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EFFECTS OF AGGREGATE TYPE AND COMBINATION ON THE COMPRESSIVE STRENGTH OF SANDCRETE BLOCKS

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Abstract:
The production of sandcrete blocks in Calabar and environ is characterised by the use of different types of fine aggregate such as river sand, gutter silted sand, quarry dust, and lateritic sand, respectively. These are either used singly, or in any combination of two types. This study investigated the impact of fine aggregate types and combinations on the mechanical and durability properties of sandcrete blocks in Calabar, Nigeria. Four commonly used fine aggregate were characterized using their specific gravity, particle size distribution, and their influences on the compressive strength and water absorption of 150mm thick, hollow sandcrete blocks. The aggregate combination of 20% river sand and 80% quarry dust resulted in the highest compressive strength, while 10% river sand and 90% laterite produced the lowest compressive strength. The study explored the impact of fine aggregate on sandcrete block properties, offering guidance for optimizing their production, considering factors such as compressive strength and water absorption.

Keywords: Aggregate, Block, Compressive Strength, Sand, Sandcrete, Water absorption.

I. INTRODUCTION

Sandcrete blocks for the construction of both load bearing and non-load bearing walls dominate the construction landscape in Nigeria, accounting for approximately 90% of all structures [1].

Studies show that most commercial sandcrete blocks in Nigeria fail to meet minimum strength requirements [2; 3]. The choice of fine aggregate significantly impacts block strength, with quarry dust and river sand at a 1:4 mix ratio producing blocks that meet standards [3]. Combining different sand types can improve block properties, particularly when mixing weaker, cheaper sands with stronger, more expensive ones [4; 5]. Vibration time during production also influences block strength, with longer vibration periods yielding higher compressive strength and improved durability [5]. These findings highlight the importance of proper aggregate selection, mixing ratios, and production techniques in achieving adequate sandcrete block strength for construction purposes.

A study by Omoregie [5] on the impact of vibration time on compressive strength of hardened sandcrete building blocks found that most of the sandcrete blocks used in the Nigerian building industry fall short of the minimum specification standards. There is evidence to suggest a wide variation in compressive strength from one block manufacturer to another, and also within block samples from a single source. This problem has been attributed to poor quality control and substandard constituent materials.

The compressive strengths of sandcrete blocks in Ondo State, Nigeria were found to be far below the recommended values. The average compressive strength of 450 mm x 150 mm x 225 mm sandcrete blocks was 0.55 N/mm^2, and the compressive strength of 450 mm x 225 mm x 225 mm sandcrete blocks was 0.45 N/mm^2. These compressive strengths were much lower than the recommended standards [6].

Partial replacement of sand with up to 40% quarry dust improved the compressive, flexural, and tensile strength of sandcrete blocks, while also meeting industry standards for compressive strength and water absorption [7].

Olaniyan et al [8] investigated the use of granite fines as partial replacement for sand in sandcrete blocks and found that a 15% replacement resulted in the highest compressive strength of 4.11 N/mm^2, which could be useful for structural applications. The inclusion of granite fines in the sand cement mixture enhanced the compressive strength of sandcrete blocks. Sandcrete blocks made with a 1:6 mix proportion and 15% replacement of sand with granite fines had the optimal compressive strength of 4.11 N/mm^2.

Another study by Alejo[9] on comparison of strength of sandcrete blocks produced with fine aggregate from different sources in Owo Local Government Area, Nigeria, revealed that sandcrete blocks produced with fine aggregate from Emure had the highest compressive strength of 5.48 N/mm^2 at 28 days. Also, Sandcrete blocks produced with fine aggregate from Ipele had the second highest compressive strength of 4.15 N/mm^2 at 28 days. However, sandcrete blocks produced with fine aggregate from Shagari had the lowest.

The above conflicting findings from studies at different locations and using different materials, underscore the need for more research to understand the changes the occur due to differences in fine aggregate materials, including their combinations to optimize compressive strengths of sandcrete blocks.

