furthermore, an increase in matrix content reduces the number of contacts between grains, reduces friction between grains, and consequently lowers sandstone strength (Bell and Lindsay, 1999).

4.2. Petrography of the ferruginous sandstone

The results of the petrographic analysis are shown in Fig. 2. Under cross-polarised light (XPL), thin sections of the ferruginous sandstones are light brown-yellowish to deep red with grain size ranging from medium to coarse and sub-angular to angular in shape (Figs. 2a-2f). The petrographic analysis revealed the Ogwashi-Asaba ferruginised sandstones comprise three varieties namely: Medium-grained, medium- to coarse-grained, and coarse-grained ferruginised sandstones (Fig. 2). They generally range from sub-angular to angular in shape. The iron oxides/hydroxides act as cement and appear to have been precipitated during the chemical diagenesis of the pristine sediments. Quartz minerals are typically strongly fractured.

The medium- to coarse- and coarse-grained sandstones have floating contact and low packing proximity as observed at Locations A, C, D, E, and J (Figs. 2b and 2c) which imply that they have lower strength than the medium-grained sandstone at Locations B and H (Fig. 2a). The medium-grained sandstone samples (B and H) have more grain contact which also suggested an increasing value of packing proximity (Fig. 2a). These types of grain contacts occur as sutured, concavo-convex, and long contacts. The number of such contacts is higher for the medium-grained sandstone and the percentage of a weak matrix is less as compared to other coarse-grained sandstones. The particles are however randomly oriented. Hence, the medium-grained sandstone tends to be higher in strength than the other two sandstone varieties in this study.

Table 1: Physical, mechanical, mineralogical, and Fe_2O_3 content of the Ferruginised Sandstone of the Ogwashi-Asaba formation

S#	[1]LAV	[2]ACV	[3]AIV	[4]SG	[5]WAC	[6]Qtz	Fe_2O_3	Matrix
A	46.2	49.5	41.3	2.66	4.8	56	20.9	38
B	42.7	46.1	39.4	2.75	3.9	66	21.8	25
C	45.4	49.2	40.9	2.69	4.7	59	21.3	32
D	62.1	65.3	45.5	2.59	6.2	46	4.11	40
E	57.6	60.4	43.7	2.62	5.3	64	15.5	27
F	50.8	54.8	42.6	2.69	4.9	62	22.7	31
G	49	52.6	42.1	2.69	4.7	61	16.7	31
H	40.3	44.7	38.6	2.77	3.5	70	24	23
I	54.8	58.9	43	2.65	5.1	48	15.6	42
J	52.3	56.1	42.8	2.69	4.9	62	15.7	31
Mean	50.12	53.76	41.99	2.68	4.80	59.40	17.8	32.0
Std	6.81	6.59	2.03	0.05	0.73	7.56	5.8	6.31
COV	13.58	12.26	4.84	2.02	15.28	12.73	32.6	19.71

1: LAAV; 2: ACV; 3: AIV; 4: SG; 5: WAC; 6: Quartz content. Note: 1-3, 5, and 6 are in %

