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Comparative evaluation of the compressive strength of treated drill cutting blocks and sandcrete blocks

Sandra Ebere Ezeani *

Uptonville Oil and Gas Institute, Port Harcourt, Rivers State, Nigeria.

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Abstract

Management of drill cuttings is a major environmental concern in the oil drilling operations. This study evaluates the compressive strength of treated drill cuttings block when compared with the sandcrete block for use in the construction industry. 100mmx 100mm sandcrete and cutting block were moulded using Portland cement as a binding agent in the mix ratio of 1; 6. The blocks were cured for 7 and 14 days. The compressive strength of both the cutting and sandcrete block were tested after 7 and 14 days. The study found the cuttings block exhibited significantly higher load-bearing capacity compared to the sandcrete blocks. The failure loads for cuttings blocks were approximately double those of the sandcrete blocks. Specifically, after 7 days of curing, cuttings blocks A1 and A2 withstood loads of 20 KN and 21 KN, respectively, whereas sandcrete blocks A1 and A2 only withstood 10 KN and 11 KN, respectively. Similarly, compressive strength of 3.1 N/mm^2, 3.2 N/mm^2 and 2.0 N/mm, 2.1 N/mm was achieved by cuttings blocks and sandcrete blocks respectively after 14 days of curing. The findings of this study suggest that cuttings blocks are a robust alternative to traditional Sandcrete blocks, particularly for construction applications where higher strength is desired. The increased compressive strength and weight gain over time, along with the blocks' ability to meet and exceed the minimum strength requirements, highlight their suitability for various building construction needs.

Keywords: Drill Cuttings; Sandcrete; Aggregate; Compressive Strength; Curing

1. Introduction

Oil well drilling process generates two types of waste namely spent drilling mud and drill cuttings. Drilling mud aids the drilling process by lubrication and cooling of the bits, and transportation of the grounded rock particles to the surface. Drill cuttings are made up of ground rock coated with a layer of spent mud which is separated at the surface. Drill cuttings are largely clay material, containing hydrocarbon and some additives from the spent mud, they undergo initial offshore pre-treatment through physical separation using shakers or centrifuges, followed by additional onshore treatment before being disposed of, reused, or recycled. Treated drill cuttings can be recycled as an addition or alternative to raw material in production or formation of new products. The construction industry is one of the leading recyclers of treated drill cuttings. Recycling options within the construction sector include using these materials in cement manufacturing, road pavement, bitumen and asphalt, as well as concrete blocks and ready-mix concrete etc. (1).

1.1. Reuse of drill cuttings in construction industry

After primary separation with shale shakers, cuttings are still coated with mud and are relatively hard to reuse for construction purpose and require secondary treatment. Further treatment such as stabilization and solidification are employed to make the material more innocuous. Fly ash, cement and other stabilising materials are used to improve the ease of handling of treated drill cuttings for use in the construction industry. To evaluating the effectiveness of Solidified and Stabilized treated (heavy metals contaminated soils (HMCS), a variety of tests are deployed, including as the

*Corresponding author: Sandra Ebere Ezeani

unconfined compressive strength (UCS) test, the durability tests, setting time test, expansion/shrinkage test, hydraulic conductivity test, and chemical leaching test(2). Solidification and stabilisation treatment of pre-treated drill cuttings improves the leachate pH and acid neutralization capacity, (3), unconfined compressive strength (UCS), durability and reduced toxicity leachate characteristic properties of the products(4)(5)

1.2. Uses of drill cuttings in the construction

Drill cuttings have been found to retain high compressive strength, when incorporated as an aggregate in concrete production (6). A high compressive material suitable for use in pavement bases construction was obtained when drill cuttings of about 50% to 80% was incorporated in the material mix (7). The findings from (8)study reveal that a mixture containing 20% cement and 80% drill cuttings demonstrates stable strength properties, making it appropriate for use in road construction. Similarly, (9) found the compressive strength of bricks, concrete mix and permeable bricks; partially substituted sand with (10% and 20%) of drill cuttings is technically adequate for use in building construction.