II. MATERIALS AND METHODS

Four different fine aggregate types were used in this study.

The materials natural moisture contents and specific gravities are shown in Table I, while their particle size distributions are shown in Figure 1.

TABLE I

MATERIALS PROPERTIES

Description	River sand	Gutter sand	Quarry dust	Laterite
Natural moisture content	21.35%	26.89%	20.87%	18.69%
Specific Gravity	2.64	2.27	2.62	2.48

Figure 1 shows that the aggregate particles generally comply with BS 882:1992 [10]. Only quarry dust particle sizes partly exceeded the specified grading envelope for sand.

Sample preparation

Batching of mortar to produce hollow sandcrete block samples was carried out by weight, using cement to fine aggregate ratio of 1:6 [11]. Water cement ratio varied between 0.7 and 0.8 depending on quarry dust and laterite contents.

Aggregate combinations were based on two types of aggregate at a time in ratios of 10:90, 20:80, 30:70, 40:46, and 50:50 percent, respectively. The details are shown below:

A. *River Sand + Quarry Dust Combinations:*

- 10% River Sand + 90% Quarry Dust
- 20% River Sand + 80% Quarry Dust
- 30% River Sand + 70% Quarry Dust
- 40% River Sand + 60% Quarry Dust
- 50% River Sand + 50% Quarry Dust

B. *River Sand + Laterite Combinations:*

- 10% River Sand + 90% Laterite
- 20% River Sand + 80% Laterite
- 30% River Sand + 70% Laterite
- 40% River Sand + 60% Laterite
- 50% River Sand + 50% Laterite

C. *Gutter Sand + Quarry Dust Combinations:*

- 10% Gutter Sand + 90% Quarry Dust
- 20% Gutter Sand + 80% Quarry Dust
- 30% Gutter Sand + 70% Quarry Dust
- 40% Gutter Sand + 60% Quarry Dust
- 50% Gutter Sand + 50% Quarry Dust

D. Gutter Sand + Laterite Combinations:

- 10% Gutter Sand + 90% Laterite
- 20% Gutter Sand + 80% Laterite
- 30% Gutter Sand + 70% Laterite
- 40% Gutter Sand + 60% Laterite
- 50% Gutter Sand + 50% Laterite

Table II shows the mix combinations which compressive strengths were determined in this study. Hollow sandcrete blocks with external dimensions: 450 x 150 x 225mm, complying with NIS 978: 2017 [12] dimensions for hollow non-load bearing blocks were moulded manually in the laboratory (Figure 2). The blocks were cured by sprinkling water morning and evening, for different periods, namely: 3, 7, 14, and 28 days respectively, before testing for compressive strengths.

TABLE II

MIX DESIGNATIONS

SN	**Aggregate Combination**	**Mix**
1	20RS+80QD	M1
2	50RS+50QD	M2
3	10RS+90LAT	M3
4	20RS+80LAT	M4
5	30RS+70LAT	M5
6	40RS+60LAT	M6
7	50RS+50LAT	M7
8	20GS+80QD	M8
9	50GS+50QD	M9
10	40GS+60LAT	M10
11	10RS+90GS	M11
12	20RS+80GS	M12
13	30RS+70GS	M13
14	40RS+60GS	M14
15	50RS+50GS	M15
16	100% GS	M16
17	100% RS	M17
18	100% QD	M18
19	100% LAT	M19