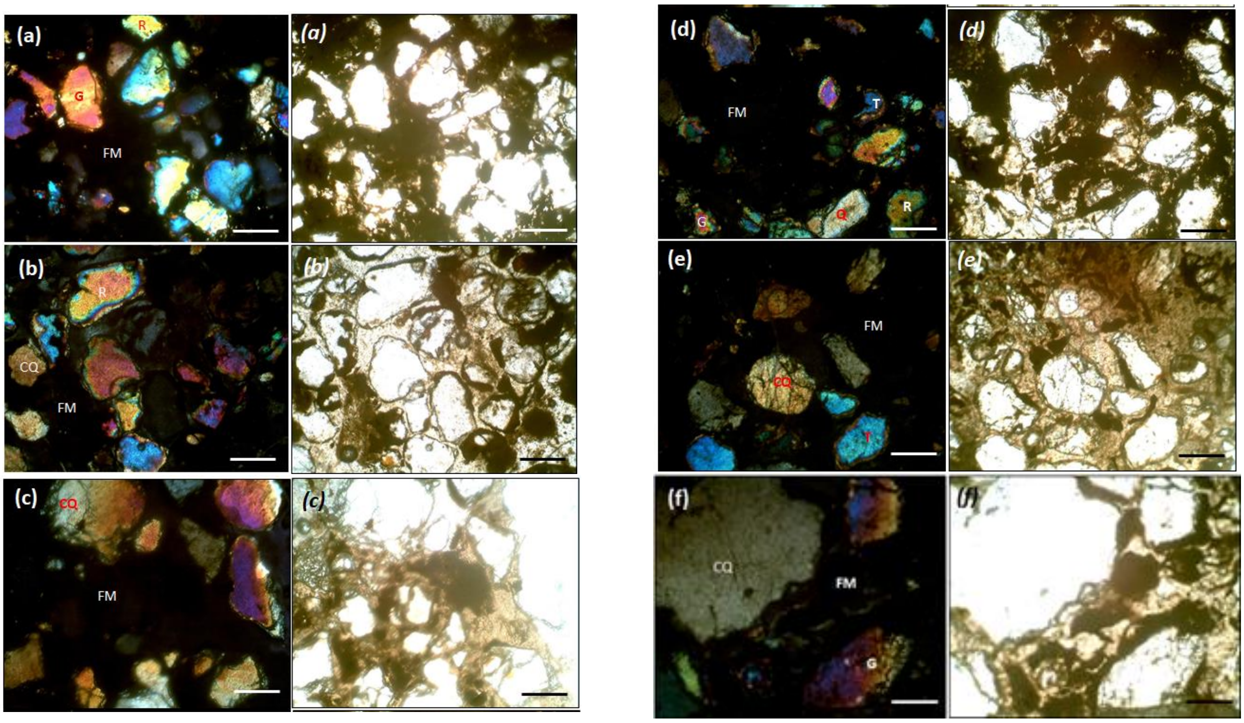

Fig. 2: (a) and (b): Photomicrographs of medium–grained sandstone, samples B and H respectively. Loosely packed, floating medium-grained, sub-angular to angular, fractured quartz and heavy mineral fragments are evident within the ferruginous matrix (FM), under cross-polarized light (XPL, labeled in the ordinary font) and plane-polarized light (PPL, labeled in italic font). Scale bar 3mm. (c), (d), and (e): Photomicrographs of medium to coarse-grained sandstone samples C, F, and G respectively indicating loosely packed, floating medium-coarse grained, sub-rounded to sub-angular, fractured, and corroded quartz and heavy mineral fragments in a ferruginous matrix (FM), under plane polar (labeled in italic font) and cross-polarized light (labeled in the ordinary font). The heavy mineral present is Tourmaline minerals Scale bar of 3mm. (f): Photomicrographs of coarse-grained sandstone, sample J, showing loosely packed, floating coarse-grained. Sub-angular, fractured, and corroded quartz and heavy mineral fragments in a ferruginous matrix, under plane polar (labeled in italic font) and cross-polarized light (labeled in the ordinary font). The heavy mineral present is Garnet. Scale bar 3mm

4.3. Fe_2O_3 composition of the ferruginous sandstone

The mean value of Fe_2O_3 in the sample was 17.8%, with a Std of 5.8, and a COV of 32.6 (Table 1). This shows a moderate degree of homogeneity of the Ogwashi-Asaba ferruginised sandstone.

4.4. Geotechnical properties of the Ogwashi-Asaba formation

The geotechnical properties of the ferruginised sandstone of the Ogwashi-Asaba Formation examined are SG, water adsorption capacity (WAC), ACV, LAAV, and AIV.

A. SG: The SG values ranged from 2.59–2.77.
B. WAC: The WAC varies from 3.5% to 6.2%. ASTM (1990) recommended that the WAC must have a maximum value of 1% for rocks to be considered good construction materials. The value shows that the rock is highly permeable due high amount of pore spaces, which means that the rock is highly porous and indicates low strength of the rock. Porous aggregates are generally unsuitable for construction purposes as they are highly permeable and can further be weakened by permeable fluids.
C. ACV: The ACV ranges from 44.7% to 65.3%.
D. LAAV: The LAAV varies from 40.3% to 62.1%.
E. AIV: AIV varies from 38.6% to 45.5%.