However, the study by(10) suggests that substituting 5% of cement with drill cutting in concrete production reduces the compressive strength of the concrete by 20%, while incorporating additives such as fly ash and silica fume will significantly improve th ecompressive strenght of the concrete.Thus using drill cuutings as filler replacement produces concrete with lower strenght grade that can be apply in foundation **blinding**, walling and concrete fill material (11). Recent and past studies on drill cutting application focused **on** the **partial** incorporation in concrete mix or use as a filler or binder in building construction.

1.3. Sandcrete blocks

Sandcrete block is formed from a loose mixture of sand, cement and water, which is compacted in a mould **to** form a dense block. Sandcrete block of various sizes are widely **used** in building constrcution. Sandcrete block exhibit high compressive strength, dimensional stability and durability after hydration, suitable for building construction (12). Due to their affordability and durability, sandcrete blocks are widely used as both load-bearing and non-load-bearing walling units in Nigeria and other African countries. Sandcrete blocks can be moulded both solid and hollow rectangular forms. **Sandcrete blocks can be moulded into both solid and hollow rectangular shapes.** These sizes typically include 450mm x 225mm x 225mm (hollow) for load-bearing walls and 450mm x 150mm x 225mm (hollow) for non-load-bearing walls. The Nigerian Industrial Standard (NIS 87: 2007) specifies the minimum compressive strength requirements for sandcrete blocks used in construction. According to this standard: sandcrete blocks must have a minimum compressive strength of 2.5 N/mm^2 for non-load-bearing walls and 3.45 N/mm^2 for load-bearing walls (13).The compressive strength of sandcrete blocks plays a crucial role in determining the structural integrity and durability of buildings and other structures. The compressive strength of sandcrete blocks relies on several factors, including the production techniques used, the curing duration, the block sizes, and the properties of the materials used in their composition (14). Sandcrete block production significantly impacts natural resources and the environment due to resource extraction. In response, researchers have investigated the feasibility of incorporating alternative aggregates into sandcrete mix designs by partially or fully substituting natural aggregates with waste materials. Utilizing drill cuttings in brick production reduces both the environmental impact of land or water disposal and minimizes resource extraction for sandcrete blocks.

To date, no comprehensive study has explored the complete substitution of drill cuttings as a replacement for sand in building construction block production.The objective of this study is to assess the strength properties of sandcrete blocks produced using drill cuttings as a replacement for sand, with Portland cement as the binder in building construction.To achieve this objective, a comparative analysis will be conducted between sandcrete blocks and drill cutting blocks produced using the same binder. The moulded blocks from both sandcrete and drill cuttings, taken from the same batch, will be cured for seven and fourteen days each, and the compressive strength of each block will be individually estimated.

2. Materials and Methods

2.1. Materials

For this study, treated drill cuttings were sourced from Delta Logistic in Onne, Rivers State, Nigeria. Other experimental materials include; sand which was sources from Emeohua river bed, Portland cement 42.5R grade manufactured by Dangote company, a block mould, a weighing balance, a sieve, an oven, and a strength testing machine. Both the sand and drill cuttings underwent oven drying to remove moisture before sieving. Calibrated sieves with varying openings (ranging from as large as 100 mm to as small as 0.075 mm) were used to separate coarse and finer grains. The objective of this analysis was to determine the grain size and the percentage of total weight represented by the grains in both the sand and cuttings. Portland cement served as the binding agent, and the mould used was a cube block mould measuring 100 mm × 100 mm

2.2. Sample Preparation

2.2.1. Sample characterization

To assess the suitability of sand and drill cuttings for block production, a sieve analysis was performed on the samples usingASTM C 136 method. The resulting particle size distribution curves were plotted, and various grading properties were determined. These properties include the nominal size, fineness modulus, coefficient of curvature (Cc), and coefficient of uniformity (Cu).In the sieve analysis process, the following steps were carried out:

2.2.2. Particle size distribution of sand and drill cutting samples

Initially, 300 grams of sand were oven-dried to remove any moisture. The dry sand was then passed through sieves with various diameters: 4.75 mm, 2.36 mm, 1.18 mm, 0.600 mm, 0.300 mm, 0.150 mm, and 0.075 mm. The percentage weight of the sand retained in each sieve was determined. Similarly, 300 grams of drill cuttings were weighed. The drill cuttings were washed using wet sieving. The purpose of washing the drill cuttings was to accurately assess their particle size distribution. The washed sample was oven-dried and re-weighed. The oven-dried drill cuttings were then passed through sieves with different diameters, and the percentage weight of the retained sample was determined. Both sand and drill cuttings size distribution were analyzed. The percentage passing through each sieve is plotted against the sieve diameter.

Effective Size (D10): The sieve diameter at which 10% of the material passes through. Uniformity Coefficient (Cu**):** The ratio of the sieve diameter at 60% passing (D60) to the sieve diameter at 10% passing (D10). It indicates the uniformity of particle sizes.

The uniformity coefficient (Cu) and coefficient of curvature can be expressed as:

$$\text{Uniformity coefficient (Cu)} = D10/D60 \text{---------------------------} (1)$$

$$\text{Coefficient of Curvature (Cc)} = D30^2/D60xD10 \text{--------------------------} (2)$$

Where:
D60 is the sieve diameter at 60% passing.
D30is the sieve diameter at 30% Passing
D_{10} is the sieve diameter at 10% passing.

2.3. Experimental procedure

2.3.1. Block Moulding Method:

The block moulding method described **by (12) was** adopted for the experiment. Separate weights of 6 kg each of drill cuttings and sand were measured. Additionally, 1 kg of cement was weighed. The mould was cleaned and lubricated with engine oil to facilitate easy block removal after moulding. The drill cuttings were mixed with cement in the ratio of 1:6, and the optimum amount of water was added. The mixture was compacted in the mould in three layers, with 25 taps for each layer. The same procedure was followed for the sand and cement mixture. Four cutting blocks and four sandcrete blocks were obtained from each mix. These blocks were removed from the mould the next day and cured in water simultaneously for 7 and 14 days. After the curing period, two blocks from each type (cutting block and sandcrete) were selected and subjected to crushing using a strength testing machine until failure occurred.

2.4. Data Analysis

To determine the compressive strength of the blocks, each block was placed in a compressive testing machine. Compressive load was applied until failure occurred. The compressive strength was then calculated as the maximum load applied to the block divided by the cross-sectional area of the block. These strength tests were conducted after curing the blocks for both 7 days and 14 days**.**

2.4.1. Gravity Determination of Specific and Dry Bulk Density

The Specific gravity and Dry Bulk Density was calculated for the Sand, Cuttings and Cement with the equation below:

Specific Gravity (G.s)

$$G.s = \frac{W2-W1}{50-(W3-W2)} \text{---------------------} (3)$$

W1= weight of density bottle
W2= weight of sand and bottle
W3= weight of sand, bottle and water

Bulk Density

$$D= (M/V)\ (kg/m) \quad \text{---------------------} (4)$$

M=Weight of the full container (g)
V= Container volume (cm^3)

3. Result and Discussion

3.1. Particle Size Distribution

The results of the sieve analysis for drill cuttings and sand aggregate are displayed in Table 1 and Figure 1. The distribution curves for both materials fall within the fine aggregate classification. The distribution curve illustrates that 100% of the drill cuttings and 99% of the sand passed through the 4.75 mm sieve, the upper threshold for fine aggregates.

