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COMPRESSIVE STRENGTH OF CONCRETE USING LATERITIC SAND AND QUARRY DUST AS FINE AGGREGATE

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ABSTRACT

This paper is part of a study investigating the structural characteristics of concrete using various combinations of lateritic sand and quarry dust as complete replacement for conventional river sand fine aggregate. Samples of concrete (eg. cubes) were made using varying contents of laterite and quarry dust as fine aggregate. The quantity of laterite was varied from 0% to 100% against quarry dust at intervals of 25%. The samples were cured for specified periods and tested in the laboratory for compressive strength. Workability tests were earlier carried out to determine the optimum water/cement ratios for three different mixes, namely: 1:1:2, 1:1.5:3 and 1:2:4. It was found that 0.5 water/cement ratio produced higher compressive strengths for 1:1:2 mix, while 0.6 water/cement ratio exhibit better workability for 1:1.5:3 mix proportion. Specifically compressive strength ranged from 17-34.2 N/mm^2 for the mixes considered. These results compare favourably with those of conventional concrete. The concrete was found to be suitable for use as structural members for buildings and related structures, where laterite content did not exceed 50%.

Keywords: concrete, compressive strength, lateritic sand, quarry dust.

1. INTRODUCTION

A number of attempts have been made to provide local alternatives to the use of river sand as fine aggregate in conventional concrete (e.g. Adepegba [1, 2]; Lasisi and Osunade [3]; Salau [4]; Jayawardena and Dissanayake [5, 6]; Osadebe and Nwakonobi [7]).

Recent developments in the building construction industry in Calabar, southern Nigeria and it's environ have witnessed an increasing use of local lateritic sand generally referred to as 'sharp-sharp sand' from borrow pits around town for block moulding and concrete works. Some combine the sandy laterite with quarry dust and this practice has continued without any reliable data on the structural integrity of the resulting structures. This is worrisome given the spate of building collapses in some major cities of the country. The works of previous researchers on laterized concrete have not addressed this problem because of the differences in physical properties such as particle size distribution couple with low values of compressive strengths.

Visual observation of the laterite material shows that the variation of sand is much sharper than those considered in previous works. This is confirmed by the preliminary assessment of its particle size distribution. There is therefore every reason to believe that this lateritic sand can be used in structural concrete production. The particle sizes of aggregates are known to affect the strength properties of concrete greatly. In a related development, substantial quantities of quarry dust are found in heaps around Calabar in the Crushed Rock sites. Quarry dust is known to be useful fillers in bituminous concrete. However, its continuous accumulation in recent times has become an environmental problem. It is logical that one way of disposing of it can be its beneficial incorporation into structural concrete system.

The knowledge of structural characteristics and performance of concrete made with these materials is necessary for the accurate design of structural elements in buildings and bridges. Compressive strength is arguably the most widely used strength parameter for concrete. This may be due to the nature of concrete, being strong in compression and weak in tension.

The focus of a good national development is to look inwards with intent to mobilize all natural resources for economic purposes. One of the policy thrusts of the present government is to provide affordable housing for the people. The use of lateritic sand in combination with quarry dust can help achieve this purpose and impact positively in reducing the cost of building materials. This study aims at proper documentation of the materials to support their specification in design and construction.

2. PREVIOUS STUDIES

2.1 Laterite

According to Makasa [8], the soil name "laterite" was given by Buchanan (1807) in India, from a Latin word "later" meaning brick. Laterite is used extensively in the construction of embankments for roads and earth dams.

Lateritic soils, according to Osadebe and Nwakonobi [7] are widely used as construction material in Nigeria and other under-developed and developing countries of the world. However, they argue that laterites have not been extensively used in constructing medium to large-size building structures, probably because of lack of adequate data needed in the analysis and design of structures built of lateritic soils. This underscores the need for more research efforts in this area.

According to Adoga [9], Laterite is a highly weathered material rich in secondary oxides of Iron, Aluminum or both. It is nearly devoid of base and primary silicates but may contain large amount of quarts, and Kaolinite. Laterite has been used for wall construction around the world; it is cheap, environmentally friendly and abundantly available building material in the tropical region [10].

Ayangade *et al*., [11] reported that approximately 30% of the world's present population still lives in lateritic structures. They observed that the restriction of laterite building to rural areas is due to lack of accepted standard design parameters for the effective structural applications of laterized concrete. They described Terracrete as a mixture of laterite (as fine aggregate), granite or gravel (coarse aggregate), cement and water in a chosen weight proportion, mixed by means that are available and equally allowed to undergo curing processes.

2.1.1 Laterized concrete

Laterized concrete is defined as concrete in which stable laterite fine replace aggregate (i.e., Sand) [12]. Adepegba was identified as the first to study the effect of using laterite as fine aggregate in concrete [13]. This was supported by Salau [12] when he asserted that "Adepegba (1975) recommended laterite upto 40% in clay for laterized concrete". In a further research by Adepegba [2], he compared resistance to high temperature, modulus of elasticity and compressive and tensile strength of laterized concrete mixes (1:2:4; 1:1.5:3 and 1:1:2 by weight) with that of normal concrete. He concluded that for high strength and workability only 25% of sand in concrete should be substituted with lateritic fine, while the mix ratio should be 1:1.5:3 (cement: sand/laterite: granite) with a water/cement ratio of 0.65.