The ACV, LAAV, and AIV are above the standard engineering requirements (<30%) recommended by the BSI (1990a) for materials suitable for use as a surface-wearing course. Keikha and Keykha (2013) noted that the lower the AIV, the stronger the aggregate, implying that they are weak and can easily wear out due to relative friction between the pavement and moving vehicles thereby causing a reduction in the stability and durability of the pavement.

Mean values were calculated to establish average results (Table 1). Std and COV were also calculated to establish the degree of heterogeneity in the characteristics of the rock samples. The ACV has a mean value of 53.76%, a Std of 6.59, and a COV of 12.26. The LAAV shows a mean value of 50.12%, Std 6.81, and COV 13.58. AIV shows a mean value of 41.99%, Std of 2.03, and COV of 4.84. The SG values show a mean value of 2.68%, Std of 0.05, and COV of 2.02. The WAC shows a mean value of 4.80%, Std of 0.73, and COV of 15.28 (Table 1).

Ideally, results for the AIV and the SG show considerable homogeneity of the rock samples with a COV of less than 10. The results of the ACV, LAAV, and WAC reveal considerable heterogeneity of the rock samples with COV between 10 and 15. The mean value of the quartz content of the ferruginised sandstones is 59.40%, Std of 7.6, and COV of 12.73. This shows a considerable heterogeneity of the rock samples (Table 1). From Table 1, the sandstone samples with higher quartz contents have lower aggregate crushing and abrasion values which indicates higher strength. On the other hand, the other samples with lower quartz content have higher aggregate crushing and abrasion values which indicates lower strength. An increase in quartz content suggests a decrease in aggregate crushing and abrasion values respectively (Fig. 3 and Table 1).

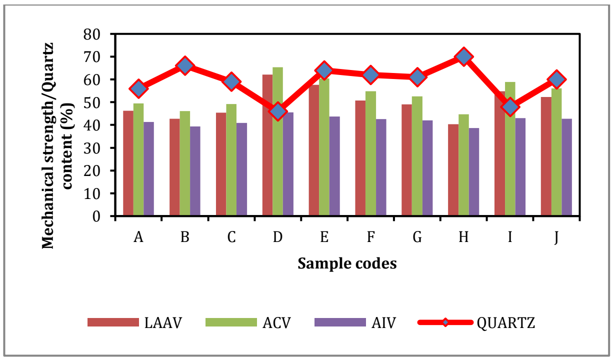

Fig. 3: Relationship between strength properties (ACV, LAAV, AIV) and Quartz content

The sandstone samples at Locations B and H have higher quartz contents of 66 and 70%; lower crushing values of 46.1% and 44.7%, and lower abrasion values of 42.7% and 40.3% respectively; these depict a higher strength than those from other locations whereas the sandstone with lower quartz contents showed higher abrasion and crushing values which indicate lower strength. The strength of rocks increases with an increase in quartz content (Ugbe, 2020). An increase in the percentage of Fe_2O_3 content shows a decrease in the percentage of aggregate crushing, impact, and abrasion values. This implies that high Fe content indicates high strength of the ferruginised sandstone (Fig. 4).

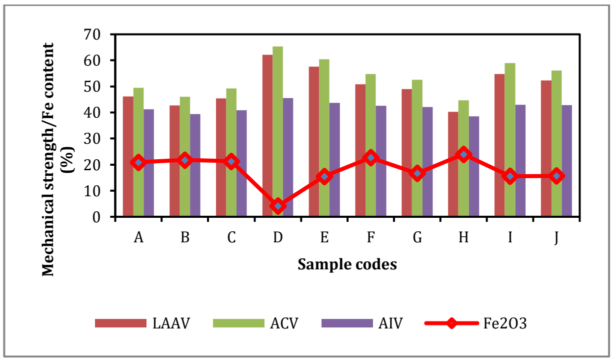

Fig. 4: Plot showing the influence of Fe on strength properties (ACV, AIV, LAAV) of the rock

An increase in water absorption values (WAV) shows an increase in aggregate crushing and abrasion values which indicates lower strength (Table 1 and Fig. 5). The sandstone sample H showed lower WAV which indicates that the sandstone sample H is less porous but higher strength than those from other locations. The sandstone sample D showed higher absorption values which indicate that it is more porous and of weaker strength than those from other locations (Table 1).