Table 1 Particle size distribution of Drill cuttings and Sand

Sieve size (mm)		Drill cuttings		Sand		
	Percentage Retained (%)	Cumulative percentage retained (%)	Percent passing (%)	Percentage Retained (%)	Cumulative percentage retained (%)	Percent passing (%)
4.75	0	0	100	1.0	1	99.00
2.36	0	0	100	2.3	3.3	96.7
1.18	0	0	100	8.0	11.3	88.7
0.600	9.09	9.09	90.91	60.3	71,6	28.4
0.300	18.18	27.27	72.73	22.00	94.0	6.00
0.150	27.27	54.54	45.46	5.3	98.9	1.10
0.075	45.45	99.99	0.1	1.0	99.99	0.1

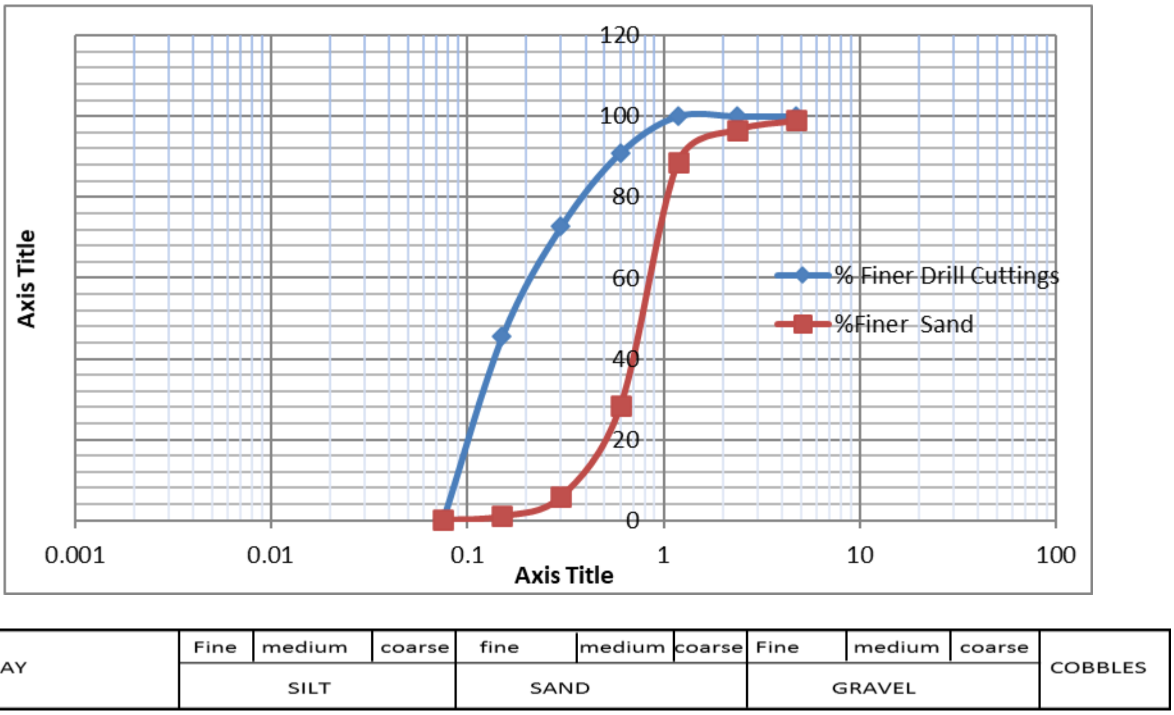

Figure 1 Particle size distribution curves of the Drill cuttings and Sand

The particle size distribution curve suggests a relatively even distribution of particle sizes with no significant gaps or concentrations. The uniformity coefficients (CU) are 2.5 for drill cuttings and 3.0 for sand, while the coefficients of curvature (CC) are 0.7 for drill cuttings and 1.4 for sand.The fineness moduli are 0.9 for drill cuttings and 2.8 for sand Indicates that both materials are moderately fine and well graded material.