According to Osunade [14], laterized concrete is concrete in which the fine aggregates are lateritic soils. Laterite is a mixture of clayey iron and aluminum oxides and hydroxides formed as a result of the weathering of basalt under humid, tropical conditions. It is readily available in all parts of Nigeria.

The quest of having concrete which is cheaper has prompted many researchers to work on laterized concrete. Different properties of laterized concrete have been considered at different stages with far reaching recommendations in favour of laterite as suitable for use in the construction industry.

Working on shrinkage deformations of laterized concrete, Salau and Balogun [15] recommended that laterized concrete with up to 25% laterite content of the aggregate could be used in load-bearing structural elements. It was also found out in another work by Balogun and Adepegba [16] that the most suitable mix for structural application of laterized concrete was 1:1.5:3 with about 0.65 water/cement ratio provided that the percentage of laterite content was kept below 50%. They asserted also that compressive strength of not less than 25 N/mm^2 was obtained at 28days for the mix with laterite content of about 25-50%. A combination of crushed granite, sharp sand and fine laterite was used in their experiment.

Lasisi and Osunade [3] listed mix proportion, water/cement ratio, curing ages, grain size ranges, stress level, laterite soils- river sand variation as some of the factors that affect the strength and creep properties of laterized concrete. They observed that increase in cement content and decrease in water/cement ratio results in increase in the compressive strength of laterized concrete.

According to Lasisi and Osunade [3], the creep of laterized concrete, unlike that of conventional concrete which showed some definite recovery after unloading, did not show any form of recovery. Lasisi and Ogunjide [17] also established that the higher the laterite/cement ratio, the lesser the compressive strength, and the fewer the grain size range, the higher the compressive strength.

Udoeyo *et al*., [18] had also agreed with other researchers that with up to 40% replacement level of sand by laterite, laterized concrete attained the strength of $20N/mm^2$. They recommended laterized concrete for the construction of buildings and rural infrastructures.

Laterized concrete has also been found to have similarity with conventional concrete in some properties: Falade [19] found that the already established variations in workability and compressive strength of normal concrete with water/cement ratios are valid for laterized concrete.

Salau [4] observed in his paper "Long-term deformations of laterized concrete short columns" that there were not many variations between the creep deformations of laterized concrete and normal concrete short columns. He further recommended 25% laterite content of the aggregate for long-term resistance and usage in load-bearing short column members.

Efe and Salau [20] showed that normal concrete cannot withstand appreciable load above 250°C while laterised concrete with 25% laterite in the fine aggregate is able to resist higher load with increase in age and at temperature up to 500°C. They achieved compressive strength of up to $30.44N/mm^2$ for laterized concrete with 25% laterite and 75% sand at 500°C. Laterized concrete according Efe and Salau [20] can be classified as normal-weight concrete as the density of all test specimens of 28-day curing age exceeds $2000Kg/m^3$. They also observed that there is economic saving if laterized concrete is used in areas of high temperature up to 500°C. This differs from the findings of Udoeyo *et al*., [21] that the strengths of laterized concrete and normal concrete decreased in a similar manner when subjected to elevated temperatures of between 200°C and 600°C.

Udoeyo *et al*., [22, 23] also found that the workability of laterized concrete increases with laterite content with slump values ranging from 2 - 20mm, while the water absorption showed a reverse trend, i.e., decrease with increase in laterite content. Also Adepegba [2] recommended 0.65 water/cement ratio as suitable for normal workability.

2.2 Quarry dust

Crushed rock aggregate quarrying generates considerable volumes of quarry fines, often termed "quarry dust". The finer fraction is usually smaller than

ARPN Journal of Engineering and Applied Sciences

5mm in size [24]. The use of quarry dust in concrete according to Chaturanga *et al*., [25] is desirable because of the benefits such as useful disposal of a by-product, reduction of river sand consumption and increase in strength. Quarry dust has rough, sharp and angular particles, and as such causes a gain in strength due to better interlocking.

Quarry dust has been identified as possible replacement for sharp sand in concrete works. Jayawardena and Dissanayake [5, 6] in their paper "Use of quarry dust instead of river sand for future constructions in Sri Lanka" identified quartz, feldspar, biotite mica, hornblende and hypersthenes as the major minerals present in fresh rock which show mica percentages between 5% and 20%. They added that mica percentages in charnocktic gneiss and granitic gneiss are always less than 5%, similar to sand and therefore suitable for use in civil engineering construction. They reported that sand mining had been banned in some areas of major rivers in Sri Lanka because of its negative environmental impact. Granite rock is abundant in Nigeria giving rise to many quarry sites with large heaps of quarry dust. Hence, quarry dust can be reasonably used as alternative to river sand.