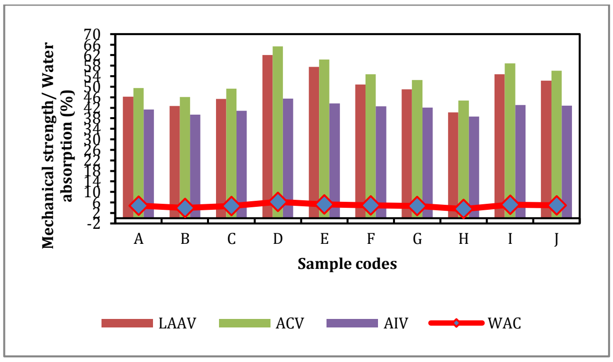

Fig. 5: Relationship between strength parameters (ACV, LAAV, AIV) and water absorption

4.5. Regression analysis

Regression analysis was performed to determine the influence of mineralogy on the mechanical strength properties and to establish possible correlations between the geotechnical parameters of the ferruginised sandstone (Table 2). Fig. 6 shows the relationship between the strength parameters. It shows a negative correlation between the quartz content versus LAAV and quartz content versus ACV and AIV versus Fe_2O_3 and ACV versus Fe_2O_3. These imply that higher quartz content suggests lower crushing and abrasion values which are an indication of rock with higher strength. Statistical significance was observed across the various variables tested. As p-values less than the pre-decided alpha value ($p=0.05$) were obtained for LAAV versus Quartz content, ACV versus Quartz content, AIV versus Fe_2O_3, and ACV versus Fe_2O_3 (Table 2).