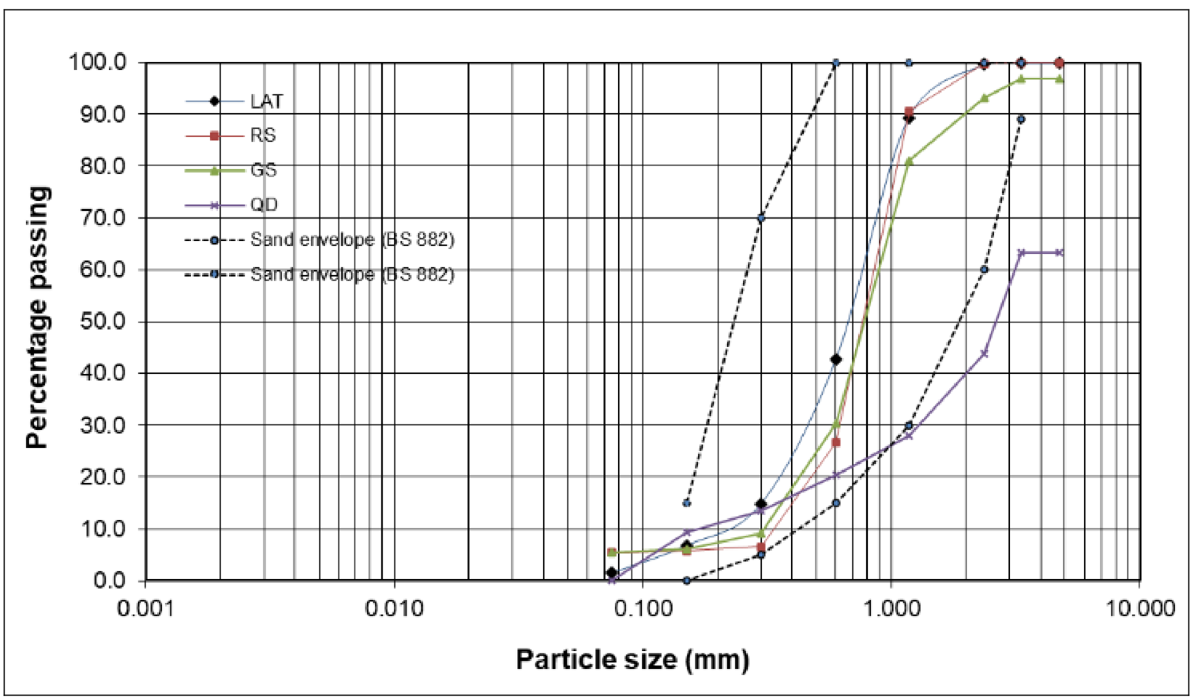

Figure 1: Particle size distributions of fine aggregate

Figure 2: Manual moulding of sandcrete block

Compressive strength test

The compressive strength of sandcrete blocks were determined in accordance with NIS 978 [12]. The test made use of an automatic compression testing machine. The sample is subjected to continuous loading between the platens. The crushing load is recorded for computation of compressive strength based on the solid cross-sectional area.

Figure 3: Compressive strength test setup

Water Absorption Test

Water Absorption Test was conducted following BS1881: part 122: 1983 [13], the water absorption test involved submerging 100mm cubic samples of the same mixes as blocks for 24 hours. The water absorption percentage was determined using the formula ((B-A)/A) *100, where A is initial mass before soaking and B is mass after soaking in water. This provides insights into the material's porosity.

III. RESULTS AND DISCUSSIONS

Compressive strength of sandcrete blocks using single fine aggregate.

The results of compressive strengths of hollow sandcrete blocks for each of the four types of fine aggregate without combinations, are shown in Figure 4. The results show that quarry dust performed better than other aggregate across all test ages from 3 days to 28 days.

This supports observations from commercial block producers who generally tend to include quarry dust in their blocks. It also supports previous findings [7; 8]

These findings also indicate that quarry dust can be used to optimize the compressive strengths of sandcrete blocks.

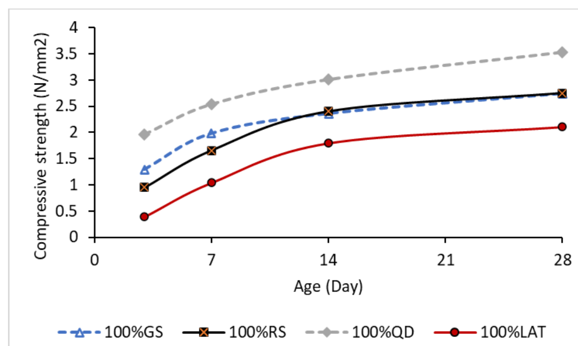

Figure 4: Compressive strength development of blocks made of Rivers sand (RS), Quarry dust (QD), Laterite (LAT), and Gutter Sand (GS)

Compressive strength of sandcrete blocks using 2 types of fine aggregate in equal proportions

The study also considered using any 2 combinations of the common aggregate in equal proportions. The results in Figure 5 indicate that the combination of river sand and quarry dust yielded the highest compressive strengths. Though slightly lower compressive strengths, the combinations with gutter sand and quarry dust showed comparable compressive strengths.