Also, Shahul *et al*., [26] observed that natural sand is usually not graded properly and has excessive silt, while quarry rock dust does not contain silt or organic impurities and can be produced to meet desired gradation and fineness as per requirement. This consequently contributes to improve the strength of concrete.

Agbede and Joel [27] described quarry dust as a cohesionless sandy material acquired either naturally (which is rare) or artificially by the mechanical disturbance of parents rocks (blasting of rocks) for construction purposes, composed largely of particles with a diameter range of 0.05mm to 5.00mm. They found in their study on "suitability of quarry dust as partial replacement for sand in hollow block production" that quarry dust is cheaper than River Benue sand during rainy season.

Sridharan, *et al*., [28] conducted shear strength studies on soil-quarry dust mixtures and observed that 20-25% of the total production in each crusher unit in India is left out as waste-quarry dust. This waste problem may be avoided as it could be converted into useful application in concrete production.

2.3 Concrete with quarry dust as fine aggregate

In a study in Thailand by Khamput [29] on the compressive strength of concrete using quarry dust as fine aggregate and mixing with admixture type E, it was found that with 70% quarry dust the concrete produced compared well with normal concrete. He recommended quarry dust for replacement with sand in general concrete structures.

Ilangovana *et al*., [30] studied the strength and durability properties of concrete containing quarry dust as fine aggregate and found that the compressive, flexural strength and durability studies of concrete made with quarry rock dust were nearly 10% more than the conventional concrete. Their workability results showed slump values ranging between 60 - 90mm and compacting factor 0.87 - 0.90 for grade 20 concrete. The range of 28 - day's compressive and flexural strengths for grade 20 concrete were found to be 23.7 - 34.50 N/mm^2 and 3.45 - 6.40 N/mm^2 respectively.

3. MATERIALS AND METHODS

Laterite one of the two fine aggregates used for this research work was obtained from a borrow pit site at Akim-Akim in Odukpani local government area of Cross River state at a depth of 2.5m. Quarry dust, the second fine aggregate used in this study was taken from the abundant deposits at Akamkpa Quarry site in Akamkpa local government area of Cross River state. Akamkpa L.G.A is adjacent to Odukpani L.G.A both in the southern senatorial district of Cross River state. The two sites are less than 15 minutes' drive from Calabar city centre. The coarse aggregate used was crushed granite chippings of 20mm nominal size produced at Akamkpa quarry site.

Ordinary Portland cement (hydraulic binder that sets and hardens by chemical interaction with water) conforming to BS12 was used. The UNICEM brand of ordinary Portland cement sold in Calabar was used in this research. The cement was well protected from dampness to avoid lumps.

Portable tap water supplied by the Cross River State Water Board in Calabar for domestic consumption was used throughout the research experiments. Water is important in starting the reaction between cement and other constituent materials. The binding property of cement cannot take effect without water.

The materials used for this research were cement, laterite, quarry dust, coarse aggregate (crushed granite) and water. Cement was purchased and taken to the laboratory in sealed 50kg bags, while the fine and coarse aggregate were obtained from piles of each material in borrow pits for laterite and quarry site- for quarry dust and coarse aggregate and transported to the laboratory. Water was obtained directly from the tap in the materials laboratory. The water was fit for drinking. The concrete samples were 150mm cubes. The tests were carried out at the materials laboratory of the Cross River University of Technology, Calabar.

The materials were air dried in the laboratory. The coarse aggregate (granite chippings) was passed through sets of sieves, the portion passing through sieve (20mm) and retained on sieve (5mm) was used. The laterite and quarry dust used in the experiments were those passing sieve (2mm) and retained on sieve (150μm). All tests were conducted according to the relevant British Standard (BS) (eg. BS 1881 [31, 32, 33]). The materials were specified according to BS 882 [34], BS 5328 [35], and BS 8110 [36].

3.1 Specimen preparation

The batching of concrete was done by weighing the different constituent materials based on the adopted mix ratios of 1:1:2; 1:1½:3; and 1:2:4, respectively. The fine aggregate portion of the mix was achieved by combining laterite and quarry dust in ratios with 25% steps starting with 0% laterite: 100% quarry dust (i.e., 0%-100%; 25%-75%; 50%-50%; 75%-25%; and 100%-0%). This was repeated for different mix ratios stated above. The materials were then mixed thoroughly before adding the prescribed quantity of water and then mixed further to produce fresh concrete. Water/Cement ratios of 0.5, 0.54, 0.6 and 0.7 were adopted.

The freshly mixed concrete was then filled into moulds in approximately 50mm layers with each layer given 35 strokes of the tamping rod. The concrete was towelled off level with the top of the mould and the specimen stored under damp sacking for 24hours in the laboratory before de-moulding and storing in water for the required curing age. A total of 195 cubes were made.

Testing of the hardened cubes were carried out after 3days, 7days, 14days, 21days, and 28days, respectively using a compression testing machine. The cube sample was placed between hardened steel bearing plates on a compression machine and load applied at the rate of 15N/mm^2 per minutes as specified in BS1881. The sample was wiped off from grit and placed centrally with load applied steadily to destruction and the highest load reached was determined. This is used to compute the compressive strength which is the ratio of the highest load to the cross sectional area of the sample expressed in N/mm^2. Three samples were used for each test and the average results adopted as the compressive strength.