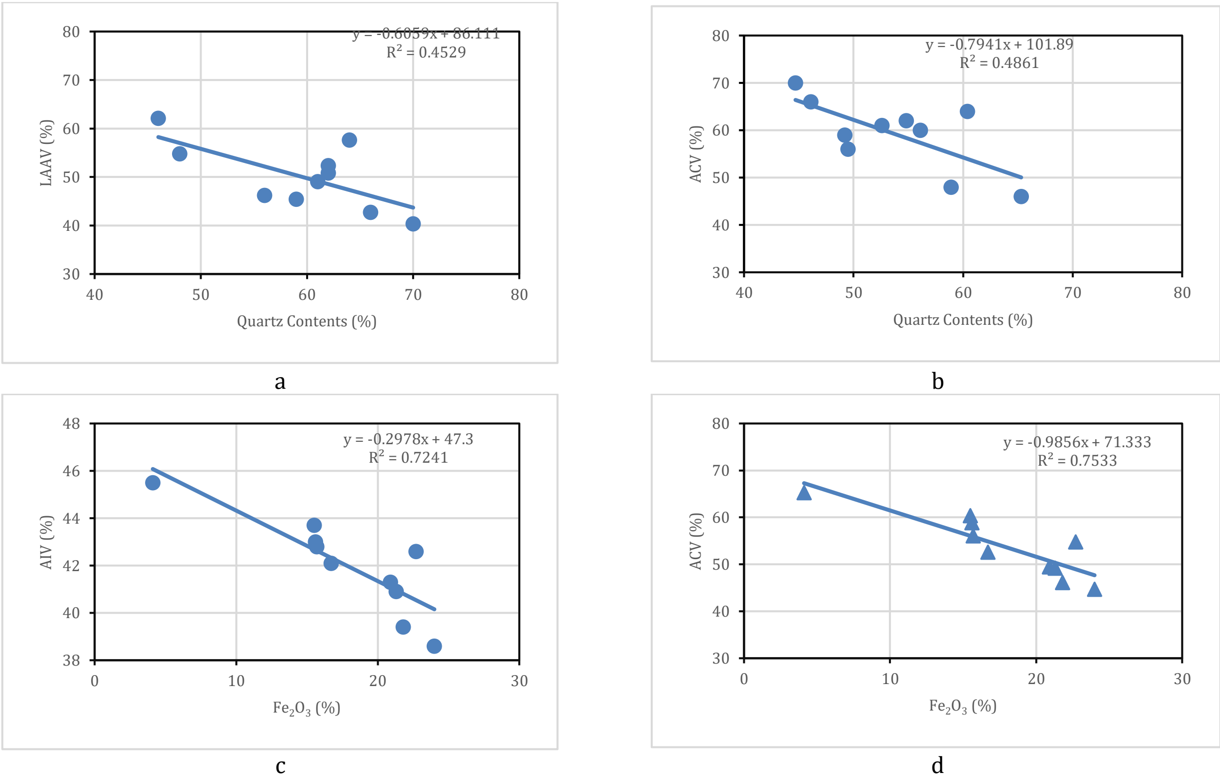

Fig. 6: (a) Relationship between quartz content vs LAAV; (b) Relationship between quartz content versus ACV, (c) Relationship between Fe_2O_3 versus AIV; (d) Relationship between Fe_2O_3 versus ACV

4.6. Comparison of Ogwashi-Asaba Ferruginised sandstones and other sandstones

The results obtained after investigating the mineralogical and geotechnical properties of the Ogwashi-Asaba Sandstones were compared with the results of recent studies, (Nwimo et al., 2021; Khan et al., 2021) as shown in Table 3.

4.6.1. Petrographic analyses

The result of the modal analysis (Table 3) revealed the Ogwashi-Asaba ferruginised sandstones to have the highest value of quartz at 66% whereas the Amasiri Sandstones (Chioma et al., 2021) had the highest value of quartz at 64%. On the other hand, the lowest value quartz (46%) was noticed in Ogwashi-Asaba ferruginised sandstones and 55% for the Amasiri Sandstones.

4.6.2. LAAV

The LAAV of the ferruginised sandstones was compared with the work of Khan et al. (2021) (Table 3). All the abrasion resistance values obtained for the current analyses are above the acceptable limit of 35% recommended by ASTM (2001) except for sample NKS-04 having an abrasion resistance value of 26%.

4.6.3. AIV

The AIV for Ogwashi-Asaba ferruginised sandstone has all exceeded the <35% acceptable limit recommended by BSI (1990b) when compared with the results of Khan et al. (2021) with almost all of the values falling within the acceptance value, except for sample TKKS-02, as shown in Table 3.

4.6.4. Aggregates crushing values (ACV)

The ACV for this study when compared with those of Nwimo et al. (2021) showed that the Ogwashi-Asaba ferruginised sandstone is unsuitable as construction aggregate with its crushing resistance value exceeding the <35% recommended by the BSI (1990a). On the other hand, the aggregate crushing resistance value which was reported by Chioma et al. (2021) all fall within the range considered suitable for aggregate which is to be used for pavement construction.

4.6.5. WAV

The WAV for the current study and those obtained by Khan et al. (2021) and Chioma et al. (2021) when compared revealed that the Ogwashi-Asaba ferruginised sandstone fell short of <2% by that recommended by ASTM (2015). For Khan et al. (2021) only samples KGKS-03 and GRKS-05 with WAV of 1.7 and 1.95% fell within the acceptance range. Similarly, in the work of Nwimo et al. (2021), only samples Q-PR-2 and Q-PR4 within the values of 1.98 and 1.37% meet the suitability requirements.

4.6.6. SG values

The SG values obtained for the Ogwashi-Asaba ferruginised sandstone all fell within the >2.55 range recommended by ASTM (2015). For Chioma et al.

(2021) the SG for samples Q-PR 1, Q-PR 3, Q-PR 4, and Q-PR 5 measured as apparent SG fell short of the range of values recommended. Similarly, the SG for Kamlial Sandstone was measured as apparent SG. However, they did not meet the <2% recommended for aggregates to be considered suitable for use in construction.