3.2. Specific gravity and dry bulk density:

The specific gravity was determined to be 2.46 for sand, 1.90 for drill cuttings, and 3.11 for cement. Materials with higher specific gravity tend to be stronger and more durable. The lower specific gravity of drill cuttings compared to sand indicates that drill cuttings are less dense. This difference could be due to a higher proportion of air spaces or less dense material in the drill cuttings. Similarly, the dry bulk density was calculated to be 2.6 g/cm^3 for sand, 3.17 g/cm^3 for drill cuttings, and 1.92 g/cm^3 for cement.The higher dry bulk densityof drill cuttings compared to sand suggests that drill cuttings are densely packed, possibly due to the nature of the parent material or compaction during drilling operation.

Table 2 The Compressive strength of cutting blocks and sandcrete blocks

Material & identification marks	**Density of block gm/cc**	**curing days**	**Load (KN)**	**Compressive Strength (N/mm^2)**
Cuttings blockA1	2.25	7	20	2.0
Cuttings blockA2	2.22	7	21	2.1
Sandcrete blockA1	2.00	7	10	1.0
Sandcrete block A2	2.01	7	11	1.1
Cuttings block B3	2.40	14	30	3.0
Cuttings blockA4	2.41	14	32	3.2
Sandcrete blockB3	2.10	14	27	2.7
SandcreteblockB4	2.11	14	28	2.8