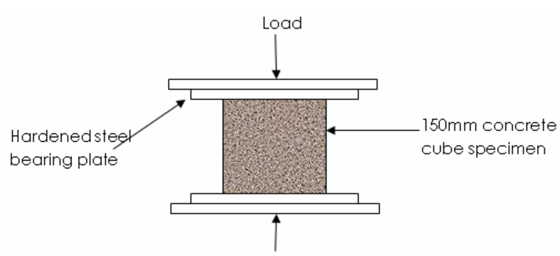

Figure-1. Loading arrangement for compressive strength test.

4. RESULTS AND DISCUSSIONS

In order to achieve the objective of this work various laboratory tests were conducted on the raw laterite and combination with quarry dust as well as the concrete derived from them in their fresh and hardened states. Below is a detailed discussion on the results obtained. The analysis is carried out in tables and graphs, while the results are discussed in comparison with works of previous researchers.

4.1 Physical properties of materials

The results of physical properties of laterite and quarry dust are first presented in this chapter followed by those of both fresh and hardened concrete produced using laterite and quarry dust concurrently as fine aggregates.

The specific gravity of materials namely: laterite, quarry dust and coarse aggregate were found to be 2.56, 2.67 and 2.71, respectively. Detailed results of physical properties are presented in appendix 1. The values are in agreement with the results of Udoeyo *et al*., [18] and Ilangovana *et al*., [30]. Bulk densities of laterite, quarry dust and coarse aggregates were found to be 1460, 1230 and 1830Kg/m^3 respectively. The densities of hardened concrete cube samples were found to be within the range of 2391 - 2591Kg/m^3. This is within the range for normal weight concrete.

The results of particle size distribution for laterite, quarry dust and coarse aggregate are shown in Figure-2. The particle size distribution of Laterite is uniformly graded with a uniformity coefficient of 3.25, while quarry dust has a uniformity coefficient of 11.25. The particle sizes of coarse aggregate range from 5mm to 20mm with a Cu value of 1.82.

The curves for different combinations of the fine aggregates are superimposed and compared with the overall limits given in BS 882:1992 [34] for grading of sand aggregate for concrete works as presented in Figure-2. The fine aggregates were found to be within the overall limits given in BS 882. The laterite used by Efe and Salau [20] which had over 80% of the particle size less than 1mm were found to be finer than the lateritic sand used in this study with 60% of the material more than 1mm in size. This indicates great difference between the Calabar lateritic sand and those used by previous researchers.

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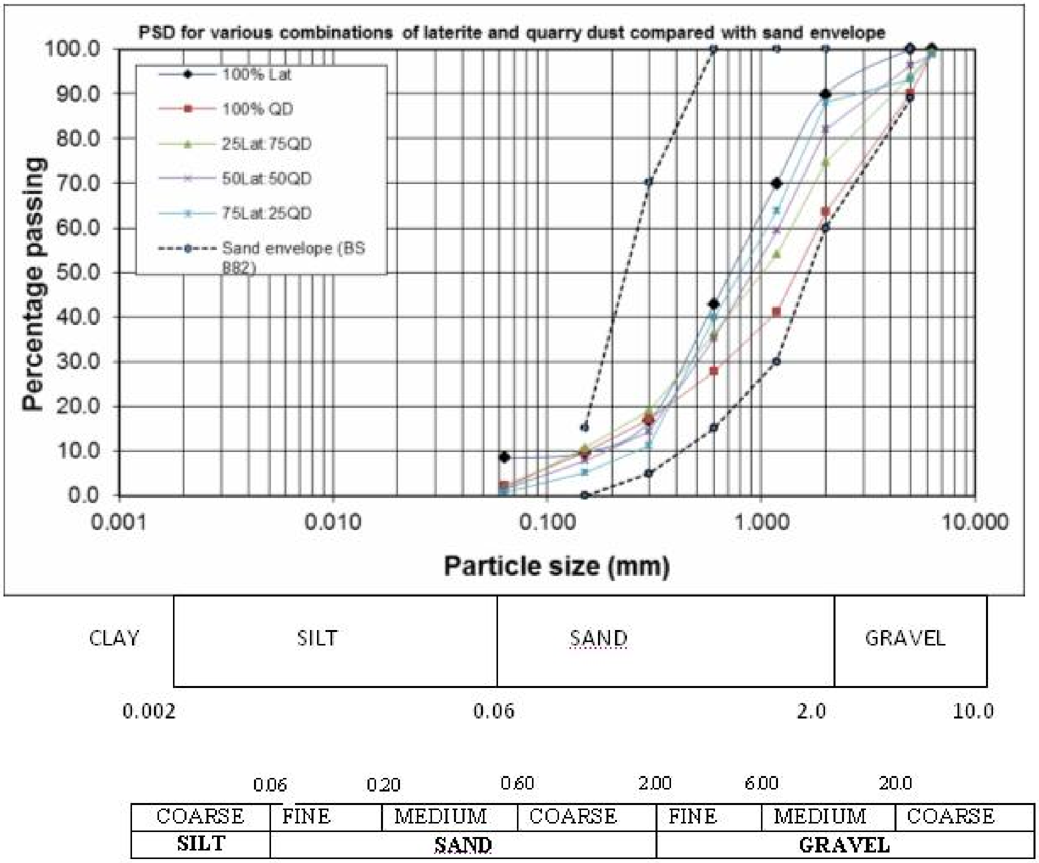

Figure-2. Particle size distribution curves for various combinations of laterite and quarry dust compared with specified sand grading envelope.