These results also show optimized compressive strengths when the aggregates were combined rather than used one type at a time. The combination of river sand and quarry dust showed 28-day compressive strength of 3.95 N/mm^2 higher than 3.53 N/mm^2 obtained at the same age when quarry dust alone was used for the block production as shown in Figure 4.

Combinations of river sand and laterite showed the worst compressive strengths, while river sand and gutter sand combination showed slightly better results.

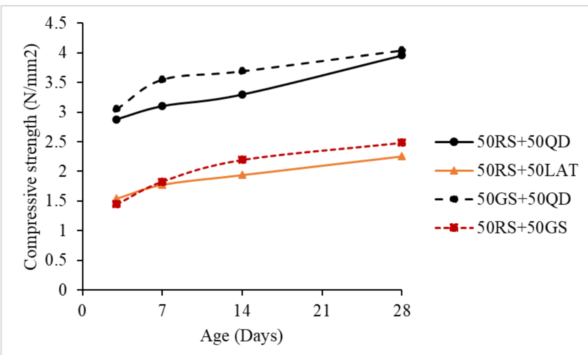

Figure 5: Compressive strength development of blocks showing 50:50 aggregate combinations

Figure 6 and Figure 7 show statistical analysis using one-ANOVA. The results in Figure 6 show that Mix M1 (20% River Sand and 80 Quarry Dust) have distinct mean that is significantly higher than all other mixes. This is evident in the strength developments for different combinations shown in Figure 8.

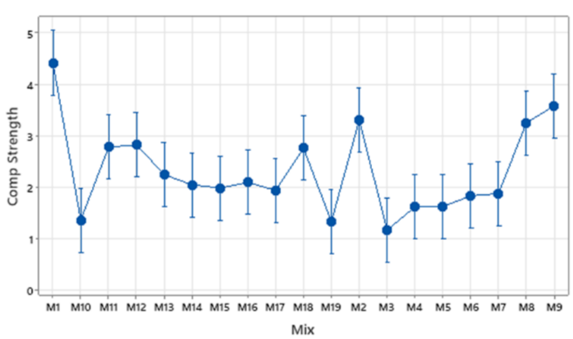

Figure 6: Interval Plot of Compressive Strength Versus Mix at 95% CI for the Mean

Furthermore, Figure 6 shows that compressive strengths generally increased from 3 to 28 days.

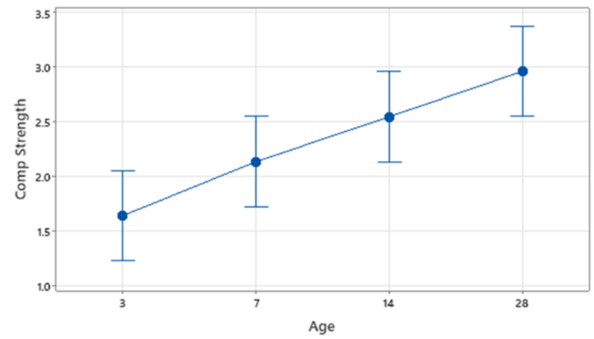

Figure 7: Interval Plot of Compressive Strength Versus Age at 95% CI for the Mean

Table III shows the results of water absorption which were generally below 10%. The results generally show that high compressive strengths corresponded to low water absorption. It is well known that low porosity suggests a compact microstructure which are necessary for high compressive strength.