5. Conclusions

This study has revealed three types of ferruginised sandstone of the Ogwashi-Asaba Formation. They are medium-, medium- to coarse-, and coarse-grained ferruginised sandstones. The medium-grained sandstone is characterized by higher strength than the others. The high strength of the medium-grained ferruginised sandstone is attributable to the following; moderately compacted and cemented, high contents of quartz, lower matrix composition, and lower WAC.

Table 2: T- and P-values

Variables	t-values	p-values	Remark
LAAV versus Quartz content	-2.573	0.033	Significant
ACV versus Quartz content	-2.639	0.030	Significant
AIV versus Fe_2O_3	-4.582	0.002	Significant
ACV versus Fe_2O_3	-4.943	0.001	Significant

Table 3: Comparison of mineralogical and geotechnical properties of Ogwashi-Asaba Sandstones with other published works

This work		Other studies (Chioma et al., 2021; Khan et al., 2021)	
Sample #	Values (%)	Sample #	Values (%)
Quartz content (%)			
A	56	[1]Q-PR1	63
B	66	[1]Q-PR2	60
C	59	[1]Q-PR3	55
D	46	[1]Q-PR4	60
E	64	[1]Q-PR5	64
F	62	[1]Q-PR6	60
LAAV			
A	46.2	[2]PNKS-01	41
B	42.7	[2]KGKS-02	67
C	45.4	[2]CHK-03	39
D	62.1	[2]NKS-04	26
E	56.1	[2]CDKS-05	34
AIV			
A	41.3	[2]PNKS-01	30.33
B	39.4	[2]TKKS-03	37.57
C	40.9	[2]CHKS-03	21.50
D	45.5	[2]NKS-04	22.33
E	43.7	[2]CDKS-05	19.00
ACV			
A	49.5	[1]Q-PR 1	31
B	46.1	[1]Q-PR 2	25
C	49.2	[1]Q-PR 3	27
D	65.3	[1]Q-PR 4	26
E	43.7	[1]Q-PR 5	29
WAV			
A	4.8	[2]TKKS-01	2.42
B	3.9	[2]THKS-02	2.30
C	4.7	[2]KGKS-03	1.70
D	6.2	[2]KGKS-04	2.10
E	5.3	[2]GRKS-05	1.90
		[1]Q-PR 1	3.83
		[1]Q-PR 2	1.98
		[1]Q-PR 3	2.68
		[1]Q-PR 4	1.37
		[1]Q-PR 5	3.03
SG values			
A	2.66	[2]TKKS-01	1.90
B	2.75	[2]KHKS-02	2.40
C	2.59	[2]KGKS-03	2.30
D	2.62	[2]KGKS-04	1.80
E	2.69	[2]GRKS-05	1.80
		[1]Q-PR-1	2.38
		[1]Q-PR-2	2.88
		[1]Q-PR-3	2.48
		[1]Q-PR-4	2.54
		[1]Q-PR-5	2.53

1: Results/values after Chioma et al. (2021); 2: Result/values after Khan et al. (2021)

The study also revealed that the greater the content of Fe_2O_3, the higher the strength of the ferruginised sandstone. The medium-grained sandstone is also characterized by a higher percentage of Fe_2O_3 than both the medium- to coarse- and the coarse-grained ferruginised sandstones. Despite the high strength attribute of the medium-grained ferruginised sandstone, they still fall short of the requisite strength that a base course material for high-density traffic road pavement requires.

The medium-grained sandstones at Locations B and H exhibit higher strength than those from other locations. It is however too weak to be used as a base course material in high-density traffic (Trunks A and B) roads because they do not meet engineering requirements; however, it can be used as a sub-base material for low-density traffic (Trunk C) roads, rural community, farm roads, and building foundations. The medium- to coarse-grained sandstone found at Locations A, C, F, G, and I which exhibit lower strength than the medium-grained sandstone in B and H can be used as a sub-grade material in low-density traffic roads. In addition, it can also be used for lintels in building structures.

The coarse-grained sandstone at Locations D, E, and J possesses lower strength than those from other locations and as such it can be used as fill material in the construction of very low-density traffic (Trunks D and E) roads such as farm roads and minor street roads because they are not mechanically stable and as such would affect the durability of the road structure.

Compliance with ethical standards

Conflict of interest

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