4.2 Workability

Concrete using lateritic sand and quarry dust as fine aggregates exhibit three basic forms of slump depending on the water/cement ratio just like normal concrete (i.e., True, Shear and Collapse). This can be seen in the slump results shown in Figure-3 (a to c). The slump is between 0 and 175mm.

(a) True Slump (b) Shear Slump (c) Collapse Slump

Figure-3. Typical slump measurement (true, shear and collapse slump).

Workability test results are analyzed in Figure-4. It can be seen that workability increases with corresponding increase in laterite content up to 50% only and this is true for 0.6 water/cement ratio alone. Beyond 50% laterite content, workability decreases with increase in laterite content for 0.7 water/cement ratio. The results of both slump and compacting factor indicate that water/cement ratio of 0.5 produces virtually no workability for 75% laterite content. This implies that the concrete is not workable at this water/cement ratio. These results agree with the findings of past researchers- Adepegba [2], Salau and Balogun [15], Balogun and Adepegba [16], *et al*., who in their separate works on laterized concrete recommended 0.65 water/cement ratio as most suitable for laterized concrete.

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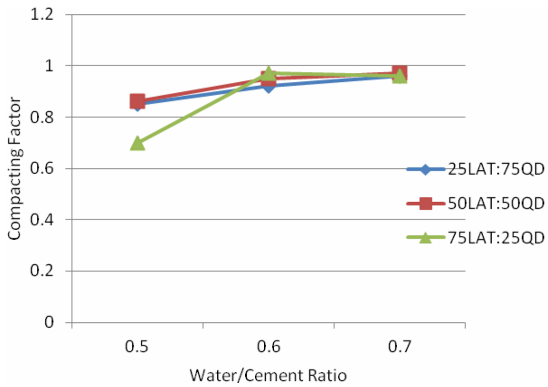
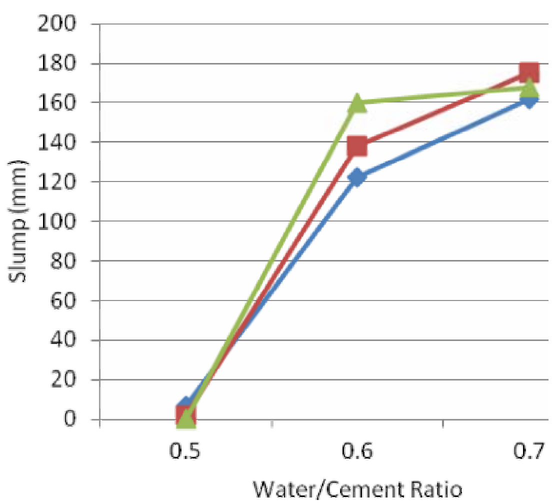
The compacting factor ranges from 0.85 - 0.97 which is close to the range of 0.82-0.95 specified in BS 1881, part 103 of 1993 [32]. It is 0.02 higher showing that laterized concrete with quarry dust with up to 0.7 water/cement ratio produces higher workability. The workability results of this study also compare favourably with those obtained by Adoga [9] for laterite rock concrete (0.81-0.99). The results of slump and compacting factor tests are presented in Figure-4.



(a) Compacting factor



(b) Slump

Figure-4. Slump and compacting factor with water/cement ratio for various mixes.

4.3 Variation of compressive strength of concrete with age

The relationship between strength and age of concrete using lateritic sand and quarry dust as fine aggregate is shown in Figure-5. 1:1.5:3 mix and water/cement ratio of 0.54 were used.

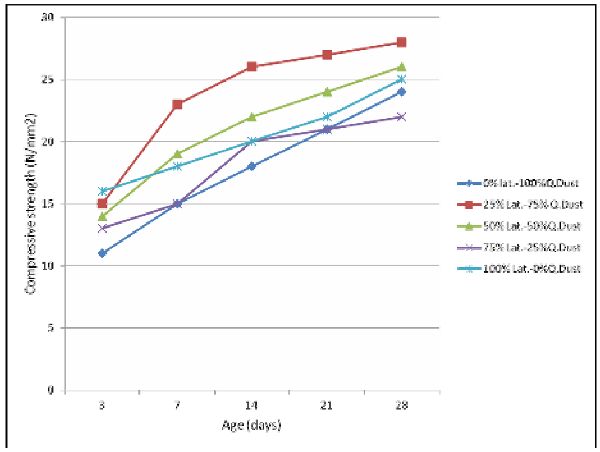


Figure-5. Variation of compressive strength with age for various mixes.