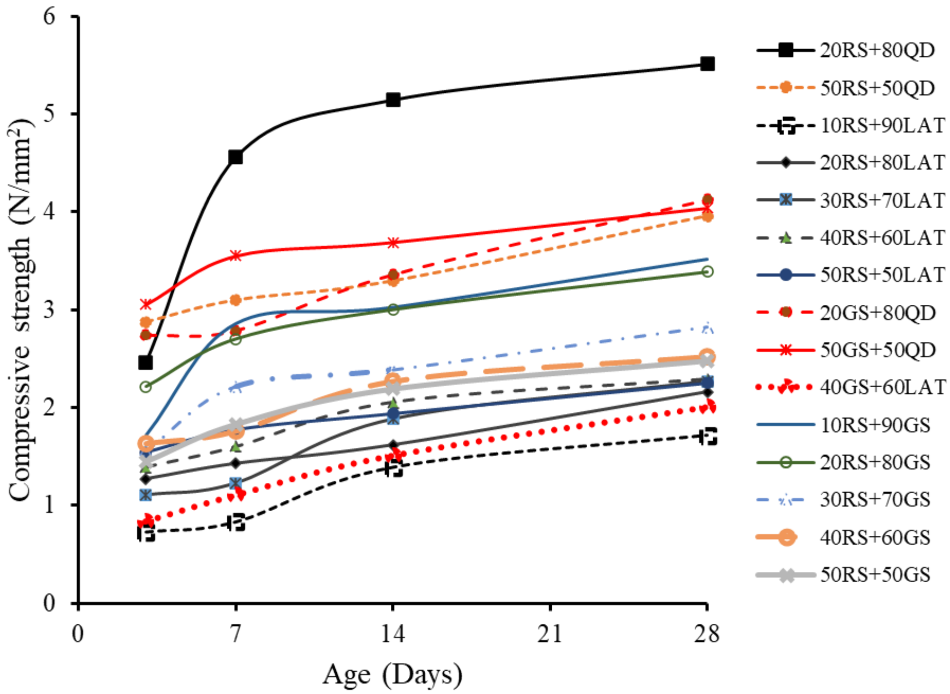

Figure 8: Compressive strength development of blocks showing different aggregate combinations

TABLE III

WATER ABSORPTION

RS-QD		RS-GS		GS-QD		RS-LAT		GS-LAT	
10RS QD	2.2%	10RS GS	3.9%	10GS QD	8.5%	10RS LAT	8.6%	10GS LAT	6.2%
20RS QD	3.2%	20RS GS	4.5%	20GS QD	11.0%	20RS LAT	8.2%	20GS LAT	6.9%
30RS QD	5.2%	30RS GS	4.8%	30GS QD	10.1%	30RS LAT	8.8%	30GS LAT	6.5%
40RS QD	7.3%	40RS GS	4.4%	40GS QD	8.8%	40RS LAT	8.4%	40GS LAT	5.8%
50RS QD	7.4%	50RS GS	4.5%	50GS QD	9.5%	50RS LAT	9.5%	50GS LAT	6.0%
Average	**5.1%**		**4.4%**		**9.6%**		**8.7%**		**6.3%**

IV CONCLUSION

This study has investigated compressive strengths and water absorption of hollow sandcrete blocks, using different aggregates, individually and in combinations.

Quarry dust showed the highest compressive strengths across all tested ages, while laterite exhibited the least compressive strengths of blocks. River sand and gutter sand did not show much difference in compressive strengths of blocks incorporating them. This supports the use of gutter sand provided the particle sizes are like river sand in line with this study.

This study has shown that using aggregate in combination optimises compressive strengths. The mix with 20% river sand and 80% quarry dust showed overall best compressive strengths across all ages.

Water absorption were mostly less than 10%. River sand combination with gutter sand exhibited the lowest water absorption, while gutter sand combination with quarry dust showed the worst water absorption characteristics.

The findings of this study will serve as a guide to practitioners in the built environment in selecting and optimizing fine aggregate and combinations to produce sandcrete blocks.

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