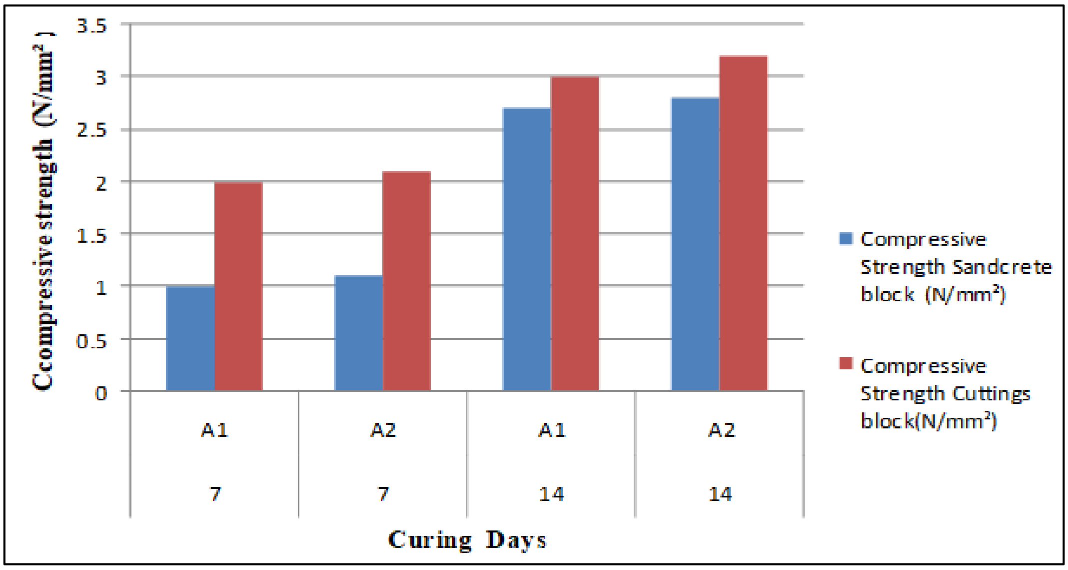

Figure 2 Compressive strength of **c**uttings blocks and sandcrete blocks

3.3. Results after Seven (7) Days

After 7 days of wet curing, the compressive strength test results for both **c**uttings block and Sandcrete blocks were obtained. The cuttings blocks A1 and B1 failed at loads of 20 KN and 21KN, respectively. Similarly, the Sandcrete blocks A1 and B1 failed under loads of 10 KN and 11 KN, respectively. These results indicate that **c**uttings block with the same mix proportion as Sandcrete blocks (1:6) can withstand significantly higher loads. Specifically, the cuttings blocks can endure twice the load of Sandcrete blocks of the same mix and size after 7 days (Table 4.2). Cement relies on the presence of water to hydrate, forming an interlocking skeleton of calcium silicate hydrates. These hydrates give the material its strength. However, if the block is allowed to prematurely dry, full hydration of the cement does not occur. Consequently, only part of the cement used contributes to the strength of the block (12). Research conducted by the DTU at the University of Warwick has shown that strength lost due to poor curing can significantly reduce the final bulk strength of the block by up to 20%. As the block surfaces lose water first, the strength loss in these regions is even more pronounced. This reduction in surface strength adversely affects both the handling and durability of the block.

3.4. Results after Fourteen (14) Days

Table 4.2 presents the compressive strength of both **c**uttings blocks and Sandcrete blocks after 14 days of curing. The results highlight significant trends and insights regarding the strength development and weight changes of these blocks over time. The study observed the increase in strength with more curing days.The compressive strength of Sandcrete blocks showed a marked increase after 14 days. This is indicative of the hydration process of cement continuing to strengthen the blocks over time. Similarly, the strength of **cuttings** blocks also increased, demonstrating the positive impact of extended curing on the material's properties. The **c**uttings blocks achieved a compressive strength of 3.1 N/mm^2 and 3.2 N/mm^2 after 14 days of curing. This aligns with the findings by (15), which showed that the compressive strength of cement-drill cutting concrete increases with curing age, irrespective of the drill cuttings' proportion used. These values are crucial as they meet the minimum required strength for building construction materials. According to NIS 87:2007; for non-load-bearing walls, the minimum compressive strength required is 2.5 N/mm^2 while the minimum compressive strength for load-bearing walls is 3.45 N/mm^2. The compressive strength of the Sandcrete blocks after 14 days (increased significantly) met the standard for non-load-bearing walls but fell short for load-bearing walls. The **c**uttings blocks not only met but exceeded the minimum requirements for both non-load-bearing and load-bearing walls after 14 days. This is a significant finding, as it demonstrates the potential of cuttings as a viable material for construction, providing comparable or superior strength to traditional Sandcrete blocks. The table (4.2) indicates that the weight of both **c**uttings blocks and Sandcrete blocks increased with extended curing time. This weight gain is likely due to the continued hydration of the cement and the absorption of moisture by the blocks, enhancing their density and structural integrity. The consistent out performance of **c**uttings blocks over Sandcrete blocks in terms of compressive strength underscores their reliability and potential advantages. This consistency reinforces the reliability of **c**uttings blocks in maintaining and enhancing strength under similar curing conditions. These results highlight the potential of using cuttings in construction materials, offering a viable alternative to traditional sand-based blocks.

4. Conclusion

The compressive strength test results clearly demonstrate that **c**uttings blocks outperform Sandcrete blocks. Cuttings blocks can handle twice the load of Sandcrete blocks with the same mix proportion. This finding highlights the potential of using cuttings as a viable alternative to traditional sand-based blocks in construction materials. Additionally, **c**uttings blocks' ability to endure higher loads establishes their suitability for various construction applications where greater strength is desired. The increased compressive strength and weight gain over time, along with the blocks' ability to meet and exceed minimum strength requirements, further emphasize their suitability for building construction. Researchers can gain deeper insights into the performance and integrity of this essential drilling waste component by assessing the compressive strength of drill cutting blocks through comprehensive testing and analysis. Future research could explore optimizing mix proportions, long-term durability, and other properties of **c**uttings blocks to fully leverage their potential in the construction industry. This might involve studying the impact of different types of drill cuttings, curing conditions, and various environmental and operational factors, such as temperature, moisture, and loading rates, on the blocks' performance.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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