The variation of compressive strength (N/mm^2) with Age (in days) for the experimental concrete at 0.54 water/cement ratio shown in Figure-5 compares well with the previous works of Efe and Salau [20], Ilangovana *et al*., [30], and Udoeyo *et al*., [18]. Furthermore, it can be seen that concrete using Calabar lateritic sand and quarry dust combination of 25% laterite and 75% quarry dust produced the highest strength in agreement with the works of previous researchers. Similarly the curve for 100% laterite and 0% quarry dust from this study also agrees with the work of Udoeyo *et al*., [18] up to 21 days of age for laterized concrete. Further observation shows that 50% laterite and 50% quarry dust curve lies between the two cases mentioned above. The strength for 100% quarry dust was low for the same water/cement ratio probably because of excessive water in the concrete which exceeds the required amount for the hydration of cement since quarry dust does not have much water absorption capacity. This agrees with the work of Khamput [29] who gave a lower water/cement ratio of 0.45 as optimum for concrete using quarry dust as fine aggregate. The result of Ilangovana *et al*., [30] for quarry dust also compares closely with others. The maximum compressive strength of 28.0N/mm^2 for 25% laterite: 75% quarry dust combination at 0.54 water/cement ratio was established using 1:1.5:3 mix proportion.

The data for 28-day compressive strength of concrete with the proportion of 25% laterite: 75% quarry dust, 1:1.5:3 mix and 0.54 water/cement ratio were fitted by different trend models, namely: linear, polynomial and logarithmic. The results show that the logarithmic model provide the most appropriate model for predicting the compressive strength of concrete using lateritic sand and quarry dust as fine aggregate up to 28 days of casting concrete. The three models are shown in Table-1 below with their coefficients of determination (R^2).

where
Y = compressive strength of concrete at any given age up to 28 days (in N/mm^2)
X = age of concrete (in days)

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Table-1. Different models for predicting compressive strengths of concrete with age.

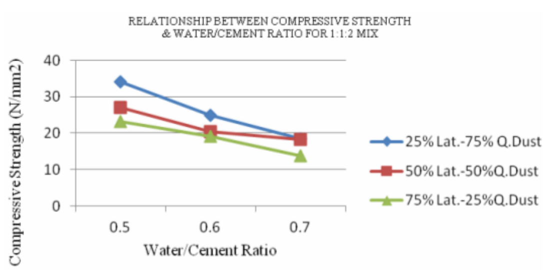
Description	Model	R^2
Linear	$Y = 0.4443X + 17.313$	0.7363
Polynomial	$Y = -0.0318X^2 + 1.4257X + 12.404$	0.9206
Logarithmic	$Y = 5.6529Ln(X) + 10.165$	0.9346

Hence, the compressive strength of the experimental concrete at any given age between 0 and 28 days can be estimated using the equation:

$$Y = 5.6529Ln(X) + 10.165 \quad (1)$$

4.4 Variation of compressive strength with water/cement ratio and laterite/quarry dust ratio

The variations of compressive strengths of concrete with water/cement ratios for various combinations of laterite and quarry dust, and those of compressive strengths with laterite/quarry dust combinations for different mixes are presented in Figures 6 to 8. It can be seen in Figure-6 that the highest compressive strength of 34.2N/mm^2 was attained for 1:1:2 mix with 25% laterite and 75% quarry dust combination at 0.5 water/cement ratio. The mix ratios agree with the work of Olugbenga [13]. As expected the strength was found to be inversely proportional to the water/cement ratio. Also, it can be seen that compressive strength of the experimental concrete decreases as the proportion of laterite increases for the 3 mixes considered.



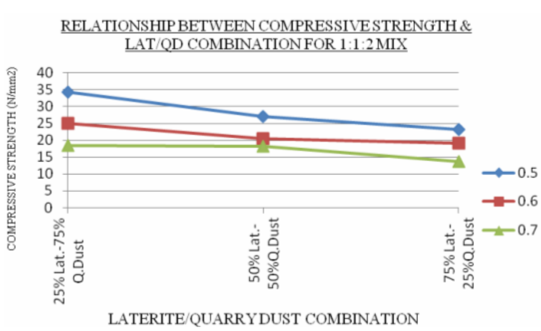
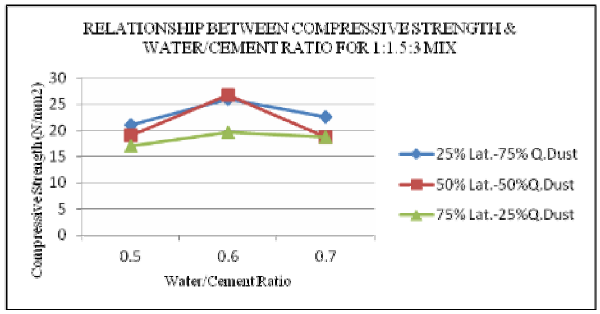


Figure-6. Variation of compressive strength with water/cement ratio and laterite/quarry dust ratio for 1:1:2 Mix.

Figure-7 shows that for 1:1.5:3 mix, the optimum water/cement ratio is 0.6. Laterite is known to absorb water which gives reason for the high water/cement ratio. The ideal water/cement ratio is that which allows optimal water absorption for laterite with just enough water remaining for the hydration of cement. This agrees closely with Balogun and Adepegba who were quoted by Olugbenga [13] that "the most suitable mix of laterized concrete for structural purposes is 1:1.5:3, using batching by weight with a water/cement ratio of 0.65, provided that the laterite content is kept below 50% of the fine aggregate content." Also the second part of the Figure-7 shows overall decrease in compressive strength as laterite proportion increases, similar to 1:1:2 mix shown earlier.



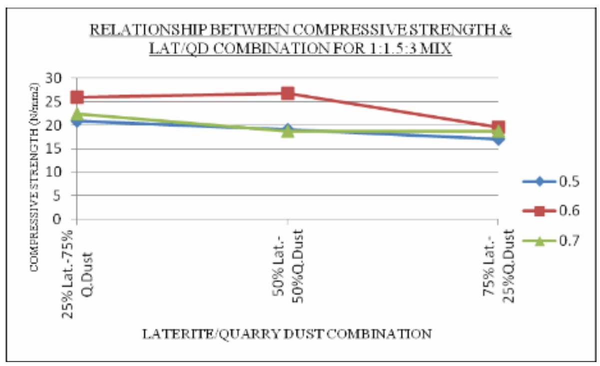


Figure-7. Variation of compressive strength with water/cement ratio and laterite/quarry dust ratio for 1:1.5:3 mix.

Figure-8 below shows increase in compressive strength with corresponding decrease in laterite content at 0.5 water/cement ratio. This may be due to the high water absorption property of laterite which left insufficient water in the mix for the complete hydration of cement. There is however a convergence at 0.6 water/cement ratio for different combinations of laterite and quarry dust. For the second part of Figure-8, only 0.5 water/cement ratio shows a trend of decrease in compressive strength with increase in laterite proportion. No clear trend is shown for other water/cement ratios, indicating that these ratios may not be suitable for 1:2:4 mix.

Udoeyo *et al.*, [18] in their study on the strength performance of laterized concrete fixed a constant water/cement ratio of 0.56 which does not reflect the variation of laterite and sand in the concrete mix. From the findings of this study, their compressive strength results could have been higher with a slightly higher water/cement ratio, since the strength of concrete at a

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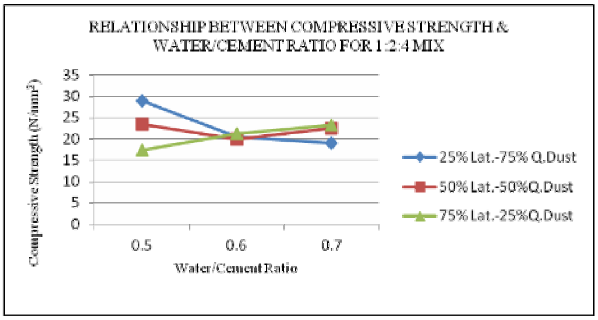
given cured age depends primarily on water/cement ratio and the degree of compaction according to Neville [37].



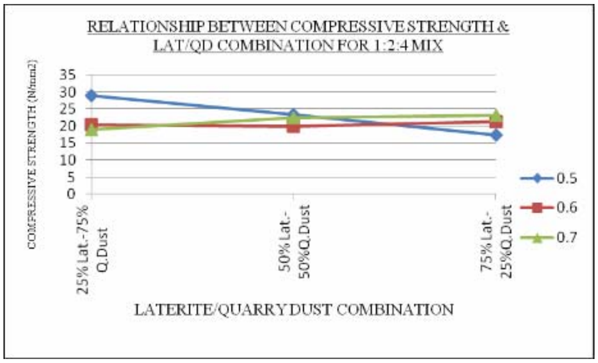


Figure-8. Variation of compressive strength with water/cement ratio and laterite/quarry dust ratio for 1:2:4 mix.

5. CONCLUSION

It can be seen from the results of this study that the combination of laterite and quarry dust to replace the conventional river sand in the production of concrete for the construction industry in Nigeria and other tropical countries of the world results in structures with reasonable structural characteristics, and should be encouraged where there is comparative cost advantage. The following conclusions can be made from this study:

i) The following physical properties of laterite, quarry dust and granite chippings were investigated, namely: specific gravity, density and particle size distribution. The specific gravities for laterite, quarry dust and granite chippings were found to be 2.56, 2.67 and 2.71 respectively. Similarly their bulk densities were 1460, 1230 and 1830Kg/m^3, respectively. The particle sizes of fine aggregates (i.e., laterite and quarry dust) ranged from 0.06-6mm, while coarse aggregate (i.e., granite chippings) sizes ranged from 5 - 20mm. These properties are within the overall limits specified in BS882 for concrete work;

ii) The workability of concrete using lateritic sand and quarry dust as fine aggregates was found to have the same trend with normal concrete. Slump and compacting factor tests were used to measure workability. The slump results ranged from 0-175mm, while compacting factor ranged from 0.85-0.97 depending on water/cement ratio. Workability was found to increase with increase in water/cement ratio. The proportion of 25% laterite to 75% quarry dust and 50% laterite to 50% quarry dust with 0.6 water cement ratio produced workable concrete with good structural characteristics;

iii) The density of hardened concrete using lateritic sand and quarry dust was found to range from 2293-2447 Kg/m^3. This is within the range for normal weight concrete; and

iv) The compressive strengths of concrete using lateritic sand and quarry dust were measured in the laboratory. Compressive strength was found to increase with age as for normal concrete. The 28 - day compressive strength was found to range from 17 - 34.2N/mm^2 for different mixes. The above strength properties were found to compare closely with normal concrete. The proportion of 25% laterite to 75% quarry dust produced higher values of compressive strength. For the same proportion of 25% laterite and 75% quarry dust at 1:1.5:3 mix and 0.54 water/cement ratio, a logarithmic model has been developed for predicting the compressive strength of concrete between 0 and 28 days.

Further work is required to get data for other structural properties of the experimental concrete. These include: flexural strength, tensile strength, shear strength, water absorption, resistance to impact, creep, etc. The knowledge of the above properties will greatly assist engineers, builders and designers when using the materials for construction works.

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Appendix-1. Physical properties of materials used.

Material	Property	Value
Laterite	Bulkdensity (Kg/m^3)	1830
Quarry dust	Bulkdensity (Kg/m^3)	1230
Coarse aggregate	Bulkdensity (Kg/m^3)	1460
Laterite	Specific gravity	2.56
Quarry dust	Specific gravity	2.67
Coarse aggregate	Specific gravity	2.71
Laterite	Liquid limit	30%
Laterite	Plastic limit	15
Laterite	Plasticity index	15
Laterite	Moisture content	13.5%
Laterite	Sieve analysis	0.6mm to 5mm
Quarry dust		0.6 to 5mm
Coarse aggregate		5mm to 20mm

Appendix-2. Results of workability (slump and compacting factor).

Mix proportion	% laterite/ % quarry dust combination	Water/cement ratios	Slump (mm)	Compacting factor
1:1.5:3	27/75	0.5	7	0.85
		0.6	122	0.92
		0.7	162	0.96
1:1.5:3	50/50	0.5	2	0.86
		0.6	138	0.95
		0.7	175	0.97
1:1.5:3	75/25	0.5	0	0
		0.6	160	0.97
		0.7	168	0.96

Appendix-3. Summary of compressive strength with age (water/cement ratio = 0.54, 1:1½:3).

Slump (mm)	Mix/age (days)	3	7	14	21	28
31-35	0% lat.-100%Q.Dust	11	15	18	21	24
30-33	25% Lat.-75%Q.Dust	15	23	26	27	28
29-31	50% Lat.-50%Q.Dust	14	19	22	24	26
28-30	75% Lat.-25%Q.Dust	13	15	20	21	22
20-27	100% Lat.-0%Q.Dust	16	18	20	22	25

Appendix-4. 28th day compressive strength for 1:1:2 mix.

% LAT/Q. dust	Mix ratio	w/c	Slump (mm)	Density	Compressive strength
25LAT:75Q.DUST	1:1:2	0.5	70	2453	34.2
		0.6	180	2347	25
		0.7	225	2190	18.5
50LAT:50Q.DUST	1:1:2	0.5	51	2421	27.1
		0.6	150	2376	20.4
		0.7	205	2302	18.3
75LAT:25Q.DUST	1:1:2	0.5	46	2406	23.2
		0.6	210	2400	19.2
		0.7	185	2344	18.7

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Appendix-5. 28th day compressive strength for 1:1½:3 mix.

% LAT/Q. dust	Mix ratio	W/C	Slump (mm)	Density	Compressive Strength (N/mm^2)
25LAT:75Q.dust	1:1.5:3	0.5	21	2424	21
		0.6	40	2434	26
		0.7	160	2388	22.5
50LAT:50Q.dust	1:1.5:3	0.5	19	2440	19
		0.6	25	2447	26.7
		0.7	99	2293	18.7
75LAT:25Q.dust	1:1.5:3	0.5	7	2437	17
		0.6	35	2388	19.6
		0.7	105	2320	18.7

Appendix-6. 28th day compressive strength for 1:2:4 mix.

% LAT/Q. dust	Mix ratio	W/C	Slump (mm)	Density	Compressive strength
25LAT:75Q.DUST	1:2:4	0.5	10	2187	28.9
		0.6	15	2342	20.4
		0.7	16	2388	19
50LAT:50Q.DUST	1:2:4	0.5	5	2305	23.4
		0.6	15	2444	19.9
		0.7	20	2390	22.5
75LAT:25Q.DUST	1:2:4	0.5	7	2163	17.4
		0.6	10	2404	21.2
		0.7	24	2376	23.2